SUSTAINING THE USE OF ICT FOR STUDENT-CENTRED LEARNING: A CASE STUDY OF TECHNOLOGY LEADERSHIP IN A SINGAPORE ICT-ENRICHED PRIMARY SCHOOL

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Abstract

Policymakers who have invested in the use of ICT in education are often motivated by its promise to realise pedagogical innovations. However, the unrelenting gap between the promise and performance of ICT has continued to prompt further research into how the affordances of technology can be better harnessed in schools. This three-year qualitative case study hopes to shed light into this matter by looking at the: 1) ecological factors of how an ICT-enriched primary school in Singapore had been using technology to support the pedagogical reform for student-centred learning; 2) conditions that led to its sustained use of technology for this purpose.

Complexity theory was employed as the analytical framework for the study. By examining the inter-connectedness of systemic influences governing the in-situ use of ICT in the exemplar school, educational leaders and policymakers can gain a holistic perspective of the factors that may promote or impede technology integration effort.

Through the use of interviews, lesson and meeting observations as well as document analysis, the trajectory of the school's ICT journey was mapped out. The development history surrounding the use of technology for teaching and learning provided a precursor to investigate how the school organisation as the unit of analysis had created favourable conditions leading to the sustainability of ICT-related innovations. Specifically, five themes had emerged: 1) continuous scanning of environment; 2) multi-pronged capacity building efforts; 3) mitigating systemic tensions amongst stakeholders; 4) shared accountability and 5) systematic pacing.

Based on the findings to the study, a complexity-informed model for technology leadership, stakeholders' dynamics and guidelines for policymaking were drawn up. The dissertation concludes with reflections on the use of complexity theory and recommendations for future research.

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Chapter 1. Statement of Research Problem

1.1 Background: Global Trends

Technological advancement has demonstrated its transformative impact on the way we speak, learn and socialise in cultural, social and economic spheres in many developed countries (OECD, 2008). Perplexingly, such robust use of technologies has yet to be integrated effectively into the formal learning sector to bring about the transformative changes that many educationalists have envisaged (Cuban, 2012; Dede, Honan, & Peters, 2005; Flanagan & Jacobsen, 2003; Romeo, 2006). The development of technological media would, as posited by enthusiasts, give learners unlimited access to diverse worldviews, nurture their spirit of inquiry and supersede traditional styles of teaching and learning.

However, after more than two decades of introducing technology in education, the disappointing reality is that the use of computers in the classroom has generally remained tokenistic despite the high penetration rate of hardware in the developed world (Cuban, 2012; Hennessy, Ruthven, & Brindley, 2005; Romeo, 2006). There is also a confounding lack of evidence to support the rhetorical claim that students' performance will be augmented as a result of the use of technology (Christensen, Horn, & Johnson, 2008; Cristia et al., 2012; Flanagan & Jacobsen, 2003; Means, 2010; Trotter, 2007; Walker & White, 2002). What is perhaps more disturbing is that

the use of instructional methods to integrate technology does not necessarily promote or expand teachers' teaching strategies to include learner-centred pedagogies that are deemed critical for the 21st century learners (Cuban, 2008; Loveless, Devoogd, & Bohlin, 2001). Schools have failed to leverage the benefits of technological tools and we see jarring gaps between the promise and performance of technology.

Many studies have attributed this gap to the inappropriate ways educators trivialise the use of technologies by not situating them within the broader vision of the social and civic roles schools should play (Zucker, 2008). Toh and So (2011) contend that the lack of systemic thinking may explain the lacklustre impact of ICT in education. It is necessary to move beyond the technology-centric perspective in order to gain insights into why technology fails to transform learning at large. Like many developed countries, Singapore is galvanising its efforts in integrating ICT for school improvement. In the midst of the transformation, schools grapple with mounting tensions and incompatibilities within the educational system. The section below is a contextual description of the use of ICT in Singapore schools.

1.2 Contextual description of the use of ICT in Singapore's schools

1.2.1 Use of ICT in education

At the time of writing, the provision of computers in Singapore schools had been widespread (Koh & Lee, 2008a). This can be attributed to the early kick-start of the

five-year IT Masterplan that was inaugurated by the Ministry of Education (MOE) in year 1997 (Ministry of Education, 2010). This first phase of IT Masterplan served as a broad-based blueprint for schools to harness ICT to equip students with essential learning skills, creative thinking skills and communication skills. These goals were aligned with the nation's broader aim to create "Thinking Schools, Learning Nation" (Goh, 1997, June 2) where dispositions of critical and creative thinking for lifelong learning are emphasised. Building on the genesis framework of the first phase of IT Masterplan, the government unveiled its second Masterplan (MP2) in year 2002 (Ministry of Education, 2010). Spanning the years 2003-2008, the goals of the new plan reflected a pedagogical shift towards a more student-centred approach. Lim (2004) articulates the three main thrusts of MP2 as the need to:

1) re-design the existing curriculum to integrate ICT seamlessly. This is to enact new teaching methods brought forth by affordances of technology;
2) move away from teacher-centred practices and gravitate towards student-centred practices;
3) allow schools to have greater autonomy in utilising their ICT funds to customise their ICT integration plans.

Lim (2004) proposes that the use of technology under the ICT Masterplan Two should be "situated in the social constructivist paradigm" where "students work together on learning tasks to construct knowledge with teachers scaffolding the process, mediated by ICT" (p169). Recognising that schools need time to internalise the shift of imperatives from MP1 to MP2, the government adopted a differentiated

approach where a realistic baseline of ICT competencies was spelt out for all schools whilst encouraging top-tier schools to intensify their efforts in ICT integration (Infocomm Devlopment Authority of Singapore, 2008; Ministry of Education, 2010). The baseline ICT competencies include the use of word processing skills, demonstration of computer operational knowledge as well as the adoption of multimedia tools, data collection gadgets (such as data-loggers) and communication medium (such as emails).

The LEAD ICT and FutureSchools are examples of trailblazers that are intended to be prototype schools that push the frontiers of teaching and learning. The former comprises schools that are either ready to achieve a higher level of IT use via action research efforts or have used ICT effectively for at least one subject across one level. Action research is highly emphasised by MOE as school teachers are expected to be able to critically examine the impact of their innovations to teaching and learning. As such, since 2006, MOE has put in placed a 'Research Activist' scheme to train teachers as part of the government's continued efforts to "build capacity, heighten appreciation of research in all schools and support development of the schools as professional learning communities" (Hogan, Teh, & Dimmock, 2011, p5). The LEAD schools are selected by MOE based on the criteria that they have demonstrated clear ICT directions, leveraged on technology to realise pupil-centred learning and achieved capacity building of teachers and leaders, delineated the scope and rationale of projects well, incorporated plans to sustain and scale up the projects

and have planned a feasible budget that is aligned with the needs of the proposed projects. FutureSchools are prototype schools that are ready to leverage on ICT to champion innovative learning approaches. The use of ICT is seen to be seamless and prolific as it cuts across all levels and subjects. These schools are selected by MOE based on the criteria of how well the proposed learning programmes are integrated into the school's curriculum, pedagogy and assessment; the readiness of school leadership; staff and culture as well as the innovativeness and effectiveness of the physical learning environment to support learning endeavours. Currently, there are 67 LEAD ICT schools which constitute about 15% of the total number of schools. At the pinnacle of ICT forerunners are 15 schools (5% of the schools) which either have been identified or will be nominated as FutureSchools through a phased approach.

It was noteworthy that the direction of MP2 was geared towards realising MOE's overarching aim to foster a "Teach Less, Learn More" culture where a qualitative transformation in teacher-learner interaction was valued over sheer quantitative improvement in education. Koh and Lee (2008a) articulate the contextual role of ICT in the transformative process from the First to Second ICT Masterplan:

> The focus in the First Masterplan was to provide schools with the basic infrastructure and provisions, while that in the Second Masterplan was to provide schools with an enhanced ICT infrastructure that could facilitate

> different modes of lesson delivery and support varied learning, that is, one that could support an undisrupted delivery of powerful multimedia and full interactivity of instructional content. (p.73)

Due to the concerted efforts from all stakeholders, MP2 had resulted in a more sophisticated use of ICT by students and teachers to enhance their productivity and presentation skills.

Being cognizant of the goals, achievements and gaps of MP1 and MP2, the third ICT Masterplan (MP3, 2009-2014) aims to ensure a greater level of technological integration in curriculum, assessment and pedagogy so as to equip students with critical competencies (IT, communication, self-directed and collaborative skills) to succeed in the 21st century. The belief underpinning this policy is that ICT has to be integrated throughout the educational process of planning, designing, enacting and assessing rather than added on to the curriculum in a piecemeal manner to provide "greater alignment of students' learning outcomes in the syllabi, national examinations, and classroom experience to 21st century skills" (Ministry of Education, 2008). This phase also calls for the provision of personalised and relevant professional development for teachers; improvement of channels for the sharing of best practices as well as the enhancement of ICT provision. In a nutshell, the cornerstone of MP3 is to transform the learning environment so that students can become self-directed learners capable of engaging in deep learning independently

or collaboratively anytime, anywhere. To see this to fruition the government body has adopted the following leadership approaches when implementing MP3:

> MOE provides top-down support for ground-up initiatives from schools for routine ICT integration into the curriculum, but continues to adopt some form of centralised, top-down approach for novel integration of ICT into the curriculum that pushes the frontiers of teaching and learning. (Koh & Lee, 2008b, p188)

Since more schools have joined the ranks of ICT-enabled schools during this phase, MOE adopts a less top-down approach to allow schools to have greater customisation and autonomy of ICT related initiatives. One of the goals of MP3 is to empower school leaders to provide direction and create conditions to harness ICT for learning and teaching.

Table 1.1 summed up the salient features and shifting priorities of the three Masterplans. The trajectory showed a growing interest in student-centred learning that had evolved towards the direction of providing opportunities for students to construct meaning through self-directed and collaborative inquiry. The infrastructure architecture and apparatus for capacity building also gravitated towards enhancing social learning and coherence in planning and enactment. These signalled that the policies involving the use of ICT in Singapore's educational landscape is now more focused on:

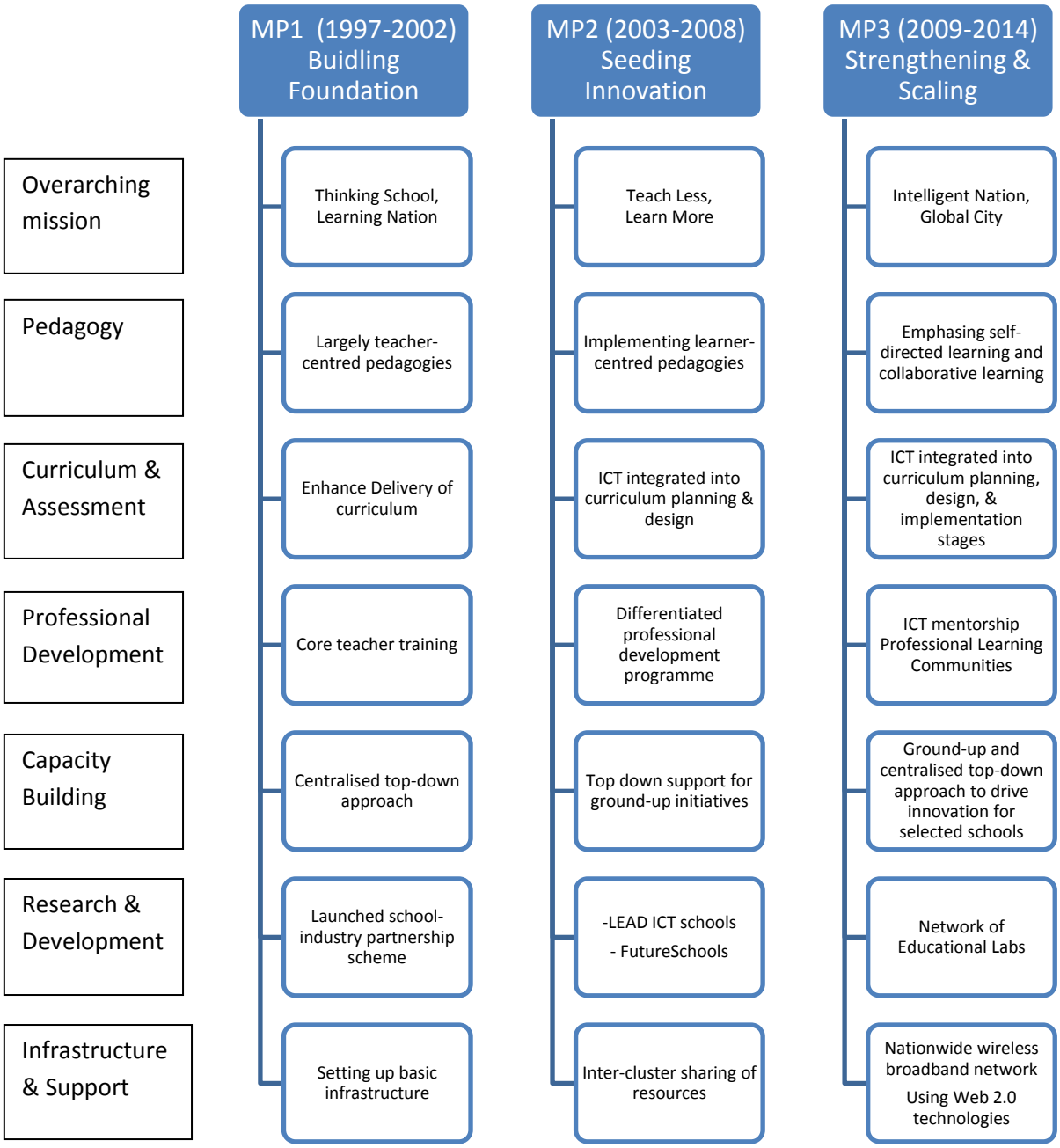

Table 1.1 Salient features and shifting emphasis of Singapore's three ICT Masterplans.

Source: Adapted from Koh and Lee, 2008; Lee et al., 2008; MOE website: The ICT connection (http://ictconnection.edumall.sg/).

1) emergent consultations amongst teachers, students and policymakers, as opposed to top-down control of instructional supremacy;

2) ecological outlook that takes into consideration the inter-relationships between different phases of ICT implementation.

1.2.2 Pedagogical innovations in Singapore schools

A series of studies conducted by the Office of Education Research (OER), a research centre at the National Institute of Education, Singapore, between years 2003-2008, provided insights into how school teachers were teaching and how students were learning in a typical Singapore classroom (Hogan & colleagues, 2009). The research team analysed data emerging from classroom observations, surveys and artefacts created in primary five and secondary three English and Mathematics lessons. Instructional strategies and activities, lesson structure and classroom discourse were some examples of research strands covered in the series of studies. The findings revealed that:

1) teachers had demonstrated more content knowledge than pedagogical knowledge and memorization remained the most prevalent pedagogy, compared to 'direct' and 'authentic instructions' which were also deployed, albeit less frequently, for differentiated instruction.
2) It was also not uncommon to see that classes were conducted and organised around the whole class as a unit. About half of all 452 Primary 5 lessons observed conformed largely to the IRE (Initiate-Respond-Evaluate) class interaction pattern as opposed to group work. With respect to this

climate, there was tendency for the classroom discourse to be laden with closed rather than open questions.

3) In terms of curriculum coverage, teachers felt the pressure to cover the entire assessed curriculum and had relied heavily on the scheme-of-work (SOW) and textbooks to prepare for lessons.
4) The use of technology as instructional tool in class was not as integrated as envisaged. Only 2% of the classes observed involved the use of Internet and Powerpoint. Worksheets were still the predominant instructional technology that teachers used for formative assessment.
5) Epistemic authority rested with the teachers and there was little evidence of teachers and students co-constructing complex knowledge collectively.

These practices reflected the tenacity of transmissionist views of knowledge, teaching, learning and assessment in Singapore as well as the minimal use of technology in routine lessons.

In short, OER concluded that the classroom pedagogy in Singapore was focused on the transmission and assessment of curriculum knowledge. Students were re-producing, instead of creating knowledge (Hogan & colleagues, 2009). All these evidence suggested that schools may have more work to do to transform themselves into student-centred institutions. The gaps were confounded by the fact

that schools were wary about the high stakes involved if they failed to do well in national assessments.

Recognising the deep roots of the problem, OER thus recommended that for pedagogical innovation to be sustainable and scalable, organizational strategies must be implemented at the classroom, school and systems level. This required a confluence of strategies which include the alignment of assessment and instruction at the classroom level; in-situ and authentic professional development as well as the establishment of learning communities at the school and system levels; and the development of pedagogical framework at the national level (Hogan & colleagues, 2009). Concomitantly, MOE's recent initiatives that emphasised action research and the establishment of Professional Learning Communities within and beyond the context of school were deliberate attempts to foster the integration of ICT from a systemic view (MOE, 2009).

1.2.3 Situating Singapore's use of ICT in education in the broader global context

In 2006, the "Second Information Technology in Education Study (SITES)" conducted a worldwide survey on the pedagogy and ICT use in schools around the world. Culminating in a report (Law, Pelgrum, & Plomp, 2008), the survey results were benchmarked against 9000 schools of 22 participating countries from Europe, Africa,

Middle East, North America and Asia. 164 Singapore schools participated in the quantitative survey. Findings related to the Singapore's context include:

1. An overwhelmingly high percentage of Singapore schools indicated that they had common types of technology applications and facilities (equipment, tutorial software, general software, multimedia production, data-logging, simulation communication software, digital resources, mobile devices, smartboards, LMS and mail accounts). Singapore's score for each category of technology was consistently among the highest, of which, the availability of datalogging, simulation, digital resources and LMS registered the most significant progress ahead of its counterparts;
2. 44% of the school leaders saw ICT as a catalyst for change, which was ranked 7th among the other countries and if we looked within Singapore itself, schools saw preparation of work and catalyst of change as the two most important pedagogical objectives of ICT use;
3. 34% of Singapore schools indicated they need knowledge and skills in pedagogical issues of integrating ICT into teaching and learning, second only to Thailand;
4. On setting priorities for training areas, the areas highlighted were: developing a common pedagogical vision among teaching staff; explaining to teachers the relevance of encouraging students to be responsible for their own learning process and outcomes; developing a strategic plan for

integrating ICT use in teaching and learning and managing the innovation of pedagogical practices in the school.

5. As for the organisational actions that were taken, Singapore schools scored overwhelmingly high in these dimensions: re-allocating workload for collaborative planning (85%), reviewing pedagogical approaches of teachers (97%), monitoring implementation of changes (94%) and having teachers collaborate with external experts (89%).

From the statistical findings, we can infer that Singapore was well endowed in terms of physical equipment and infrastructure. Many schools also recognised the intrinsic value of technology in terms of preparing students for the future and using it as a means to change school practices, as opposed to the extrinsic values of improving scores and pleasing stakeholders. Notwithstanding the value of technology in these areas, schools were also aware of their limited competency in integrating ICT into lessons as school leaders struggled to develop a common pedagogical vision of student-centred learning which teachers could identify and subsequently internalise. The broader implication of the SITES 2006 study, as posited by the authors, was that ICT can be used as a catalyst for pedagogical change if used in students' learning activities. However, the data also showed that many leaders of participating countries did not perceive the catalytic effect of technology as an important pedagogical objective in the first place, suggesting divergent views about conceptions of learning and the use of technology to advance the purpose. More

empirical substantiation is needed to shed light on this perceived affordance of technology.

1.3 The nature of the research problem

From the contextual description of Singapore's ICT landscape, we see that there have been calls from the MOE for schools to integrate the use of ICT for student-centred classroom practices. When these imperatives are cascaded down to the school level, we see huge variability in how schools responded to such perturbations. Literature has suggested that the outcomes of school reforms often hinge primarily on how school leadership fosters or impedes technology integration efforts.

Such concurrence can also be found in other studies (Law, et al., 2008; Wilmore & Betz, 2000) which conclude that principals' vision for technological use to support lifelong learning, technical support for ICT use and priority for leadership development are important factors which influence teachers' use of technology. Much of the foregoing discussion has indicated the need for leaders to provide leadership since the implementation of technology in schools is considered as a large-scale systemic reform (Anderson & Dexter, 2005; Creighton, 2003; Jazzar & Algozzine, 2007; Technology Standards for School Administrators, 2001). What follows from the arguments is that aspiring school leaders and administrators can no longer afford to be naïve about the new educational opportunities as well as the social and economic changes precipitated by technology (Hollingsworth & Mrazek,

2004; Mehlinger & Powers, 2002). Therefore, in order for any systemic technological reform to achieve results, it is an imperative for leaders to first acquire some basic understanding about the affordances of educational technologies so that they can fully appreciate the catalytic role it can play in the institutions' quest to re-design pedagogy (Casson et al., 1997; Dimmock, 2000).

However, Ng and Renshaw (2008) points out that "changing pedagogy is a highly complex process" and many "individual, departmental and school factors need to be addressed" (p12). Looi, Lim and Hung (2005) contend:

> Schools either jump from one innovation to another, or that implementations failed to consider the complexity of the educational system, societal needs, policies, curriculum, pedagogy, practices, epistemic beliefs, skills and others. (p244)

Law, Yuen and Fox (2011) concur that a major challenge in education is to sustain and scale up innovations. Herein lies the essence of problematising the use of ICT for school improvement for this study. The conundrums are manifold: Firstly, moving away from a teacher-centred to student-centred pedagogy requires deep-seated changes in the school climate, which can only be brought about by leaders who are willing to exert strong political will to take calculated risks and teachers who are willing to enact pedagogical interventions, even when confronted with assessment incompatibilities within the system. Secondly, to sustain such practices

requires prolonged conviction of the whole school community so that these practices are enacted even in the changing face of organisational stewardship. Thirdly, technology, which is claimed to have the potential to bring about these deep-seated changes, poses a 'wicked problem' (Stahl, 2006). The problem stems from the fact it takes time for emerging technologies to capture the imagination of educators so that they can be harnessed effectively. It is even more important for these successful practices to be sustained over a long period of time to reap the desired effects of deep learning. This act of problematising brings the discussion closer to the heart of my research objectives and motivation, which are outlined in the subsequent section.

1.4 Research motivation and objectives

Technology leadership often makes a significant difference to how well-positioned schools are in terms of realising the full potential of technology. However, the nuances of good technology leadership remain largely elusive. It is in this light that the study critically examines how an exemplar IT school responds to the imperatives of reform for student-centred learning through ICT. In particular, this study strives to understand how successful technological leaders can bring about a systemic technology reform that is sustained over time. Equally, it is important to find out how schools deploy technologies in all organisational aspects to address the challenges of their pursuits in pedagogical innovation.

In general, there are many studies revolving the use of piecemeal ICT-related innovations at the classroom level. However, studies that investigate how schools have sustained ICT-related reforms through a whole-school approach are scarce. I am also struck by the lack of theoretical framing in terms of expounding the notion of technology leadership. This provides a research impetus for me to explore ICT-related reform from a complexity perspective to develop a more ecological view of whole-school reform and the notion of technology leadership that encapsulates such changes.

The research questions of this thesis are:

1) **What was the development trajectory of a Singapore ICT-enriched primary school that harnessed technology to meet the demands of pedagogical reform for student-centred learning?**

2) **How did the school organisation create the conditions that support the sustainable use of technology for student-centred learning?**

1.5 The importance and contribution of the study

Given the relatively recent phenomenon of technology reform, there is limited research on the role of technology leadership in sustaining innovations. Studies that analysed technology leadership from a systemic perspective anchored in the context of educational reforms are also rare. In this study, I chose to use the relatively new

complexity theory as a frame of reference to understand the systemic factors underpinning the complexities of technology leadership. By using the emergent lens, the study transcends the utility-driven or prescriptive milieu to instead illustrate the ecological instabilities associated with technology-mediated reforms.

Additionally, there are also very few studies about how leaders in schools use technology to transform or re-design a school to promote learner-centred principles. Even if insights can be gained from the limited pool of literature, it is also unclear if these principles can be applied to Singapore's context which still emphasise standardised national examinations.

At present, the IT infrastructure in Singapore schools has been adequate. However, Cuban (2008) notes that "massive infusions of technology do not necessarily translate into teachers altering their daily practices, even when 1:1 exists" (p154). Moreover, according to Dr Ng Eng Hen, Singapore's Minister for Education and Second Minister for Defence, "a gap continues to exist between familiarity with ICT and translating this into effective teaching" (Ministry of Education, 2008, 5 August). Thus, there is a need to situate this study within the activities of the participants to understand "how technology can help a comprehensive school reform exert school wide influence and improve the educational power of the school's approach to teaching and learning" (Bain, 2007, p208).

Findings of the study can contribute to leadership practices for the following reasons:

1) They could help school leaders to map and gain a deeper understanding about the inter-connectedness of the multi-scale interactions taking place within the school ecology.
2) By gaining a holistic perspective on the school and external environment, school leaders can have a better grip on the contextual factors that promote or impede technology integration efforts for pedagogical reforms in the school.
3) By being aware of the impediments, school leaders can work to mitigate tensions and forge greater alignment between technology integration efforts and overarching goals of school improvement.
4) These insights can be used to heighten awareness on how emergent success may be sustained through purposeful re-organisation of resources and re-alignment of goals.

Against the backdrop of a litany of literature that reports the limited role of technology in advancing pedagogical change, the case school featured in this study provided a countervailing example where the use of technology was not only sustained, but sustained through a transformative process that was both emergent and evolutionary. Instead of relegating the role of technology to piecemeal innovations or empowering individual students just to be computer literate, technology was used as an enabler to actualise a more learner-centred pedagogy in conjunction with a systemic whole-school approach that involved re-culturing and

re-structuring. My contribution to the body of work on sustainability of innovations can be summarized as such:

1) Devising a complexity-informed model for technology leadership, accentuating the importance of how information flow can lead to the co-production of knowledge;
2) Fleshing out the multi-level tensions and dynamics amongst stakeholders and articulating how these interactions can lead to adaptive changes;
3) Establishing complexity-informed principles for policymaking purposes and re-defining the roles of leaders, middle managers and teachers.

1.6 Researcher Positionality

As an educator in the education scene for the past 14 years, I had the opportunity to teach in both traditional and full-fledged problem-based learning classrooms for pre-university students, design courseware for the K12 market and conduct research in the field of learning sciences in the capacity of a researcher at a local university research centre. At this point, it is perhaps useful to clarify my role as a researcher. I have been working together with a pool of NIE researchers on a government-funded project which focuses on the use of mobile technology to create a seamless learning environment for students so that they can bridge the gulf between formal and informal learning. Within the project team, there are two subgroups. One of which focused on classroom learning where the researchers worked intensively with teachers to co-design lessons using design-based intervention; the other subgroup

shadowed target students to study their use of mobile phones in informal learning setting using naturalistic observation. I belonged to the informal learning subgroup and thus had not directly intervened to influence teaching and learning strategies. On most occasions, I was a participant-observer with regard to aspects of classroom learning. For this study, the interviewees comprised teachers who had participated and those who were not involved in the abovementioned project.

Due to my prolonged immersion in the school over the years, I had access to insider perspective but at the same time, was able to maintain some distance with the participants due to my positioning as a participant-observer. The participants felt psychologically safe to share their thoughts, knowing that I did not have a direct involvement in the design of interventions. As I was no complete stranger to my participants, establishing trust and rapport throughout the data collection process was not an uphill task, but there were other challenges that accompanied these advantages. For example, some interviewees were forthcoming in their comments and exchanged views on sensitive and valuable data which they would want to go off-record. Tensions which manifested in the form of personal struggle arose when there was vested interest to provide a 'true' account of the phenomenon and at the same time, keeping in mind that trust should not be breached and participants not psychologically harmed in any way because of the research. My positioning as a researcher became very intricate when oscillating between the two objectives. Dickson-Swift et al. (2007) write that researchers may open the 'Pandora's Box' or 'a

can of worms' and have to subsequently act as a 'secret-keeper' (p338). In these cases, I respected the wishes of participants even if it had to come at the cost of research. However, to continue to pursue deeper understanding of the phenomenon, I triangulated these sensitive data with other forms of data sources, which at times, could be retold in a less personal way based on alternative evidence without jeopardising any participant.

My personal belief towards learning could also affect how I viewed my data. Due to the myriad of exposure I had gained during my career, I was able to observe a wide spectrum of ways in which technology had been used in local schools from multiple perspectives, ranging from that of a practitioner, commercial partner to that of a researcher. There was propensity for me to be more sympathetic towards student-centred learning as my experience suggested that students were more engaged when their voices could be heard. I had experienced a shift in my own mental framework to focus more on the learning processes than outcomes. To keep such biased views in check, I had to remind myself not to dismiss the views of interviewees whose philosophy did not resonate with me. Instead, these interviewees could provide a critical examination of organisational ethos, pedagogical beliefs and how and why technology should or should not be used. Essentially, I was undertaking the "verstehen" position where "qualitative inquirers strive to understand their objects of interest" (Lindlof, 1995, p9). This would reduce

the tendency to supplant my own experiences and losing awareness of what was actually happening.

I was also mindful of committing the fallacy of "confirmation bias" during the data collection stage and the best way to avoid the pitfall is to practise what complexity theory advocates – allow emergence. There should be room for data to "emerge" without relying solely on pre-conceived notions of what to observe or make premature judgment of what is being observed. To keep the essence of complexity perspective in mind, knowledge and 'truth' co-evolve through multi-scale interactions with actors and the environment, therefore keeping an open mind and constantly checking against multiple perspectives as a form of triangulation are vital in dealing with research bias.

1.7 Overview of thesis

This introductory chapter provides a contextual background on how Singapore schools are using ICT for student-centred learning. In broad strokes, the ICT landscape is painted and the evolution of the nation's ICT journey elucidated. The rationale for embarking on this study is organised around the themes of research problem, motivation, questions, significance and contributions. Chapter 2 reviews the current literature related to this study. As this is a trans-disciplinary study, the literature surveyed includes school reforms, use of ICT in schools, leadership studies, pedagogical trends and innovation sustainability. Chapter 3 details the methodology

used, ranging from the researcher's ontological and epistemological positions to the justification of the chosen conceptual framework, research approach as well as research design. Issues of reliability and validity are also discussed. Chapters 4 and 5 expound on the major findings related to the first and second research question respectively. Chapter 6 discusses the findings by mapping out the ecological influences and situating them among the literature scanned. Chapter 7 considers the implications of the findings to policymakers, middle managers, teachers and future research directions from the complexity perspective. It also presents a model of how the use of ICT for student-centred learning can be sustained over time by building critical connections.

Chapter 2. Review of Related Literature

2.1 Introduction and Purpose

The purpose of this chapter is to establish the context of the topic, identify the research gaps, gain conceptual and methodological insights on the lens and tools I can use to explore the research problem, and to provide a framework to link my findings to the existing body of knowledge in the area of technology leadership.

Although educational leadership and the use of technology in education have been broadly discussed, there is little scholarly dialogue between the two areas (Albion, 2006). In addition, this study entails the sustainability of reforms, thus accentuating the paucity of literature pertaining to the confluence of the three fields. As the subject of inquiry is cross-disciplinary and scarce in nature, I have to conduct a broad review covering four areas of literature:

1) nature of technology-mediated school reforms;
2) theoretical frameworks on leadership;
3) sustainability of educational innovations;
4) pedagogical considerations underpinning the use of technology in schools

2.2 Nature of technology-mediated school reforms

2.2.1 Conceptual background

There is growing recognition that leadership is one of the key ingredients of successful implementation of educational technologies. However, the progress in the study of the relation between educational leadership, ICT in education and school reforms has remained modest and understated (Hollingsworth & Mrazek, 2004; Shuldman, 2004; Yee, 2000). Despite this modest progress, there still exists notable shifts in the literature devoted to the study of the above. The first being the shift away from undertaking dichotomous positions to the adoption of judicious view where one should not be overly critical or optimistic when it comes to the use of technology (Brown & Duguid, 2000; Buckingham, 2007; Carbone, 1995; Oppenheimer, 2003; Walker & White, 2002; Zucker, 2008). The main lesson that we can draw from the above strand of literature is that school leaders need to articulate the ideas behind the debates of technophobes and technophiles so that they can be more astute when integrating technology into their practice.

While the above insights may provide school leaders with a useful conceptual background to examine technological use in schools, they do not inform school leaders on issues related to ICT reform and implementation. The second shift in the literature from atomistic to holistic perspective on technology integration addresses these areas. The restructuring movement now calls for educators to view ICT reform

holistically to engineer a comprehensive reform in schools where technology will blend in seamlessly with all aspects of teaching, learning, staff development, administration and community relations (Burns & Dimock, 2007; Creighton, 2003; Dimmock, 2000; Driscoll, 2001; Kozloski, 2006; Krikman, 2000; Riedl et al., 1998; Zhao & Frank, 2003). It is the inter-connectedness of the myriad of related factors that should be explored. Zhao and Frank (2003) explain:

> [P]revious research has resulted in a long, almost exhaustive, list of factors that may affect the uses of technology in schools. However, these factors are often examined in isolation from each other or from the system in which they interact. Rarely are they studied together under a framework to sort out their relative importance and to identify the relationships among them. (p809)

The authors use the metaphor of "ecology" to highlight the systemic relationships of factors affecting technology use in schools and to illustrate how the use of ICT in schools is similarly dependent on a broader socio-cultural context. Such musings point to the need for leaders to look at the whole system when technological leadership is concerned since one aspect of change in the organisation may have ramifications throughout the whole system.

2.2.2 Levels of ICT integration and implementation

The surge of literature linking school reforms and the use of ICT in schools started to emerge during the last decade (Downes et al., 2002). Notwithstanding its relatively short history of scholarship when compared to other established fields of study in education, the literature does proffer some insights on ICT reforms in schools. Notably, the report in "Making Better Connections" (Downes, et al., 2002), a study funded by the Commonwealth Department of Education, Science and Training (DEST), has articulated the different levels of ICT integration by categorising its nature as follows:

Type A: Encouraging the acquisition of ICT skills as an end themselves;

Type B: Using ICTs to enhance students' abilities within the existing curriculum.

Type C: Introducing ICT as an integral component of broader curricular reforms that are changing not only how learning occurs but what is learned;

Type D: Introducing ICTs as an integral component of the reforms that alter the organisation and structure of schooling itself.

(p23)

The framework is immensely useful for defining and distinguishing the different types of ICT reforms in schools. Owen and Demb (2004) make the observation that institutions which adopt incremental responses to ICT such as adding more technological courses sporadically will not be able to exploit the opportunities or

manage the challenges wrought by technologies. In the wider literature on ICT integration, the use of technology without accompanying systemic changes in professional development and curriculum reforms, as exemplified in Type A and Type B reforms, will be regarded as bolt-on additions to the existing institutional frameworks and their efficacies to revolutionise how students learn and how educators teach will be limited due to the piecemeal approach (Burns & Dimock, 2007; Coppola, 2004). Type C reform is a little more ambitious in the aspect of incorporating pedagogical innovations but as argued in the previous section, reforms cannot be effective if there are no systemic changes to the institutions and this philosophy is quintessentially embedded in type D reform. Schlechty (2009) makes similar assertions that systemic changes would be required "before the disruptive innovations might produce the effects it promises" (p19) - a sobering thought for leaders who tend to believe that innovations can be delivered within the existing bureaucratic system. What follows from this vein of argument is that Type D reform which encompasses the introduction of curricular reforms should be viewed as a precursor to successful integration rather than an absolute consequence of using ICT. Type D reform is central in framing the scope of my proposed study on how school leaders can possibly transform a teacher-centred school to a student-centred school and sustain the use of technology for student-centred learning. The framework provides the cornerstone to drive and inform the direction of my research when selecting exemplary school as case study.

Tong and Trinidad (2005) as well as Mooij and Smeets (2001) suggest that a school needs to go through several phases of ICT implementation before it approaches maturity. Tong and Trinidad's model for "Innovative Pedagogical Practices Using Technology" (IPPUT) aims to help school leaders identify which phase of development the school is at by looking at the conditions and constraints in school. Table 2.1 illustrates the model.

Phases of IPPUT Development	Conditions in the school			Constraints in the school		
	Necessary (teacher expertise, favourable attitude, clear vision, sufficient facilities, technical support)	Sufficient (innovative teachers, quality support structures, PD focused on pedagogy, institutionalize innovations)	Sustainable (teacher activist, PD meeting individual and school needs, change of school culture, more connected, instructional leadership)	Critical (inaction teachers)	Inhibitory (inadequate direction, knowledge, support,, evaluation, cultural change)	Tolerable (inadequate resources for future development, professional development not pedagogic specific)
Pre-adoption	Less	Less	Less	More	More	More
Initial-adoption	Must	Less	Less	No	More	More
Institutionalisation	Must	More	Less	No	Less	More
Sustainable Development	Must	More	More	No	Less	Less

Table 2.1 Tong and Trinidad's (2005) IPPUT model.

The study is premised on the assumption that ICT can be utilised to enhance a pedagogically-sound environment for constructivist learning and that it is possible to integrate the innovation into the curriculum and sustain its development. According to the authors, all the necessary, sufficient and sustainable conditions will be satisfied and all critical, inhibitory and tolerable constraints of ICT implementation

will be eliminated by the school at the final phase of the development. However, such conceptualisation can be problematic for a number of reasons. First, the authors assume that the concepts of conditions and constraints are static and linear, and can be eliminated in a step-by-step fashion. More often than not, conditions and constraints are dynamic, inter-locked and iterative instead. Second, there seems to be a lot of mesh-up between outcomes and conditions. For example, changing culture can be a pre-requisite and outcome of interventions. Third, the status differentiation between "necessary", "sufficient", "sustainable", "critical", "inhibitory" and "tolerable" appears to be arbitrary, subjective and indeterminable. What is perceived as "tolerable" constraint can become "critical", depending on the changing circumstances, rendering it difficult for school leaders to fulfil all conditions, eliminate constraints, and utilise this model for planning as the authors posited.

Mooij and Smeets (2001) on the other hand, devise a five-stage model for ICT implementation after analysing 10 secondary schools in Holland. The successive stages are:

1. Incidental and isolated use of ICT by one of the teachers;
2. Awareness of the relevance of ICT for the school and subject-related departments;
3. ICT co-ordination and the hardware facilities in the entire school;
4. Didactic innovation and ICT education support;

5. Integrated ICT support of learning processes

(p279-280)

As articulated by the authors, these stages represent a gradual transformation of learning processes mediated by ICT. The authors also map out possible intervention actions which could be adopted by school leaders for each of the phases. However, as Law, Yuen and Fox (2011) have critiqued, the model may not be appropriate for such purposes as it focuses more on the "technical history of ICT use in schools rather than the implementation and development history in schools" (p115). Moreover, as with Tong and Trinidad, the developmental pathways are also linear in nature, which may not be the case in actual implementation.

2.3 Theoretical frameworks on leadership

2.3.1 Attributes of technology leadership

Much of the limited literature on technology leadership has examined the role, core competencies as well as personal attributes of principals. Two of the most widely cited works in this area are those of Yee (2000) as well as Flanagan and Jacobsen (2003). Yee's eight categories of leadership styles are derived from her qualitative study on 10 principals of ICT-enriched schools from Canada, New Zealand and the United States whereas Flanagan and Jacobsen's framework is derived from a programme of studies on the technology integration efforts of kindergarten to grade 12 schools in Alberta, Canada.

Chang et al. (2008) proffer a more updated review on the principal's role as a technology leader. The authors draw conclusions from their large-scale quantitative survey of 1880 teachers from 188 Taiwanese elementary schools on perceptions of principal's role in leading and facilitating technology use in their schools. The three studies are then juxtaposed with Fullan's (2002) personal insights on what school reforms in general entail for educational leaders. The notion was subsequently expanded in another co-authored article (Fullan, Cuttress, & Kilcher, 2009). Together, these studies are compared in an attempt to reveal the similarities and differences about the nature of technology leadership, as articulated by the prominent scholars in the field as well as how different this notion may be when situated in the wider field of educational and change leadership. Table 2.2 summarises the list of leadership attributes and practices which the authors think are paramount to the success of reform. To facilitate comparisons, similar ideas across the board are grouped together.

	Yee (2000)	Flanagan & Jacobsen (2003)	Chang et al. (2009)	Fullan (2002), Fullan et al. (2009)
Vision Mapping	**Learning-focused Envisioning** Transmit vision and sense of purpose: focus on student learning.	**Leader of Learning** Ensuring continued focus on higher level outcomes such as communicating, inquiring, decision making and problem solving.	**Articulate Shared Vision** Clearly articulate a shared vision by organising and empowering a technology planning team,	**Creating and Building Knowledge** Acknowledge information only becomes knowledge through social process and foster culture of sharing and continuous learning.

	Yee (2000)	Flanagan & Jacobsen (2003)	Chang et al. (2009)	Fullan (2002), Fullan et al. (2009)
Goal Monitoring	**Constant Monitoring** Review and monitor teaching practices to ensure they are aligned with the new vision.		**Structure evaluation and research** Incorporate technology use as part of the staff assessment component. Monitor technology plans and use. Benchmark school data against district or national data for insights on performance and trends.	**Fostering Coherence Making** Focus on student learning and not allow too many projects to detract the school from the main purpose of reform. Examine how big picture fits together.
Altruistic Provision	**Equitable Providing** Provide necessary resources such as time and support to all staff members and students.	**Leader of Pupil Entitlement** Committed to ensuring equity of access to technology for all pupils including those who are under the charge of teachers who are technophobes.	**Ensuring Timely Access** Provide technology and infrastructure support. Ensure timely access, support and maintenance.	**Engaging People's Moral Purpose** Strive to act with the intention of making positive changes to the environment (which includes other schools in the district) and improving educational systems to raise overall literacy achievement.
		Leader of Resource Management Manage all resources necessary for technology integration and ensure their availability to teachers and students.	**Managing technology resources** Advocate for school technology resources, exercise fair and reasonable judgement in resource allocation, implement a reasonable technology plan and manage technology facilities and resources.	
Capacity Building	**Patient Teaching** Willing to impart what they know to all stakeholders. Create flexible learning opportunities for professional development.	**Leader of Capacity Building** Empower ICT leadership amongst teachers, pupils and parents so that shared leadership can emerge. Establish a climate that promotes risk-taking and collaboration.	**Nurturing technology skills** Train and encourage teacher's technology development. These should be planned, designed and customized. Set adequate time for such endeavours.	**Building Capacity** Design policies, strategies, resources and actions to increase collective power to move forward to deliver new capacity.
	Adventurous Learning Showing desire to learn along with staff members and pupils by experimenting new technologies.			

	Yee (2000)	Flanagan & Jacobsen (2003)	Chang et al. (2009)	Fullan (2002), Fullan et al. (2009)
Policy Implementation	**Careful Challenging** Challenge assumptions and traditions but have political sophistication to gauge the latitude of risk-taking that can be tolerated without creating difficulties for the school.		**Leading Restructuring** Lead school improvement on restructuring and use emerging technologies as core resources for educational change. Long-range planning is needed.	**Understanding Change** Develop commitment with others who are resistant to the reform. Foster day-to-day reculturing on the basis of what people value. Establishing enduring conditions for continuous improvement.
	Protective Enabling Encourage shared leadership so that staff members are more committed to the vision. Defend vision when faced with external threats.			**Developing Cultures for Learning and Evaluation** Include knowledge and affective dimension for enhancing "we-we" identity and to establish a culture of disciplined inquiry to sort out promising ideas, such as using technology to analyse student data for corrective actions.
Social Engagement	**Entrepreneurial Networking** Build relationships with administrators and ICT vendors.	**Leader of Community** Take a pro-active stance in collaborating with the community, which includes forging partnership with business entities and parents.	**Maintain Positive Relationship** Actively communicate to all stakeholders to understand technology needs and motivate them to use information for professional growth.	**Building Relationship** Possess emotional intelligence to maintain cordial relationship with diverse groups of people.

Table 2.2 Juxtaposing priorities and attributes of technology leaders

Source: Yee (2000); Flanagan & Jacobsen (2003); Fullan (2002); Fullan et al. (2009) and Chang et al (2008)

Table 2.2 suggests that vision mapping, goal monitoring, altruistic provision, capacity building, policy implementation and social engagement have been the salient priorities of technology reform over the decade. However, there is more foregrounding of shared vision, systemic evaluation and immersive integration of technology in teaching practice, as enumerated by Chang et al. Whilst the dimensions of technology leadership do not appear to be radically different when

compared with those of educational leadership, technology leadership emphasises more on resource management and maintenance, suggesting more complexity in this area compared to non-technology innovations. Law, Yuan and Fox's (2011) recent analysis of 82 case reports on principal leadership also indicate high occurrence of resource planning for innovations by principals.

2.3.2 Distributed and complexity leadership

The above discussion has coalesced around the role of principal as the main champion in advancing technological reforms. However, a number of trends has contributed to the paradigm shift away from directive leadership where the decision-making process is highly unilateral (Morrison, 2002) to distributed leadership where leadership practice is perceived as a product of the interactions between actors, including both leaders and followers, artefacts and situations (Ho, 2009; Spillane, Halverson, & Diamond, 2001). An example of directive leadership is transactional leadership. Its command-and-control bureaucracy has been criticised for exemplifying high-handedness and self-aggrandizement. Transformational leaders, on the other hand, are change agents of organisational learning and culture building with anchored frames of commitment and trust (Bennis & Nanus, 1985; Harris, 2000).

Although more humanistic and less directive in outlook, transformational learning remains largely leader-determined (Morrison, 2002). Distributed leadership however transcends individualism. It views leadership as "more than the mere sums of its parts" (Gronn, 2002, p656) and for sustainability sake, leaders should be developed at all levels of the organisation (Spillane, Halverson, & Diamond, 2000). Leithwood, Mascall and Strauss (2009a) highlight that distributed leadership calls for "implicit coordination, if not intentional planning, of leadership distribution if the superior capacity development assumed by collective learning is to materialise in the first place" (p5). That is, formal leaders should orchestrate the efforts of disparate sources of expertise for problem solving.

Although leadership can be interspersed at all levels, the notion of distributed leadership can be democratic or autocratic depending on how decisions are made and whose agenda the organisation is pursuing (Spillane, 2005). Jettisoning the autocratic form of distributed leadership, Sheppard (2003) asserts that distributed leadership that can leverage on organisational learning will be one that "moves away from technological, hierarchical, rational planning models, towards cultural, collaborative approaches". His study of 15 Canadian schools provides empirical evidence to suggest that school principals' influence in ICT usage becomes more powerful when it is indirect, usually as "champions for organisational learning" while teachers become empowered champions of specific change initiative.

Scholars are not without reservations about distributed leadership. Timperley (2009) cautions that distributing leadership may result in "the greater distribution of incompetence" (p220), especially when the activities are not coherently tied to the goal of providing more effective instruction. Leithwood et al. (2009b) provide another possible reason for such distribution of incompetence:

> When informal leadership is ascribed to prototypical persons, those persons may or may not have the capacity or motivation to move their organisation forward. Indeed, their motivation might just be the opposite – to preserve strongly-held group norms that, nevertheless stand in the way of the group becoming more effective. (p233)

A prototypical person is one who shares similar views to the members of a group and deviates most from those outside the circle. The most effective type of informal leader, according to Leithwood and his colleagues (Leithwood, et al., 2009b) would be one who possesses both expertise and prototypicality so as to earn trust and shorten the "buy-in" time of key stakeholders. Also related to social interactions, Kowch (2004) postulates that the technology leaders need to look beyond implementation processes and management to design and guide "bonding within homogenous groups", "bridging across horizontal cleavages" and "linking between different stratas" (p511) to accomplish projects.

Distilling the ideas from the above literature, the notion of distributed leadership is multi-faceted and very little is written about what model of distributed leadership schools should adopt. It is unclear what kind of decision-making model will work well in a context such as Singapore where policymakers, although practising decentralisation over the years, still have heavy influence on schools. Also, to what extent can the leaders delegate and concomitantly avoid the pitfalls elucidated by Spector (2001) as well as Hollingsworth and Mrazek (2004) where leaders only take a perfunctory approach to IT? The art of delicate balancing is needed and the issue is "how". Complexity leadership, a nascent perspective in leadership studies, appears to take these observations about distributed leadership further by positing a frame of reference to help us understand the conditions for "emergence". Emergence refers to:

> … the "natural tendency of agents (individuals, groups, departments etc.) in a social system to interact in complex, dynamic ways – to exchange information, take actions, and continuously respond to feedback. These interactive dynamics produce real change, the creation of novel order and ultimately system-level adaptation. (Jennings & Dooley, 2007, p23)

According to Leithwood et al. (2009a), complexity science holds "promise for unpacking the nature and consequences of distributed leadership" (p6). Complexity scholars such as Hazy, Goldstein, Lichtenstein (2007) as well as Uhl-Bien, Marion and

Mckelvey (2007) note that innovation and adaptability can be encouraged by creating the conditions within which novel and coherent structures can flourish during the self-organising process in a "complex adaptive system" (CAS) characterised by semi-autonomous agents that have the capacities to adapt to the changing environment. The authors, however also point out that complexity leadership is far from the notion of passively waiting for everyone to "self-organize". It calls for formal leaders to "enact formal organizational policies and processes for emergence and self-organisation to happen" (Hazy, et al., 2007, p95). This parallels Papert (1997), Tyack and Cuban (1995) as well as Lewin and Regine's (2000) proposition that leaders should just concentrate on creating the right conditions for reform to happen. In Papert's (1997) seminal paper, he argues that deliberate design of reforms in the fashion of "centralized social engineering inexorably goes wrong" (426) and instead advocates the following:

> (S)ome changes, arguably the most important ones in social cultural spheres, come about by evolution rather than by deliberate design…the shift from the stance of reform to a stance of evolution does not exclude active intervention, but the role of the change agent becomes less like the architect or builder and more like the plant or animal breeder whose interventions take the form of influencing processes that have their own dynamic (p417-418).

Uhl-Bien et al. (2007) refer to these influencing processes as the dynamic interfacing between bureaucratic, administrative functions of the organisation and the emergent, informal dynamics of CAS. Goldstein (2007) suggests that more research needs to be done to understand what the abovementioned roles entail. By adopting the complexity perspective as the conceptual framework of this study, I hope the dynamics underpinning the interactions amongst actors of the case school can be better illuminated.

To further illustrate the nature of dynamics, Tan (2010) and Dexter (2007) note that technology leadership is a school characteristic that evolves from iterative interdependencies amongst leaders, followers, situations and artefacts (Tan, 2010; Dexter, 2007). Dexter's study on four case studies of U.S. middle schools with laptop programmes illustrates the nature of technology leadership:

> It is distributed across a team of people that altogether provide technology expertise and decision making authority and who take responsibility in setting direction, developing people, and making the organization work for educational technology. (p20)

This insight is important as it justifies the use of the whole school as a unit of analysis for this study on technology leadership. It is by looking at the ecology of school that the benefits of distributed cognition can be explicated and sustainability of reforms be studied in a more holistic manner. Chapter 3 (methodology chapter) further

elaborates the main constructs and rationale of using complexity theory to study the ecology. The next section explores the literature on sustainability of reforms.

2.4 Sustainability of reforms

2.4.1 Sustainable leadership

For reforms to spread and last, Hargreaves and Fink (2004) advise that "sustainable leadership must also be a fundamental priority of the systems in which leaders do their work" (p10). However, our current literature does not say much about how school leaders as change agents can plan for inter-generational sustainability. Moreover, the mounting pressure to perform may prompt leaders to take short-term measures rather than to plan for sustainability, if at all. Fullan and Sharratt (2009) contend that factors like leadership renewal and the accompanying changes can threaten the hard work of sustaining cultures. This problem, according to them, can be mitigated by "making what works explicit and by enabling more and more leaders at all levels of the system to be aware of the conditions that energize themselves and those with whom they work" (p176-177). Coppola (2004) argues that the consistency, coherence and appropriateness of school culture, predicated on "honoured traditions" (p154), can give organisations the power to sustain innovations.

Hargreaves and Fink (2004) highlight the following seven principles for sustainable leadership: focusing on lasting and real impact that augment student learning;

preparing for leadership succession for continued success; ensuring that influence and decision-making responsibility are distributed; maintaining social justice so as to mutually benefit all students, the school organisation and the community; renewing the energy of leaders by husbanding financial and material resources; celebrating diversity instead of conforming to standardization and engaging in perpetual dialogue with the environment to leverage on all forms of support to advance meaningful cause.

Riggan and Goertz (2010) suggest that to circumvent the challenges associated with leadership renewals, school leaders should focus on the political interfacing amongst district and school leaders to reach a common understanding on the latitude of innovation and measurement of progress; forge innovation within and across classrooms; ensure systematic sharing and interpretation of feedback as well as organise resources around instruction.

What stands out from the abovementioned literature is the common emphasis on distributing responsibilities and empowering personnel at all levels of the system to cushion the instabilities that accompany leadership renewal. However, Hargreaves and Fink foreground a stance that is more egalitarian, inclusive, multi-perspectival and long-term as they take into consideration the interaction between actors and environments.

2.4.2 Sustaining innovations

Much has been written about how innovations can possibly be sustained. Fullan (2002) espouses the need of alignment in terms of focusing not on the quantity of innovation, but to "innovate selectively with coherence" and to foster a culture which can tolerate teething problems associated with trying something new. This has to be accompanied by "fundamental transformation in the learning cultures of schools and of the teaching profession itself". However, Fullan himself admits that the concept of coherence-making is elusive. In another publication, Fullan (2009) expounds on how real continuity of programmes can be eschewed and be subjugated to leader's ego-feeding aggrandizement:

> …[W]e dubbed schools with high levels of incoherence "Christmas tree schools." Such schools were well-known showcases because of the variety of programs they boasted. Frequently, however, these programs were uncoordinated and perhaps even philosophically inconsistent. (Sebring and Btyk, 2000, p441-442 as quoted in Fullan, 2009, p60-61).

For such schools, sustainability and coherence-making are distant priorities as compared to raising the school's profile to gain public recognition quickly. It is purely an organisational perspective with student-centric needs being sidelined.

Levin and Fullan (2009) outline seven premises for sustainable improvement:

1) A small number of ambitious yet achievable goals, publicly stated
2) A positive stance with a focus on motivation
3) Multilevel engagement with strong leadership and a "guiding coalition"
4) Emphasis on capacity building with a focus on results
5) Keeping a focus on key strategies while also managing other interests and issues
6) Effective use of resources
7) Constant and growing transparency, including public and stakeholder communication and feedback

(p191)

Here, the authors accentuate the leader-centric perspective and largely ignore the quality of interaction between the actors (especially informal leaders) and the broader landscape that influences those reforms. As a result, this argument on sustainability of school improvement appears to be de-contextualised from the milieu of education, as compared to Fullan's (2002) earlier dialogue on "coherence-making". Conversely, Blumenfeld et al.'s (2000) discussion on the concept of sustainability appears to have more valence to practitioners as it helps leaders to conduct a gap analysis between the demands of innovations and the existing capacity of organisation by locating innovation along the micro and meso dimensions of school culture, capability of practitioners and policy/management. This, according to Looi et al. (2005), empowers leaders to look at opportunities and processes for sustained success.

In a rare exposition of sustainability from the complexity perspective, Lemke and Sabelli (2008) argue that the structural features of school practices such as student-teacher ratio, use of textbooks, curriculum areas and teacher training institutions are stable over a long period of time and thus suggest "there are powerful system-regulatory relationships maintaining this stability" (p120). On the other side, there are features that are dynamic. Complexity theory, according to them is a useful lens to understand why some features are tenacious and the conditions under which they would change. In short, to study sustainability, they advocate the study of "relationships among the timescales of change processes in different elements of the system and between the system and the larger socio-political-economic systems in which it is embedded and in which its functioning depends" (p120). Based on the meta-analysis of several major reform practices in U.S., the authors find that early successes and widespread commitment are critical determinants of sustainability. However, the authors state that it is unclear whether the traditional assumption that structural changes are not needed to maintain sustainability actually holds true. They argue for the need to conduct detailed case studies of reform efforts. This is another area which this study could potentially contribute.

In another complexity-informed study, O'Day (2002) uses the complexity lens to examine school reforms, but focuses on how information passes through complex systems such as schools and conclude that the concomitant use of whole-school administrative and professional accountability is the key for implementing reforms

that are meaningful and lasting. The complexity perspective bespeaks a stance that is different from the socio-cultural or organisational positions as it focuses more on the inter-connectedness between system and sub-systems of the school – an area which will also be explored in this study.

2.4.3 Sustainability of ICT reforms

Whilst the preceding section looks at the sustainability of educational innovations in general, this section looks specifically at the sustainability of ICT reforms in the educational landscape. Scholarly exchanges in this area are scarce, probably due to the fact that ICT-mediated reforms are relatively recent phenomenon and thus the topic about its sustainability has yet to gain significant momentum, as compared to other non-ICT pedagogical innovations.

Drawing insights from the data collected from 174 schools across 28 countries, Owston (2006) organises the determinants for sustainability of innovations into two broad categories: essential and contributing conditions. The former refers to student support as well as teacher support, which is inter-related with teacher's perceived value of innovation and professional development. The latter refers to supportive plans and policies, funding, innovation champions, internal and external recognition and support such as partnership with universities and private sector. Also highlighting school-university collaborations, Fishman et al. (2004) note that

researchers can serve as sources of continuity for innovations by interfacing with new leadership.

Exploring the perspectives of teachers, Wong and Li (2006) conducted a large-scale quantitative survey on 1076 teachers from 130 Hong Kong schools to find out the critical determinants that affected the sustainability of on-going development of ICT in teaching and learning. The authors found out that the teachers perceived "continuous funding", "on-going staff development pertaining to ICT in education", "appropriate allocation of resources" and the "provision of suitable software that is suitable for school's curricula" (p333) as the top four vital conditions. However, there are discrepancies between what was perceived as important and the actual establishment of conditions. Interestingly, from the same survey, conditions such as risk-taking culture, shared vision, evaluation of school readiness and changes in assessment mode were ranked in the bottom half of a total of 12 dimensions. This is counter-intuitive when we situate the findings against the conventional literature on important attributes of technology leadership (see preceding section). This may suggest a gulf of intentionality, concerns and tools between teachers and formal leaders.

Looking specifically at Singapore's context, Looi and his colleagues (2011) have identified a few critical determinants of why their ICT-enhanced intervention could be sustained and scaled across different schools. These reasons include: creating

readiness of teachers and students through enculturation and capacity building efforts; on-going evaluations and creative renewals of intervention; emphasising routine (instead of sporadic) use of intuitive technology from the outset; focusing on collaborative learning; tapping on existing curriculum; co-designing lessons to prepare for the shift of ownership from the researchers to practitioners as well as the alignment with the school's strategic plan. Impediments to sustainability include traditional assessment modes, rigidity in curriculum structure and the steep learning curve experienced by teachers as they adjust to new teaching practices. The rule of thumb, as posited by the authors is to advocate evolutionary rather than revolutionary changes.

The proposition underpinning the abovementioned studies is that the sustainability of ICT reforms is multi-factorial. The concept of "alignment" is the linchpin that anchors these studies. To elaborate, alignment, as abstracted from this segment of literature review, can be construed as the confluence of physical (devices, technology), social (meaningful interaction between stakeholders), human (expertise, knowledge, experience), cultural (values, norms, enculturation), political (interpreting political needs) as well as financial (funding, budget) capital.

2.4.4 Inter-relationship between sustainability and scalability

Another related though not equivalent notion of "sustainability" is "scalability". The former looks particularly at sustaining reforms over time while the latter comprises

four interrelated dimensions: *depth* of change in classroom practices, *sustainability* of reforms in face of competing priorities and changing circumstances, *spread* of activities, beliefs and norms as well as *shift* from external to internal reform ownership (Coburn, 2003). Dede (2006) expands Coburn's work to add another dimension of scalability - "*evolution*" where the original designers of the innovation take a contemplative look at the improvisation made by adapters and use it to re-conceptualise the innovation model. In other words, sustainability may not result in the other constructs of scalability but if it does, it helps in creating a more lasting and profound impact of reforms at a wider school level. Lemke and Sabelli (2008) define their inter-relationship lucidly:

> Scaling is a useful strategy for testing the robustness of the process, making it more sustainable, and finding its weakest spots. This points to the interdependence of scaling and sustainability as a key issue for any model. (p120)

Compared to sustainability, scalability is perhaps a more direct and tangible criterion often used by policymakers to gauge the success of innovations due to its relative ease of quantifying the magnitude of scaling. However, both Fishman (2005) and Coburn (2003) argue for the need to move beyond numbers and rethink scale as an encapsulation of "deep and consequential changes in classroom practice" to "alter teachers' beliefs, norms of social interaction and pedagogical principles as enacted

in the curriculum" (Coburn, 2003, p4). The frameworks of Coburn (2003) and Dede (2006) are not prescriptive in nature, but they serve as a useful conceptualisation tool to operationalise the construct of sustainability and evaluate the state of technology usage for the case school.

Some key issues raised in this section on sustainability of reforms are how coherence-making can be forged in the face of leadership change and how the critical determinants that affected sustainability can be distilled by operationalising the study of relationships among the timescales of change processes in both the systems and sub-systems embedded in the learning ecology. The literature prompts us to think further about what needs to be aligned and the role of scalability in sustaining technology-related innovations.

2.5 Pedagogical considerations underpinning the student-centred use of ICT

2.5.1 Unpacking student-centred learning

Student-centred learning foregrounds the needs of students in teaching practices and learning processes. Although the term is defined differently by scholars, much of the interpretations in the foregoing literature converge along the line of giving students more voice, which is often accompanied by a shift in power from the teacher to the students. Drawing insights from a series of literature on student-centred learning, Lea et al. (2003) encapsulate the tenets of this broad concept:

1. the reliance on active rather than passive learning
2. an emphasis on deep learning and understanding
3. increased responsibility and accountability on the part of the student
4. an increased sense of autonomy in the learner
5. an interdependence between teacher and learner
6. mutual respect within the learner-teacher relationship
7. a reflexive approach to the teaching and learning process on the part of both teacher and learner

(p322)

It is noteworthy that although some of the tenets mentioned by the authors, in particular the engagement of deep learning strategies may also be observable in a traditional teacher-directed classroom, they are not by design or foregrounded in the instructional process. The underlying thrust is that the design of learning opportunities or facilitation will influence the strategies that learners adopt. In student-centred classrooms, learners may have more propensity to be engaged in deep learning due to the emphasis on knowledge construction. In relation to this, Brandes and Ginnis (1986) expound on the importance of participatory culture as learners manage their learning trajectories through facilitation by teachers in student-centred classrooms. Learners are no longer the passive recipients of knowledge as explicated in traditional classrooms characterised by didactic teaching. Instead, they are "co-producers of knowledge who have gained sovereignty over

what and how they want to learn" (Looi et al., 2009, p1121). The inferences are that teachers relinquish their tight control over the prescribed curriculum, imbue epistemic curiosity and facilitate lively discourse in the learning environment.

As O'Neill and McMahon (2005) point out, the theoretical standing of student-centred learning is "often surprisingly absent in the literature" (p28) but appears to draw on learning theories such as constructivism and socio-constructivism. Smeets and Mooij (2001) term this relationship between learning theories of constructivism/socio-constructivism and the pedagogical strategies of student-centred learning a "good fit" as they are rooted in the common belief that learners learn better when they actively construct knowledge. Hirumi (2002) also articulates how constructivist design principles can inform educators in creating strategies to transform from teacher-directed into student-centred learning environment.

Originating from Piaget's theory on knowledge internalisation, accommodation and assimilation, the constructivist perspective hinges on the principle that we construct meanings individually based on our interactions with the world. Knowledge is constructed subjectively and is imposed on the world by us instead of existing as an independent objective reality (Duffy & Jonassen, 1992; Lefoe, 1998). Social constructivism, on the other hand, gives higher priority to the interactions between individuals and groups to participate in the on-going creation of their perceived reality. Strongly influenced by Vygotsky's (1978) work on "zone of proximal

development", the implication for teaching is that facilitators should scaffold or engage students via social discourse that supports higher-order thinking skills and the consideration of multiple perspectives. Through guided facilitation by teachers or coaching by peer experts, students can move from their existing to their potential level of understanding. New pedagogies such as problem-based, inquiry-based, project-based, active, collaborative and discovery learning are largely aligned with this principle (Lefoe, 1998; Pritchard, 2006).

The above literature focuses on the cognitive and social aspects of student-centred learning. McCombs and Whisler (1997) argue for a more encompassing definition to include respecting individual differences as learners are unique and distinct:

> Learners' unique differences include emotional states of mind, learning rates, learning styles, stages of development, abilities, talents, feelings of efficacy, and other academic and non-academic attributes and needs. These must be taken into account if all learners are to be provided with the necessary challenges and opportunities for learning and self-development. (p10)

In this study, the term "student-centred learning" is thus used as an umbrella term that describes the tenets common to the abovementioned constructivist-oriented perspectives where students take ownership of their learning by "actively constructing and assimilating knowledge rather than through the passive addition of discrete facts to an existing store of knowledge" (Mtika & Gates, 2010, p396) as well

as the disposition for facilitators to take into account the individual differences of learners.

There are a few more critical questions that need to be addressed before we consider the link between technology and student-centred practices in the light of constructivist learning theory. First, is student-centred instruction necessarily superior compared to teacher-centred instruction? What then are the implications on pedagogical strategies? There seems to be no consensus on this debate. Strommen and Lincoln (1992) enumerate the purported cognitive benefits of constructivism:

> Rather than simply absorbing ideas spoken at them by teachers, or somehow internalizing them through endless, repeated rote practice, constructivism posits that children actually invent their ideas. They assimilate new information to simple, pre-existing notions, and modify their understanding in light of new data. In the process, their ideas gain in complexity and power, and with appropriate support children develop critical insight into how they think and what they know about the world as their understanding increases in depth and detail. (p468)

The above articulation appears compelling but other researchers also caution the perils of only focusing on student-centred learning. As Dimmock (2000) puts it, some knowledge is esoteric and without much prior knowledge, the help of experts

to "induct students into the intricacies of their subjects" (p138) is still very much appreciated. Cuban (2008) points out that "there is no preponderance of evidence yet available to demonstrate the inherent superiority of either pedagogy in teaching the young" (p161). Aligned with this realisation is that educators need to allow students to experience the range of learning environments. They should re-think the fundamental principles when considering the deployment of technology, especially in the light of incorporating constructivist learning environments (Dimmock, 2000; Loveless, et al., 2001; Samarawickrema, 2007; Yuen, Law, & Wong, 2003). Another response to this question is to see both the teacher and student-centred instruction as a continuum (Barrett & Tikly, 2010; O'Neill & McMahon, 2005), although more often than not, they are represented in a dichotomous fashion for illustrative purpose. In short, teachers need be acquainted with a wide repertoire of pedagogical strategies and match them to the right contextual factors. This study is not set out to prove the supremacy of any pedagogy, but rather, it serves to explore how schools can restructure themselves to infuse student-centred learning practices through the use of ICT. The study's implicit value judgement about learning is that constructivism should not be viewed as a "new religion" (Reigeluth, 1992, p149) and "pedagogical dogmatism" (Harris, 2005, p118) should be avoided as both constructivism and other perspectives have much to offer to educators, especially when taking into account the diverse range of learning situations.

2.5.2 The link between technology and student-centred learning

As argued by many researchers, the primary motivation to use technologies in education is the belief that it can support constructivist practices (Creighton, 2003; Kozloski, 2006; Owen & Demb, 2004; Salomon, 1993; Tan, Hung, & Scardamalia, 2006). Papert (1993, 1996), one of the most influential pioneers in exploring the use of technology in education, is highly optimistic that students can be highly engaged and worked together on meaningful tasks with the scaffolding aid of technological tools. His arguments are predicated on a set of assumptions about learning (child-centred constructivist practices). He believes technology can aid procedural thinking and help students to understand more about the way they think and rationalise, accommodate diverse learning styles and thus accelerate their intellectual development. Hannafin and Land (1997) draw explicit connections between technology and student-centred learning by elucidating how a technology-enhanced student-centred learning environment can promote constructivism:

> Technology-enhanced student-centred learning environments require that individuals are active in the learning process. They emphasize not only assimilation but the development of meta-knowledge for both solving existing problems and generating new ones. Through experience, learners become increasingly facile with available tools and resources, and skilled in assessing how and when to employ them. Learning environments often

> utilize activities that aid learners in constructing and generating artifacts of their understanding. (p190)

According to them, technological tools such as Microworlds can "support building and revising on-going beliefs" (p173), an important concept for building mental models. Spiro et al. (1992) argue that the multidimensional and nonlinear hypertext systems embedded in computers have the power to "convey ill-structured aspects of knowledge domains and to promote features of cognitive flexibility that traditional learning environments cannot" (p58). That is, the above non-linear learning environment can foster "flexible reassembly of preexisting knowledge to adaptively fit the needs of a new situation" (p59).

The above outlines the constructivist elements of appropriate technologies. However, whether technology is necessarily a constructivist tool depends on the designers' inscriptions aimed at shaping learners' behaviour as well as the in-situ context of how it is being used in the learning ecology. For example, the learning environment created by Spiro et al. (1992) allows the coverage of diverse content and inter-meshing of prior knowledge for learners to master complexity and increase resources for future transfer of knowledge. Extrapolating such inscriptions to recent developments, it can be said that many emerging technologies such as social software (wikis, blogs) are built with this constructivist vantage point in mind. These open tools are embedded with the functions of collaborative writing and peer

reviewing and are heralded as one of the most promising vehicles in the history of educational technology to bring about the much anticipated change in reframing classroom discourse to create knowledge through social processes (Grant, 2006).

There also exists a wide array of technological tools in the market that may not be compatible to the philosophical underpinnings of constructivism. Examples are drill and practice kind of software that encourages individual rote learning, software that promotes didactic teaching and digitized lectures that are uploaded for student retrieval. According to Spiro et al., such designs will lead to higher performance in measures of declarative knowledge. The implications are that it is not difficult to plant technology into the curriculum if the aim is just to replicate the teacher-centric model of learning, which is analogous to the Type A or B reforms discussed in the preceding section. Such usage of technology will limit the institution's success to transform itself from a teacher to a student-centred school.

There is also software that can increase the administrative efficiencies of schools but "they do not have a direct impact on the quality of instruction experienced by students" (Means et al., 2003, p161). Cuban (2008) collected 1044 direct observations of how teachers teach with ICT between 1993 to 2005 and concludes that "teacher and student use of ICT at home and in school is widespread in doing assignments, writing, preparing lessons, internet searches, and email, but lags behind in routine use for classroom instruction" (p151). There are only a few

exemplary cases of significant changes in pedagogy which can be attributed to the pervasive use of ICT. Cuban contends that even if marked changes do occur, they are premised on the fact that teacher beliefs are predisposed toward student-centred pedagogy in the first place, and not necessarily that technology promotes that kind of pedagogical change.

Such comment on the lack of a catalytic effect is also repeated in other literature. Surmising from the evidence presented in literature, Weston and Bain (2010) conclude that scalable and sustainable changes from both technology and non-technological reforms are limited and the widespread availability of computers merely "automates the prevailing paradigm" of "non-differentiated large-group instruction" (p10). Harris (2005) also notes the unsuccessful two-decade long attempts for schools to change the nature of teaching and learning. Although the dismal performance of technology to promote student-centred learning has been widely reported, academics and practitioners differ in their interpretation of such "failures". Some ascribed it to individuals such as teachers, principals and administrators (Jacobson et al., 2010; Riel & Becker, 2000); while others consider the complex interaction between people, innovation and culture (Coppola, 2004; Lim, 2007; O'dwyer, Russell, & Bebell, 2004; Tondeur, Valcke, & van Braak, 2008). Harris (2005) attributed the futile efforts to the phenomenon of "technocentrism" (p116) and "pedagogical dogmatism" (p118). She calls for educators and academics to respect "pedagogical plurality" (p121) and to re-define the essence of successful

technology integration to encompass the appropriate use of technology for various instructional orientations, and not just for constructivist, student-centred practices. Weston and Bain (2010) call for school to collectively use technology as a cognitive tool through bottom-up self-organising efforts. However, Cuban (2010) critiques that the lack of empirical substantiation has undermined the credibility of the authors' proposition. The conclusion drawn from literature is that the theories explaining the apparent under-utilisation and failure of technology to transform teaching and learning are aplenty, while empirical examples of successful reforms remain few and far between. This research study on a countervailing case school provides further opportunities to understand the conditions leading to its success and how it converges or diverges from the findings of wider literature.

2.5.3 The link between technology, student-centred practices and policies

Wong and Li (2006) note that the focus of literature related to educational technology has largely shifted away from studying the efficacies of particular technologies on the impact of student learning, to studying how technology can be effectively integrated into the learning environment. Instead of studying the school's use of technology in isolation, the authors propose studying the phenomenon in the broader context of pedagogical and organisational intervention. A conceptual change of teaching and learning from a teacher-centred to student-centred approach that accentuates higher-order thinking and problem-solving skills would

suggest success in pedagogical reform. A change from piecemeal teacher training to human and social capital development would suggest a more holistic organisational support mechanism. Based on the data obtained from a questionnaire survey disseminated to around 1000 teachers from 130 schools in Hong Kong, they reported that about 70% of teachers felt that the use of ICT had enabled them to encourage students to conduct more exploration and inquiry. However, only 60% of the teachers agreed that ICT allowed students to determine their learning activities.

In the 2006 SITES report, Voogt (2008) describes the changes in the teaching practices of Mathematics and Science teachers across 21 participating educational systems. More than 80% of participating teachers indicated that the use of ICT had led to an increase in the variety of learning resources and activities used. About 70% reported on increase in available content. More than half felt that they can better cater to individual needs of students, improve the quality of instruction and promote collaboration among students. Teachers who were using technology on a more regular basis (as compared to sporadic use) saw a greater magnitude of change in educational practices, a finding that is congruous to that of Wong and Li (2006) who also conclude that teachers who use ICT for less than one hour daily perceived a smaller paradigm shift among their students.

Drawing commonalities between the two large-scale reports, ICT appears to be an enabler to reshape pedagogical practices in the aspect of encouraging student involvement and distribution of responsibilities if used regularly, but its effect on promoting student autonomy is relatively limited. As Voogt (2008) remark, "the teachers were still the main initiators of teaching and learning activities" (p250).

In terms of policy implications, SITES concludes that ICT utilisation in classrooms is dependent on school-related factors such as level of support and national curriculum policies. Most importantly, the report highlights the following:

> Policies that adopt a balanced, holistic approach catering for leadership development, professional development, pedagogical and technical support for ICT-use as well as improved ICT infrastructure in schools will be more successful than policies focusing on one or two strategic areas. (Law, et al., 2008, p227).

This stance on holistic approach is much in line with the scanned literature on systemic reform. For technology to become a catalyst for change, it has to be "embedded seamlessly within strong instructional techniques and aligned to curricular goals" (Burns & Dimock, 2007, p22).

Synthesising the four broad areas of literature review, three key questions arose from the existing body of knowledge:

1) How important is the role of distributed leadership in sustaining the use of technology for student-centred learning?
2) Is the traditional assumption that structural changes are not needed to maintain sustainability true?
3) Why is the case school an exceptional case against the backdrop of literature that reports the limited role of technology in promoting pedagogical change?

These three questions would be used to frame the findings in the discussion chapter.

2.6 Chapter Summary

There is a need to look at ICT reform in a holistic way, as opposed to adopting a compartmentalized techno-centric view. The findings of the literature review have also crystallised my understanding about the notion of "student-centred learning" and provided methodological insights on site selection and design of interview questions. More importantly, the literature on complexity leadership brings forth the idea that leadership is about fostering inter-dependence and allowing dynamic interactions to emerge, rather than relying solely on top-down influence. Notwithstanding the seminal works reviewed in this chapter, additional investigation is needed to find out how school organisation, including its nested sub-systems and the broader socio-cultural environment it interacts with, can shape and create a constellation of right conditions over time to sustain the school's use of ICT for student-centred learning. Such rich interplay of influences is not prominently

featured in the scanned literature which in general either focuses on the empirical evidence related to specific interventions, musings at the theoretical level or analysis at the sub-system level. Also, the lack of rich narratives often obfuscates the contextual factors that have real explanatory power over the school's ability to harness ICT longitudinally. Complexity theory can be a useful framework to address the abovementioned gaps for this study. The methodological justification will be detailed in the next chapter.

Chapter 3. Methodology

3.1 Paradigm Rationale

This chapter details the implications of my ontological and epistemological beliefs for the choice of research paradigms and approach. By establishing tripartite connections between ontology, epistemology and methodology, the choice of investigative methods for the proposed study is distilled.

Ontology, which comprises the range of perceptions regarding the nature of reality, can give rise to epistemological assumptions, which are ways we come to know about that reality. These in turn, have bearings on methodological considerations that will impinge on the issues of instrumentation and data collection (Cohen, Mannion, & Morrison, 2007; Creswell, 2003; Krauss, 2005; Morrison, 2007)

Scott and Morrison (2006) note:

> Methodology is the theory (or set of ideas about the relationship between phenomena) of how researchers gain knowledge in research contexts and why. (p153)

Paradigms are, according to Guba and Lincoln (1994), the "basic belief system or world view that guides the investigation" (p105). Bassey (2007) enumerates such epistemic notions as:

> a network of coherent ideas about the nature of the world and the function of researchers which, adhered to by a group of researchers, conditions the patterns of their thinking and underpins their research actions. (p42)

The two most prevalent research paradigms in educational research are positivism and interpretivism. However, this study adopts the complexity perspective and its paradigmatic justification and methodological design are discussed below.

3.1.1 Complexity thinking

The positivist stance is closely related to the investigative methods used in traditional scientific research. Aligned with the ontological underpinnings of realists, the goal of positivists is predicated on the atomistic analysis of variables to account for the absolute and independent truth. Interpretivists, on the other hand, posit that knowledge claims are socially and historically constructed as well as collectively negotiated. The central motivation of research is therefore to explore the subjective reality or lived experiences of the participants through interactive and in-depth qualitative studies (Hamilton, 1994; Merriam, 1998; Morrison, 2007).

Arising from the above discourses is a nascent paradigm – complexity thinking (Davis & Sumara, 2006; Morrison, 2002). It departs from the positivist stance by advocating a holistic view in understanding the studied phenomena. Borrowing ideas from the metaphor of ecosystem, the stance argues that change is ubiquitous

and should be investigated as a whole to encapsulate the dynamic interactions among the interconnected variables. Radford (2008) explains such interactions "give rise to emergent properties that could not have been identified from analysis prior to the interaction" (p152). The tenets of emergence do not rest on the fact that the sum is greater than its parts, but rather, "there are system effects that are different from their parts" (Urry, 2005, p5). Capra (2005) describes this emergence as "emergence of order at critical points of instability" (p37). In this system, both order and chaos co-exist in a perpetual state of disequilibrium. (Capra, 2005; Davis & Sumara, 2006; Houchin & MacLean, 2005; Urry, 2005). Representations have no meaning on their own and will only be given a lease of life when they are situated and become "part of a greater distributed network of meaning" (Davis & Sumara, 2006, p34).

In other words, "truth" is not about the objective reality as suggested by the positivists, nor is it a sheer description of inter-subjectivity among human participants, but rather, more precisely, it is about "interobjectivity" which Davis and Sumara (2006) describe as "mutually affecting relationships between phenomena and knowledge of the phenomena" (p70). The authors describe the essence of "complexity truth":

> It is not just about the object, not just about the subject, and not just about social agreement. It is about holding all of these in dynamic, co-specifying,

conversational relationships while locating them in a grander, more-than-human context. (p15)

Thus, individual inquirers can be interpreted as autonomous agents whose sense-making endeavours are emergent and constantly shaped by their interactions with other actors and a more-than-human context such as rhetorical, axiological and physical environmental factors in the ecology. Complexity scholars maintain that there is a temporal dimension to learning where subjective and objective knowledge shape and are shaped by each other. Figure 3.1 illuminates the essence of knowledge and knowing under the complexity frame as evinced by Davis and Sumara (2006).

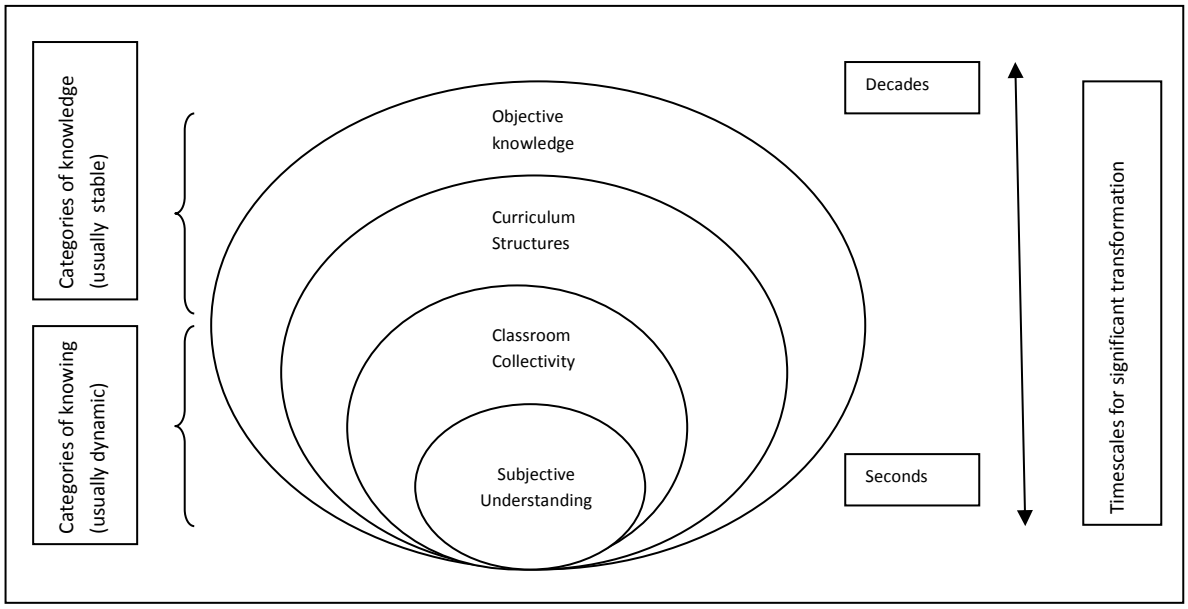

Figure 3.1 Metaphorical representation of knowledge and knowing

Source: Davis and Sumara, 2006

Based on Figure 3, learning is about knowing how to manage the enfolding and unfolding of individual and collective knowledge and a learner is "a complex unity

that is capable of adapting itself to the sorts of new and diverse circumstances that an active agent is likely to encounter in a dynamic world" (Davis and Sumara, 2006, p14). This tinkering process is exemplified when it comes to the use of technology for education. Educators' beliefs towards the efficacy of technology are evolving alongside new innovations such as the emergence of social applications. This epitomises how the interaction between human and more-than-human context are mutually-constituting elements in shaping our epistemological beliefs. Such iterative process, according to Smith (1993), will inevitably be bounded by interests and values. To understand such truth, it is necessary to engage in "participatory epistemologies" as the truth is not out there or within.

Kuhn (2008) details the ontological and epistemological standpoints of the complexity theory:

> From a complexity perspective both the nature of the world and human sensemaking are dynamic and emergent. Ontologically, complexity depicts the world as self-organising, non-linear, sensitive to initial conditions and influenced by many sets of rules. Epistemologically, human-sense making is also construed in exactly the same way, as self-organising, non-linear, sensitive to initial conditions and influenced by many sets of rules. (p182)

Extrapolating from the above, all human endeavours are purportedly non-linear, self-organising, adaptive, indeterminable and are bounded by both the present and

historical contexts. These dynamic and emergent properties are akin to how organisms in an ecosystem are capable of perpetually re-invigorating and disintegrating themselves without much external intervention (Cohen, et al., 2007; Haggis, 2008; Horn, 2008; Kuhn, 2008; Raford, 2008). The implications for researchers are that they cannot isolate any individual factor as all factors may "compound each other's' effects in ways that both increase and diminish their aggregate influence" (Mason, 2008, p45). Self-organisation also requires researchers to adopt participatory, collaborative and multi-perspectival approaches to educational research. In other words, complexity theory embraces heterogeneous views, different voices and multiple representations of reality (Cohen et al., 2007) . Through collaborative meaning-making, it is possible to create shared reality based on common values even in the face of uncertainty.

3.1.2 Distilling an appropriate approach

The framework of Smith (1983) is used as a guide to distil an appropriate approach amongst the labyrinth of stances. Three guiding principles that are conceptually useful are: 1) the goal of the investigation; 2) the relationship of the investigator to what is investigated and 3) the relationship between facts and values in the study.

Goal of the investigation

The research aim of the proposed study is to investigate how an ICT-enriched school has harnessed and sustained the use of technology for student-centred

learning. Creswell (2003) suggests that "if a concept or phenomena needs to be understood because little research has been done on it, then it merits a qualitative approach" (p22). To date, there is limited research on the factors that sustain technology-based innovation in schools (Owston, 2006). Even if there are insights to be gained from the literature, it is also unclear if these principles can be applied to Singapore's context. By acknowledging this, I am already subscribing to the notion that leadership strategies are context-specific. Implicit in this standpoint is that there are multiple realities, instead of an independent and universal one. These multiple realities constantly interface with objective knowledge and "learning was recast in terms of on-going fitness, whereby both knowledge and understanding were subject to continuous tinkering to maintain viability" (Davis & Sumara, 2006, p62). This assertion serves as a rationale for me to eliminate the positivist stance as a framing paradigm for the proposed study.

Moreover, to understand the nature of tensions brought forth by re-structuring, many authors in the field of school and technology reforms advocate the use of integrated and holistic approaches to explore the inter-connectedness of the factors that contribute to those tensions (Creighton, 2003; Dimmock, 2000; Driscoll, 2001; Zhao & Frank, 2003). This argument converges with the paradigm of complexity theory.

Relationship of the investigator to what is investigated

In order to understand the complex nature of school and technological reforms, it is essential for me to interact with the agents of change. Through interaction, I can gain insights about the multiple realities negotiated by the participants situated in the same ecology. A participatory and collaborative culture is favoured and agents of change should be extended to include parents, community and professional organisations so as to sustain the improvement efforts (Fullan, 2002; Siu, 2008). This also calls for me to "get inside" the worlds of their research participants by engaging them intensively and respectfully. When the actors in the system are networked at multi-dimensional layers, agreement between the researcher and the participants is reached not by adhering to an external referent as articulated by the positivists but instead by negotiating a "social agreement" (Smith, 1983, p10) which co-evolves with objective knowledge.

Moreover, schools are quintessentially complex adaptive systems as they evolve over time. They have to adapt to micro and macro politics and need to "position themselves in relation to the wider society" (Morrison, 2002, p27). The organisation has to respond to frequent external shocks as well as conflicting demands from various stakeholders. It would therefore be misleading to deploy a deterministic approach to study the non-linear outcomes (Stacey, 2006, p96).

Relationship between facts and values in the study

The message underlying the notion of "social agreement" is that there is a common value base appreciated by all agents in the system. As far as school reforms are concerned, leaders are expected to provide vision and establish values that are meaningful to the members bound by the system. The values embraced by the technological leaders and the wider socio-cultural practices of the society will also have implications for leadership and collaborative styles. Thus, there are inter-locking systems and sub-systems that interact to constitute multiple and dynamic realities (Haggis, 2008). This dynamism is the hallmark of complexity theory.

The preceding discussion suggests the need for the study on technology leadership to depart from the positivist epistemology. After consolidating the considerations of systemic reforms, distributed leadership, multiple perspectives and the collective negotiation of meanings, I maintain that complexity thinking is more capable of addressing the research concerns as it interfaces with both the participants' subjective worldviews as well as non-human agency such as the systemic environment where the impetus of Singapore's top-down and bottom-up innovations necessitates spates of changes.

However, there are some inherent limitations of complexity theory. Rooted in physics, biology, chemistry and economics, it is only recently that the theory is evinced in the field of educational change. Kuhn (2008) has pointed out that

complexity theory does not really address normative commitments, resulting in a misfit between the non-prescriptive nature of complexity theory and goal-oriented emphasis of education. In his words, "complexity merely describes whereas education aims to make a difference" (p179). Despite this limitation, the complexity lens is promising in helping us gain deeper understanding about the underlying complexities of change and to appreciate the richness of diversity in the sense-making endeavours related to change. In this way, policymakers can be more informed about how to create conducive conditions for emergence and self-organisation to flourish. To summarise, three attributes of complex system constitute the analytical framework for the study. They are: 1) the co-existence of chaos and order; 2) the self-organising, non-linear and interconnected nature of complex system and 3) co-evolution of actors and more-than-human context.

It is important to create alignment between the interpretive lens and research approach in order to maintain the integrity of the research methodology. Inevitably, complexity thinking lends itself to the use of qualitative case study approach. Cohen et al. (2007) write:

> In addressing holism, complexity theory suggests the need for case study methodology, action research, and participatory forms of research, premised in many ways on interactionist, qualitative accounts; i.e. looking through the eyes of as many participants and stakeholders as possible. This enables

> multiple causalities, multiple perspectives and multiple effects to be charted. (p34)

Yin (2003) defines case study as an "empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomena and context are not clearly evident" (p13). Merriam (1998) provides another insight:

> As the product of an investigation, a case study is an intensive, holistic description and analysis of a single entity, phenomenon or social unit. (p34)

The case study approach allows me to collect rich data in a multi-dimensional fashion. It is promising as it can explore the complexity of social truths that arises among contesting viewpoints held by different actors (Adelman, Jenkins, & Kemmis, 1980; Bassey, 2007; Simons, 2009; Stake, 1995). Moreover, as Simons (2009) posits, case study research has the predisposition for "exploring and understanding the process and dynamics of change" (p23) and identify critical factors affecting implementation as well as the linkages and patterns between them. This is very relevant in the light of the implementation of educational innovation for this study. The introduction of technology in schools often becomes a point of contention within the teaching fraternity. These conflicts can happen at many levels, be it intrapersonal or interpersonal, and also amongst different layers of leadership.

Yin (2003) has also proffered a useful list of consideration for research strategies. He advocates that if the research questions are more of "how" and "why" questions, coupled with the fact that the researcher has no control over actual behaviour of actors and that the degree of focus is more on contemporary events, then the research favours the use of case study (p5). The research problem of this thesis lies in exploring how schools are harnessing technology for student-centred learning and is dealing with "operational links needing to be traced over time" (p6). In addition, I have no control over leadership changes and there is a need to understand how past and contemporary events unfold. Consolidating all these considerations, the paradigm "match" has exemplified the aptness of using the holistic qualitative case study approach to study the complex phenomenon. Table 3.1 sums up the ontological, epistemological and methodological preferences of the research study.

Philosophical and paradigmatic beliefs		Linkages to research study
Ontological beliefs	*Inter-objectivity* There is no universal truth and truth is not sheer subjectivity. Knowledge is the co-evolvement of subjective understanding and collective knowledge.	The study looks at how a primary school uses technology to meet the demands of student-centred learning. It involves subjective interpretation of actors' own experiences and interaction with the collective knowledge of other actors. This inter-objectivity is shaped by the objective knowledge about the affordances of emergent technology, the national curriculum and the essence of student-centred learning.

Theoretical framework	*Complexity theory* Theory emphasises on the non-linearity and unpredictability of changes.	Taking the ecology of the school as an unit of analysis, complexity theory is able to provide a systemic lens to examine how the case school can operate in a state of disequilibrium and co-exist with both order and chaos when external shocks such as technology is being introduced to the ecology. It allows us to analyse the dynamic evolution of change processes over time and incorporate multiple perspectives and influences, "ranging from overarching macro influences to micro influences of individual human interaction" (Hendry, 2003, p71).
Epistemological beliefs	*Participatory* Heterogeneous voices are being heard when participatory episteme is deployed.	The study looks at the inter-relationships between different actors as well as the environment. The co-construction of knowledge entails the use of participatory methods to understand the lived experiences of the actors involved and gain insights on how collective knowledge shapes individual knowledge. Multi-perspectivity is critical here.
Approach	*Case study research* An intensive, holistic description and analysis of a single entity, phenomenon or social unit.	Case study research enables one to "dig" further to understand complex dynamics. It also calls for the use of myriad of data collection methods.

Table 3.1 Methodological justifications for the research

3.2 Case Study Selection

The focus of this thesis is on primary school as there is less fragmentation of the curriculum as compared to higher levels of education. Moreover, primary school teachers in Singapore generally have to teach another subject (English, Mathematics and Science) in addition to their speciality. As Inkster (1998) suggests, "instructional technologies are used more uniformly in elementary schools" and this more consistent distribution also means that in elementary schools, technology leadership is less likely to reside just in department heads and is therefore more likely to be distinct and observable" (p78-79).

"Purposive sampling" is used as it allows me to "select information-rich cases whose study will illuminate the questions under study" (Patton, 1990, p169). I spent considerable time deliberating whether to conduct a single case or twin-case study. The merits of twin-site study is that it can reduce the drawbacks of localisation and subjectivity inherent in single case-study methodology and that multiple cases can "add weight to the results by replicating the pattern-matching, thus increasing confidence in the robustness of the theory" (Freebody, 2003, p84). However, the trade-off is "the study of more case dilutes the overall analysis" (Creswell, 2003, p76). In the spirit of complexity thinking, the unit of analysis is the whole school, thus the study warrants a very intricate analysis of the phenomenon. To fulfil the need for depth within the constraints of time and resource, a single case study is preferred.

The emphasis of this study is on technology-based transformation, thus the selected case ought to fulfil the following criteria: First, as the study can only be explored in the context of technology-using schools, the case school must demonstrate evidence of usage of innovative technologies. Second, as sustainability is one of the themes of exploration, the school must have demonstrated prolonged and effective use of technology over at least one cycle of leadership renewal. In Singapore's context, a typical leadership cycle lasts for about six years. A third feature is that computer infrastructure should be adequate and the ratio of student to computer usage be kept low. Fourth, drawing from the review of the report in "Making Better Connections" (Downes, et al., 2002), the selected school should demonstrate Type C

or Type D level of IT integration levels where ICT has become an integral component of the reform that alters how learning occurs or the organisation and structure of schooling itself.

3.2.1 Context of selected site

As a government-aided neighbourhood school, Fortitude Primary School[1] receives partial funding from the government and supplementary funding from private sources. It was founded in the 1940s by a Chinese clan association to provide basic education for the children of immigrants from China. Situated in a populous new town since its move to the present location in December 2000, the school has enjoyed strong enrolment annually, due to the demographic composition and its consistent performance in achieving better results than the national average standards in its Primary Six Leaving Examinations (PSLE). FPS' students generally come from lower-middle and middle income groups and the student population is therefore considered similar in terms of socio-economic status.

The classes at FPS are structured according to students' academic results, especially in Mathematics and Science. They are grouped into blocks of high, mixed and low achievement classes. The school has 9 classes for each level and the typical class size is about 40 students for upper primary (Primary Three to Six) and 30 students for lower primary (Primary One to Two), thus totalling the student intake to about

[1]For anonymity sake, pseudonyms are used for all names (including school, participants and projects) that appear in this and subsequent chapters.

1900 students. Typically, teachers in Singapore's primary schools (except for teachers teaching the Mother Tongue) would need to teach more than one core subject (English, Mathematics, and Science). As the form teacher of the class teaches several subjects, there is latitude for teachers to re-structure the class periods to create continuous blocks of learning time. Each period lasts for 30 minutes. The practice of cross-teaching different subject underlines the reason why primary school curriculum is less fragmented and the use of ICT more distributed across departments.

FPS' emphasis on ICT is prevalent. Along the stairway near the general office, the school has displayed acrylic posters of media reports, ICT projects they have embarked on and the awards they have received over the years. The posters cascade along the three storeys and are updated regularly. Together with the write-ups of early (2002-2005) projects displayed in the multipurpose hall, the living documentation allows visitors to have a glimpse of the evolvement of the ICT projects. These projects can be bottom-up teacher-initiated efforts, or top-down leader-suggested initiatives that entail longer-term collaboration with university researchers. The current cornerstone programmes of FPS can be broadly divided into 3 categories, namely: 1:1 computing (use of netbooks or slates for collaborative learning), mobile learning (suite of mobile learning fieldtrips for all students) and seamless learning (hybrid of devices that leverages on ubiquitous technology) to bridge learning across both formal and informal learning contexts.

In terms of infrastructure, FPS has two computer labs that are located on the fourth level of the school. Each lab has 42 computers that are placed back to back in clusters of four to allow students to sit facing each other during group discussion. Only the teachers and ICT support staff can access the labs and therefore these facilities are only utilised during school hours. More recently, a futuristic classroom and micro lab for lesson observation are added. In terms of connectivity, FPS has good coverage of wireless technology on the school compound but its connectivity can be unstable at times (fieldnotes).

In terms of equipment, the school has more than 1000 devices, ranging from computers, netbooks, UMPCs, smartphones, iPod Touch, iPod Nano, printers, projectors and visualisers. It has enough UMPCs for two classes' usage and 200 sets of iPod Touch for all Primary 1 and 2 students. In terms of classroom facility, every class is equipped with a visualiser and a projector. There is no computer in most of the classrooms as the school has evolved into the stage of using mobile devices instead of relying on desktops that are relatively less portable. Equipment charging is carried out in a well-equipped charger room, which according to Frederick, the ICT executive, is "bigger than other schools" (interview, INFR 100602128). The room comprises charging racks with multiple extension cords to charge 50 sets of mobile devices at one go. There are many trolley bags in the charger room that can be used to move the equipment to the classrooms. The room also doubles up as an inventory room to store equipment. Compared to other primary schools, FPS is

considered advanced in terms of its infrastructural build-up and equipment provision, thus fulfilling my selection criterion of the school having adequate infrastructure and low student-computer ratio. Whilst the students are likely to benefit from all these cutting-edge resources, the teachers have to be patient when it comes to upgrading their equipment as they only get to upgrade their tools once every five years. Most of the available funds are channelled into acquiring tools for students.

FPS relies on a strong seven-member ICT support team to support teachers in their usage of technologies. The team comprises two IT executives, one technical assistant, one programmer, one multi-media assistant and two trainers. Their job scope includes: troubleshooting technological problems; preparing (charging and delivering) mobile equipment for use in classroom; maintaining and upgrading hardware, servers, software, online discussion forum and learning portal; providing ICT training for all students; tracking inventory as well as evaluating and recommending suitable devices or programmes (Frederick, interview, INFR 10060277). The team members' contracts are renewable on a yearly basis. In terms of knowledge upgrading, the small knitted group learns on-the-job and makes it a point to share knowledge. Each of the members has their own speciality but will also be able to cover one another if need be (Gabriel, interview).

Fortitude Primary School (FPS) was particularly favoured and chosen as the case school as it had a long history of ICT usage. According to the information on their website, the neighbourhood school had been experimenting with 1:1 learning with mobile devices since 2001 but "they were largely restricted to individual data collection and interpretation" (FPS website). Recognising this, the school had planned for a more constructivist learning model to promote higher order thinking in 2005. Thus, I considered FPS might have been a good case for me to delve deeper into the school's evolutionary use of technology to advance student-centred principles. Moreover, the school had received recognition for its innovative use of technology in changing pedagogical practices from a teacher-centred to a student-centred orientation. It had earned a string of accolades over its decade-long use of technology in education, including on the global front its accreditation as a "Microsoft Worldwide Mentor School". The school had also been recognised by the MOE as a Centre of Excellence for Information Technology and for its ability to offer sustainable and excellent ICT programmes for its students. Also earmarked as one of the 15 FutureSchools by the government, the school served as an exemplar for integrating the use of ICT in its curriculum, pedagogy and assessment across all levels. Additionally, the school had received the government-awarded "Innovation Class Award" for its good leadership practices to create an environment that promotes innovation.

The slew of awards garnered internationally and nationally over a decade attested to the school's prolonged commitment to seamlessly embedding the use of ICT into its learning ecology. Unlike many schools, however, technology had also been a catalyst for driving whole-school transformation instead of just propagating piecemeal innovations. This can be seen from the fact that the school leaders of FPS had actively promoted, in tandem, the importance of technology and action research since 2005. They perceived research as an effective reflectivity mechanism where teachers can critically examine their teaching strategies and the impact of their interventions. When the new principal came on board in 2008, he again foregrounded the idea of "teachers as researchers" and formally incorporated this dimension of competency when profiling the ICT skills of the teachers based on the results of teachers' self-reported surveys (See Figure 3.3 in subsequent section) as well as into the cornerstone detailing the three critical roles of educators: Teachers were expected to promote quality learning by equipping themselves with content knowledge; developing students' potential holistically by reaching out to them, practising effective classroom management and monitoring students via relevant assessment; and becoming an informed practitioner by conducting action research. In general, teachers were busily juggling with teaching load that averages between 15 to 17.5 hours per week, managing multiple projects and conducting action research. A lot of after-class time was taken up for meetings and professional development programmes coalescing around pedagogical issues and innovations. All these suggested that FPS was a "Type D" school that had integrated the use of

technology in many aspects such as curriculum design, professional development and profiling of teachers. It can be considered as a rare example where the use of ICT had accompanied ICT reforms.

Coupled with the fact that FPS had experienced leadership renewal in 2008, it enabled me to examine the coherence of the school's vision in its ICT usage under different stewardship and study how institutional memory and leadership can promulgate or hamper the expansive potential of projects. The school had also become an "intrinsic" (Stake, 1995) case study in the midst of the investigation due to its distinctive and accelerated trajectory of growth from 2011-2012.

Besides deploying the above criterion sampling method, I was also drawing on the convenience of having unrestricted access to the site. Being a research associate with the Singapore's National Institute of Education (NIE), Learning Sciences Laboratory (LSL), I had the comparative advantage of practising prolonged engagement in the field. This enabled me to gain information that had proved to be invaluable to the study.

3.3 Data collection methods

As argued above, the nature of the topic of technology leadership is descriptive, exploratory and laden with intangible constructs, thus the qualitative method of data collection is favoured. Pluralistic data collection methods are recommended for

intensive case studies as it can enhance the depth of the analysis. In addition, as expounded by complexity thinking, it is also critical to see how such interobjectivity is related to objective knowledge at the systemic level too. The focus is on collecting complex rich data, making meanings and interpreting contextual accounts generated from purposive sampling of participants. The main methods of data collection for this study include but are not restricted to interview, observation and documentary research. The conversations in the corridors, informal sharing sessions with NIE colleagues who are immersed in the daily lives of the participants, emergent discussions that took place at the sideline of meetings as well as information gathered from serendipitous events form the corpus of data that was collected over the three years while collaborating with FPS.

3.3.1 Interview

Interviews are useful to find out more about the strategies and intentions of leaders, which may be difficult to elicit from other sources of data collection. Yin (2003) mentions that case study interviews are mostly open-ended so as to elicit richer responses from the interviewees who are free to offer their insights. Miller and Glassner (2004) make attempts to demonstrate that "collaborative accomplishments" (Holstein & Gubrium, 2004, p141) between the interview and interviewee are meaningful as long as it is predicated on the grounds that we "understand how and where the stories are produced, which sort of stories they are, and how we can put

them to honest and intelligent use in theorising about social life" (p138). Hence, there is a strong case for using interviews to achieve deep mutual understanding.

Patton (1990) provides other compelling reasons for using interviews:

> We interview people to find out from them those things we cannot directly observe….We cannot observe feelings, thoughts and intentions. We cannot observe behaviours that took place at some previous points in time. We cannot observe situations that preclude the presence of an observer. We cannot observe how people have organised the world and the meanings they attach to what goes on in the world. We have to ask people questions about those things. The purpose of interviewing, then, is to allow us to enter into the other person's perspectives. (p196)

Through interviews, past events can be re-constructed. This is especially important as FPS' use of technology started a decade ago. The only means to understand these past events is through interviewing personnel and sifting through documents.

Bringing the focus back to the theoretical framework, complexity theory suggests that the unit of analysis should transcend individuals, institutions, communities and systems. These entities should merge to become a web or ecosystem, and it is this web that would constitute a unit of analysis (Cohen, et al., 2007; Lemke, 2001). In other words, the unit of analysis will comprise the whole school system, including

leaders, teachers, technical officers, MOE, Singapore's social, political and cultural environment as well as the global phenomena that affect our educational landscape. By doing so, I am looking at the dynamic systems of connected factors. This is an example of holistic case study where the global nature of the institution is viewed in totality (Yin, 2003).

Profile of interviewees

To understand the complexities underlying the use and diffusion of technology in FPS, I had interviewed many personnel across the different layers of hierarchy. The organisational chart of FPS, which was adapted from the staff list posted on the school website, is re-configured in Figure 3.2:

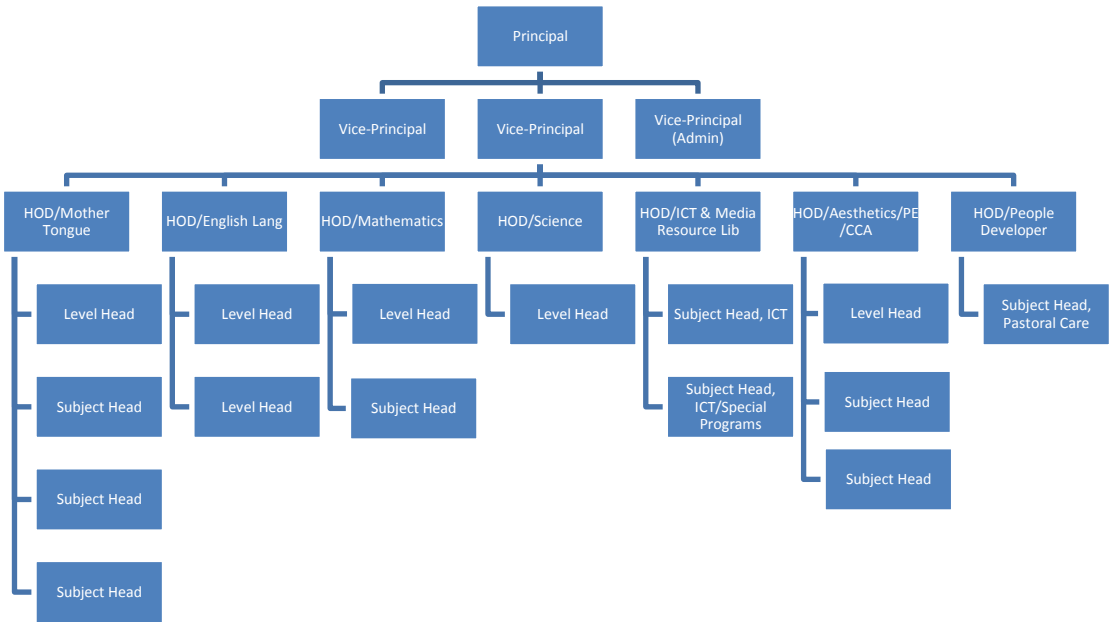

Figure 3.2 Hierarchical chart of FPS

Source: Adapted from staff list of FPS website

Altogether, I interviewed 17 people across the hierarchy. They were identified based on the position they held, the roles they played in relation to the myriad of ICT-related projects, teaching experience, recommendations from the school and resident researchers, preliminary classroom observations and their ICT profile. According to a school-wide self-reported survey, all teachers are being divided into 4 levels based on dual-track criteria: competency in action research and knowledge in integrating ICT into lessons. See Figure 3.3 for more details.

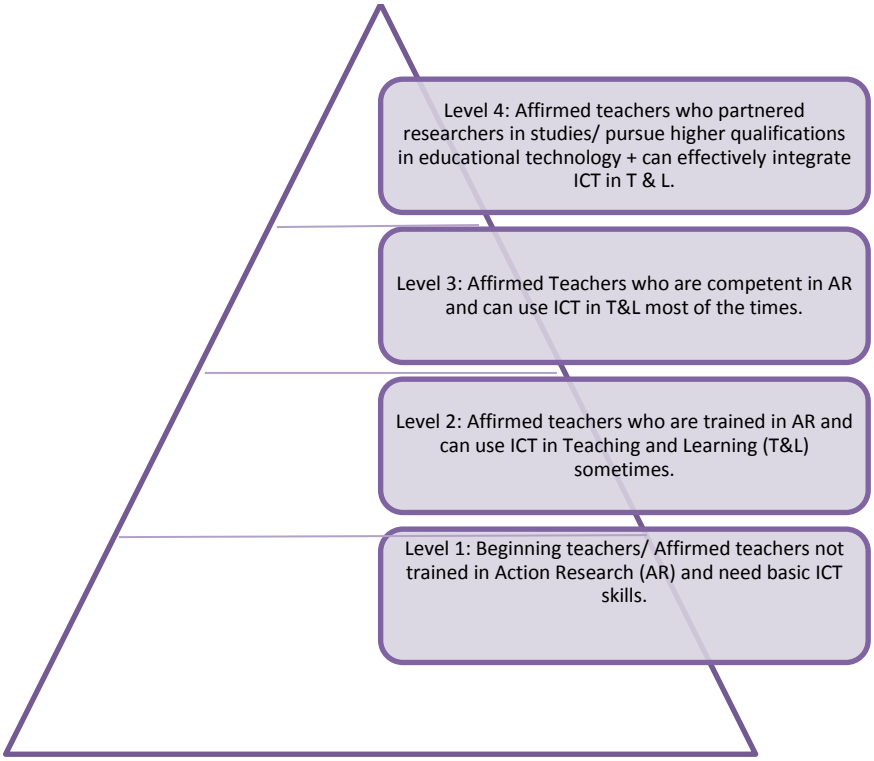

Figure 3.3 ICT profiling of FPS staff

Source: FutureSchool proposal, PP FS110216

By interviewing teachers along this wide spectrum (Level 1 – Level 4), I hoped to gain insights on how student-centred learning was being enacted in classrooms and

how newer teachers with developing pedagogical and technological knowledge were supported to elevate their skills.

To observe the anonymity of the participants, I had re-grouped the 17 interviewees into four broad categories: senior management (Principal, HODs), middle management (Level heads, Subject heads), teaching staff and support staff. Subjects are also grouped under two headings: Arts (English language, Chinese language, Arts and Craft) and Sciences (Mathematics, Science, and Information Technology). The participants' years of teaching experience is grouped using three-point scale. Pseudonyms are also used to protect the interviewees' identity. The profile of the interviewees is delineated in Table 3.2.

Participant	Designation	Department	Years of teaching exp	Rationale for interviewing
Terrence	Current Principal	FPS	-	Second and current principal of since 2008. Key personnel for providing stewardship and vision.
Carl	Ex-principal	FPS	-	Ex principal of FPS. Instrumental in shaping FPS' policies, thus helps in tracing the developmental efforts undertaken by the school to advance learner-centred instruction.
Katherine	Senior Management	Arts	16-18	Member of upper management of Arts Department who is very supportive of the ICT initiatives in her department.
Nigel	Senior Management	Sciences	7-9	Current IT HOD (2011-) who shapes the ICT policies of FPS.
Gabriel	Ex Senior Management	Sciences	10-12	Ex IT HOD who (2005-2011) shapes the ICT policies of FPS.
Han	Ex Middle Management	FPS	5-7	One of the ex-key personnel and pioneers who has insights about the use of technology in FPS.
Amelia	Middle Management	Sciences	10-12	One of the administrative leaders who has to coordinate key ICT-related projects and to craft proposals.
Hannah	Middle Management	Sciences	13-15	One of the administrative leaders who has to coordinate key ICT-related projects.
Sheila	Middle Management	Arts	7-9	One of the middle managers and also a level 4 teacher who is widely recognised as having advanced pedagogical and technological knowledge.
Jamie	Middle Management	Sciences	7-9	One of the middle managers who is involved in special ICT programme.

Janis	Middle Management	Sciences	4-6	One of the middle managers and also a level 3 teacher who is competent in AR and can use ICT in teaching and learning most of the time.
Gavin	Middle Management	Arts	16-18	One of the middle managers and level 2 teacher who coordinates all ICT projects within the department and is teaching experimental class.
Yolanda	Teaching Staff	Arts	7-9	Level 2 teacher who is trained in AR and can use ICT in teaching and learning most of the time.
Jazz	Teaching Staff	Sciences	7-9	Level 2 teacher who is trained in AR and can use ICT in teaching and learning sometimes.
Sherry	Teaching Staff	Sciences	1-3	Level 1 beginning teacher with developing pedagogical and proficient technological knowledge but has opportunity to partner with NIE researchers for action research.
Lisa	Teaching Staff	Sciences	28-30	Level 1 teacher who has many years of teaching experience but relatively less experience in using ICT.
Frederick	Ex Support Staff	Natural Sciences	-	One of the ex ICT support staff who helps the ICT HOD to oversee operational issues.

Table 3.2 Profile of interviewees as of 2010

Approaching interviewees

To kick-start the data collecting process, I first emailed the principal to seek his support to conduct the study on-site. The principal was supportive and suggested keeping the ICT HOD in the loop for discussion. I spent about 45 minutes illustrating to the principal what my study was about and the requirements of the study. A summary of the research plan was also given to him so that he was aware what this project entails and be more assured that the study would cause minimal disruption to school and classroom activities. Separate emails were then sent to interviewees to seek their consent to participate in the study prior to arranging the time and venue of the interview. On the day of interview, the participants were again briefed on the research study and were told about their rights to withdraw from the study anytime if they wanted to. They were also aware that the transcript would be sent to them.

Interview process

This study uses semi-structured interviews to gain insights into interviewees' perceptions on the use of technology to advance student-centred learning. Semi-structured interviews are preferred as predetermined interviews only "get reactions to the investigators' preconceived notions of the world" (Merriam, 1998, p74). The hallmark of unstructured interviews lies in the prevalent use of open-ended questions that are flexible and exploratory in nature. Although many authors agree that insights can be gained from such conversations, it is also difficult to analyse the maze of dialogical exchanges (Cohen, et al., 2007; Creswell, 2003; Holstein & Gubrium, 2004; Merriam, 1998). Another criticism of open-ended interview is that "both parties (interviewer and participants) bring biases, predispositions, attitudes, and physical characteristics that colour the interaction and the data elicited" (Holstein & Gubrium, 2004, p87).

For semi-structured type of interviews, there is a mix of loosely structured and open-ended questions. During the actual interviews, the sequence and phrasing of the questions were not fixed. It is known that many factors can affect the dynamics of a conversation. Holstein and Gubrium (2004) describe this intricate interplay as "pull of conversation" and "push of inquiry" (p146). I went with the natural rhythm of the conversation and probed more at issues that may shed light on leadership issues. By doing so, it gave me the bandwidth to explore serendipitous findings and also practise the "push of inquiry" to cover five main areas of interviews: reasons for

using technology, technology integration, technology implementation, technology support and technology advice. The interviews with senior management lasted for 1.5 hours on average and 1 hour for other interviewees. The questions were customised for different groups of interviewees. Table 3.3 shows an example of how the interview questions are informed by literature and mapped to the research questions.

Research Questions	Process of Fracturing RQs into 5 Areas	Interview Questions
RQ1: What was the development trajectory of a Singapore ICT-enriched primary school harness technology to meet the demands of pedagogical reform for student-centred learning?	A) Reasons for using technology - Informed by literature review section 2.5: The motivation, pedagogical beliefs, nature and rationale of ICT projects are distilled.	How do you think our students can learn best in this 21st century? What are the skills they should be equipped with and why? Do you think the use of technology can help advance those skills? Why?
		Could you please walkthrough with me your school's ICT journey and describe some of the main IT projects that left a deep impression in you? To what extent do you think these projects and technological provisions have helped the students achieve those skills? Are there any gaps? If so, what are they? How do you intend to close those gaps?
		Given the rapid progress of technological innovations in present times, how does the school decide which emergent technology is appropriate for learning, and subsequently, to purchase?
		Describe any concerns you may have regarding the use of technology for learning. How do they influence your philosophy for technology usage?
	B) Integration of technology-enhanced lessons - Informed by literature review section 2.5. Questions are aimed to distil how the use of technology may change teachers' instructional practices and the influences that may impede the use of ICT for student-centred learning.	Describe how you would go about implementing an ICT-enhanced lesson for your students (venue, format, objectives, and process).
		What are your students' attitudes towards the use of technology for student-centred learning? How would you encourage your students, especially those who may be apprehensive towards technology (if any) and/or new learning approach to participate?
		Do you think technology have changed your role as a teacher/leader? If so, in what ways? How do you feel about these changes?
		Describe the ideal scenario of how technology should be used for student-centred learning. Will you able to carry out lessons in the ideal way? Why? How would you perceive the impacts of technology in meeting those pedagogical objectives in your school?
RQ2: How did the school create the conditions that support the sustainable use of	C) Technology implementation - Informed by literature review section 2.3 and	What are the key decisions that your school has made regarding technology? How are those decisions made? Who are involved in the decision-making process? What is the role you played? What do you think of the whole decision-making process?
		How does the school evaluate which kind of ICT projects to pursue?

Research Questions	Process of Fracturing RQs into 5 Areas	Interview Questions
technology for student-centred learning?	section 2.4. The process of decision-making, modes of communication channels and leadership sustainability are distilled.	How do you avoid spreading yourself too thin? What counts as successful outcomes of innovations?
		How are insights about the use of ICT spread to members of the school?
		Let's say there are changes in staffing over time. How would you preserve and sustain the school's technological vision? (For new leaders in transition: How do you get acquainted with the technological vision of the school? What are the changes you have made? What's your reason for implementing those changes? What challenges did you face during the transition?)
		Who do you think are the technology leaders in your school and why? How would you rate yourself as a technology leader? Describe what you feel best about yourself in terms of technological implementation and where you would like to be from here on.
	D) Technology support - Informed by literature review section 2.4 Factors that enhance or threaten the longevity of projects are distilled.	What kind of support do you receive in terms of technological integration? How do you feel about the level of support you have received so far?
		What are some of the challenges that the school still faces in relation to technological implementation? What kind of support is needed to overcome those problems?
		How would you encourage your staff, especially those who may be apprehensive towards technology to integrate IT into their lessons? Can you tell me more about the "converts", if any?
	E) Technology advice	What advice will you give to other technology leaders if they wish to use technology to re-design their schools for student-centred learning?

Table 3.3 Mapping of interview questions to research questions

3.3.2 Observation

As Robson(2002) posits, the actions of people may depart from what they say they do. Through observation, "the use of immediate awareness, or direct cognition, as a principal mode of research has the potential to yield more valid or authentic data than would otherwise be the case with mediated or inferential methods" (Cohen, et al., 2007, p396). I had first-hand experience in gathering 'live' data as information

unfolded in a naturally occurring setting. This augmented my ability to gain insights into complex situations, explore topics that may be uncomfortable for participants to discuss openly or pick up unusual aspects as information is revealed (Cohen, et al., 2007; Creswell, 2003; Moyles, 2007). Cohen et al. (2007) contend that observations allow "live" (p396) and open-ended data to be collected in-situ directly by the researcher as events unfold in the learning context, thus can infuse freshness to data collection. It can be a good data collection method if "your purpose is to 'see' what happens and what is enacted" (Moyles, 2007, p250).

The type of observation used for this study is primarily unstructured. Whilst it is relatively easy to analyse the data of a highly structured observation, such technique is behaviourist, episodic, ignores the inter-connectedness of unfolding events and emanates from the conceptual framework of researcher, thus is too oblique a tool to understand the intentions and motivations of the participants. Unstructured observations tend to have a more fluid agenda and leverages on the conceptual framework of the informants. However, there were still some signposts that I had identified to provide broad scoping to the observations. The flags used were predominantly the two main research questions and the critical moments where student-centred learning was being fostered. Examples of unstructured observational sessions for this study include lesson observations, professional development courses and meetings.

Lesson and fieldtrip observations

As my aim is to look at how technology is used by teachers who regularly incorporate ICT into their lessons to advance student-centred learning, the teachers must be involved, be it directly or indirectly, in projects that emphasised the use of technology for constructivist practices. However, the teachers should also be represented across levels 1-4 for maximum variation. For each teacher, there were at least two observations so that the teachers would be more comfortable with my presence during subsequent visit(s). The first observation also served as a form of triangulation about the profiles of teachers, gathered from different sources: management, interviewees as well as NIE researchers based in the school. Table 3.4 is a profile representation of teachers at the point of data collection.

Teacher	Teaching exp (Yrs)	Profile	Date of actual lesson observation used	Date of interview
Sheila	7-9	One of the middle managers and also a level 4 teacher who is widely recognised as having advanced pedagogical and technological knowledge.	3 Sept 2010	2 June 2010
Janis	4-6	One of the middle managers and also a level 3 teacher who is competent in AR and can use ICT in teaching and learning most of the time.	26 Aug 2010	12 Apr 2010
Jazz	7-9	Level 2 teacher who is trained in AR and can use ICT in teaching and learning sometimes.	19 Nov 2010	6 Sept 2010
Yolanda	7-9	Level 2 teacher who is trained in AR and can use ICT in teaching and learning most of the time.	10 Feb 2010	26 July 2010
Sherry	1-3	Level 1 beginning teacher with developing pedagogical and proficient technological knowledge but has opportunity to partner with NIE researchers for action research.	23 Aug 2010	23 Aug 2010 26 Aug 2010
Gavin	16-18	One of the middle managers and a level 2 teacher who coordinates all ICT projects within the department and is teaching experimental class.	26 Aug 2011	16 Aug 2011

Table 3.4 Profile of observed teachers as of year 2010 – 2011.

With the exception of Gavin who was selected in 2011 due to new information and opportunities for lesson observations, the rest of the candidates were selected in 2010 and their lesson observed within the same year. In addition, these six teachers were also interviewed by me. In terms of scheduling, all lesson observations were flexibly arranged to take place before or after the interview, depending on the preference and availability of teachers. There was also a short interview of about 20 minutes after the lesson observation to clarify matters related to pedagogical strategies. Table 3.5 shows an excerpt of fieldnotes taken during one of Janis' lesson.

Date: 26 August 2010 Time: 8am-9am Venue: Grade 4 Emerald class Tpoic: Magnets Teacher: Janis Lesson description: Students are discerning the properties of magnets and magnetic objects.		
Process	Lesson flow	Comments
Lesson Trigger	Janis shows a video clip on how magna doodles work. She addressed students' query raised last week. She said there were iron filings in the doodle and these were swept by magnetic force.	Facilitation encourages SDL as queries were revisited and validated, but not immediately so students will have space to ponder.
Validating	Deducing what counts as magnetic material Janis : "How can I prove a material is magnetic?" Jeremy demonstrated that the paper clips got attracted to the magnet. "So, you tell me it is made of metal..and this is magnetic...if this is magnetic, what material would it be?" Students: "iron", "steel". Next, she used a rivet. "What is a rivet?" One student thinks it is copper....Jeremy said copper is non-magnetic...Janis: so if it does not attract, can I prove it is copper?" Jeremy: "No.....there are many other non-magnetic materials." Janis is doing the test on battery now. She said some students got this wrong in worksheet. Shawn showed to the class that battery is attracted to magnet. Wendy had a question. "Is titanium magnetic?" Janis parked the question on white board: "You know what happened when you see a question on the board right? "Do research..." Class continued to experiment with other objects. Janis used fridge magnet.	 Emphasising cognitive skill of deduction and induction. Identified students' misconceptions and addressed them through demonstration. Empowering students.

	Someone said "it attracts to the fridge. Janis:" If something is attracted to the object, does that mean both are magnets?" Student: No…….as long as one is magnet…"	
Deliberating	"So how are you sure fridge magnet is magnet?" Someone said, "there is magnet attached behind the plastic…" Jeremy says fridge magnet has magnet, therefore it attracts. One side repels the other attracts. Janis: who agrees? Some students hands shot up..who disagree? Ron? Still thinking….ok, give you some time to think…who else disagree? No one raise hand? Suddenly everyone agrees?? Laughter. Jeremy elaborated magnetic objects are attracted to both poles, will not repel. But for magnet, like poles will repel, unlike poles attract.. Ron says, "magnetic object possible to repel too.." Janis parked another question on the white board: can magnetic materials repel? There are mixed responses. Ron thought there may be more examples but not tried yet. Janis: "Do you all think you can find ways to convince Ron? Until he is convinced, come and tell me…." Janis gave instructions on the homework on temporary magnets.	Ron is thinking about the "black swan". Janis gets students to convince one another, instead of validating right away.
Closing	Okay, we have a bit of time…update your KWL and do your Pico Map (digital concept map). Pico Map can be ongoing right? She wrote on board "update your KWL, if you want to update KWL at home, then do PICO Map now…I let you choose… A handful of students did not bring their phone, perhaps they only bring when Janis told them to do so. Many technical problems surfaced: long time to boot up, cannot log in etc. Sally is reading information on temporary magnets. She googled it and jotted what she found on note pad. "they are made stroking the substance with magnet." Someone found out that titanium is "para magnetic".	Giving choice. Pockets of technical issues still exist. Multiple pathways for students to learn: some went to explore more on titanium.

Table 3.5 Excerpt of fieldnotes, 26 August 2010

(Code: FNJA 100826)

The notes were taken in a chronological order so that it would be easier for the bigger picture to emerge and for me to identify mutually constituting elements that affect the usage of technology for student-centred learning. There was no high-level abstraction or judgement of the classroom events at this stage. The comments and reflections were added to the fieldnotes after the lesson observation, usually within two days to prevent memory lapse. Comments were not included on the spot as having some distance from the data was preferred to allow reflection. This practice

of withholding judgement also enabled me to go with the flow of the lessons as events unfolded and helped me view the lesson in totality.

I also had the opportunity to observe three fieldtrips that utilised the use of mobile technologies. Focus is placed on teachers' facilitation, students' self-agency and the interaction between teachers, students and technology to understand whether student-centred learning was attenuated during these trips.

Professional development courses and meetings

I had observed six professional development courses conducted by NIE researchers as well as external consultants from U.S.-based universities engaged by FPS. Such courses emphasised both theoretical frameworks of 1:1 computing and translation of theory into practices. Both the school management and the teachers voiced concerns, sought advice and critiqued current practices. For smaller-scale development courses organised for the working groups, NIE researchers would work very closely with the school's curriculum taskforce to co-design lessons that incorporated the use of mobile technologies. I acted as a participant observer on these occasions to take minutes on what was discussed. Figure 3.4 shows an excerpt of exchanges taken place during one the PD session.

Date: Nov 9, 2009
Time: 2pm-5pm
Venue: Meeting Room

Participants: Beatrice. Vice-Principal; Gabriel (IT HOD); Theresa (HOD of Sciences department); Katherine (HOD of Arts department); Janis (participating teacher); Sherry (participating teacher); Edward and Cassandra (both are U.S.-based external consultant); NIE researchers

Nature of meeting: Review an on-going project on mobile learning that has been running for half a year.

A. Moblized Learning Environment framework

1. Cassandra's suggestion: mobile technology is essential, not enhanced. Should change the proposition to "essential mobile technology". Mobile technology is invisible but essential and everywhere.
2. Theresa believes in the potential of technology but does not see them as essential. Teachers can get by without it. It's more about acquisition of soft skills and research skills.
3. Edward commented that if schools did not use the tools that students are using, it's equivalent to telling them that the things they do outside school does not count.

B. Assessment and Inquiry process

1. Beatrice queried how teachers can find the time to check students' work on their phones. She believes strongly that teachers should not pick and check students' artefacts randomly. However, as more time is needed to go through the electronic artefacts, she felt the tracking and monitoring time may be compromised.
   (NIE researcher 1 felt that verbal just-in-time formative feedback can be just effective. NIE researcher 2 felt this is not a technology specific problem.)
2. Beatrice felt that there is a need to provide more structure and tighter relationship between MLE lessons and student assessment. She is wary of putting in too much resources but generating disappointing outcomes. She wants more data to allow the school to move ahead and to scale up.

Figure 3.4 Excerpt of short notes taken during professional development session

(Code: FNPD 091109)

These notes served as a form of data triangulation in addition to interview data. More importantly, such contextualised discussions tend to bring out multiple perspectives of key leaders in a more natural setting as compared to individual or focus group interviews. In addition, for leaders that I did not or could not interview, these notes allowed me to gain insights of their views on a myriad of issues raised.

I also had many opportunities to observe and at times, participate in the meetings conducted by the school. These could take shape in the form of: 1) dialogue between FPS and NIE on the status of on-going projects. Such meetings usually

involved presentation and Q&A sessions; 2) weekly one-hour sharing ("White Space") for teachers of the same level to share and reflect on their successes or woes related to teaching practices. In particular, I observed one session of "White Space" to understand the challenges faced by teachers in enacting the new mobilised curriculum that was just rolled out to the whole level; 3) key events hosted by FPS. These include the launch of the school-based research centre, meeting with parents to seek buy-in for projects and visits by foreign delegation.

3.3.3 Documentary sources

Documentary analysis allows readers to "locate, interpret, analyse and draw conclusions about the evidence presented" (Fitzgerald, 2007, p279). Documentary sources can provide a well-spring of information, especially if used for longitudinal analysis. It can provide clues to how situations have evolved over time by "capturing the dynamic situation at the time of writing" (Cohen, et al., 2007, p201). It is also a conduit for connecting the "past and present on the one hand, and between public and private on the other" (McCulloch, 2004, p28). These were especially important for this research as it entailed the study of the transformational phases of schools which happened in the past and cannot be re-enacted; hence the justification of studying documents to fill the unobservable historical gaps. The data gathered from the documents could also be used to triangulate data gathered from both observation and interviews. Table 3.6 is a summary of the types of document collected for this study.

Document Type	Nature of document
Meeting minutes	Meetings with: 1) NIE research group; 2) between NIE and FPS key personnel; 3) researchers and teachers; 4)FPS key personnel, NIE researchers and external consultants.
Lesson plans	Teacher's lesson plans or lesson plans co-designed with NIE researchers.
Emails	Non-confidential email exchanges between MOE, NIE researchers, members of FPS and external consultants.
Presentations	Powerpoint presentation by FPS teachers, documents prepared for award accreditation, keynote speeches by stakeholders, conference posters.
Publications	Action research papers written by FPS personnel; newsletter disseminated to external parties.
ICT policy paper	School's ICT roadmap.
Photos	Photos: 1) Displays of ICT projects; 2) classroom activities; 3) infrastructure.
Publicity material	Press releases and newspaper articles, FPS' website.

Table 3.6 Examples of documentation sources

3.4 Data Analysis

3.4.1 Data management

Data collected were stored in my personal desktop computer, laptop and portable hard disks. These data were first organised according to data type for easy retrieval. Sub-folders can be indexed according to date, interviewee profiles, document type or authors. For interviews, I transcribed the audiotaped sessions with the use of freeware, Express Scribe where the pace of the dialogues can be controlled with a speed button to facilitate the transcribing. The format of transcript was a word template that comprised line numbers and side panel for entering codes. I also engaged a transcriber to help with some of the transcribing work. She was briefed on the use of template, focus of study, type of transcription needed as well as the importance of observing the confidentiality clause. These audio snippets and templates were uploaded to a password-enabled site for the transcriber to

download. All transcribed works were cross-checked by me against the audiotapes to ensure factual accuracy.

3.4.2 Coding method

I adopted the method of inductive analysis, starting off with "open coding". According to Miles and Huberman (1994), coding is the process of reviewing a set of field notes and dissecting them in a meaningful manner so that the relations between the parts are intact. Codes are "tags or labels for assigning units of meaning to the descriptive or inferential information compiled during a study" (p56). Merriam (1998) details that the researcher can begin with a particular incident from the data and compares it with another incident in the same or another set of data. These comparisons can culminate in "tentative categories that are then compared to each other and to other instances" (p159). The challenge is to construct categories that are able to cut across the "preponderance of the data" (p179).

Bearing these in mind, when the first interview transcript was ready, I input open codes in the margins. After walking through the entire script, codes that appear to go together were clustered. Next, the second set of transcripts were checked against the first to see if these categories apply as well. Merriam (1998) suggests that these two lists should be merged to form a master list where it "constitutes a primitive outline or classification system reflecting the recurring regularities or patterns" which subsequently forms the "categories or themes into which subsequent items are

sorted" (p181). Refer to Figure 3.5 for example of initial coding. As Merriam (1998) suggests, the categories should be "mutually exclusive", "sensitising" and "conceptually congruent". This implies that "the same level of abstraction should characterise all categories at the same level" (p184).

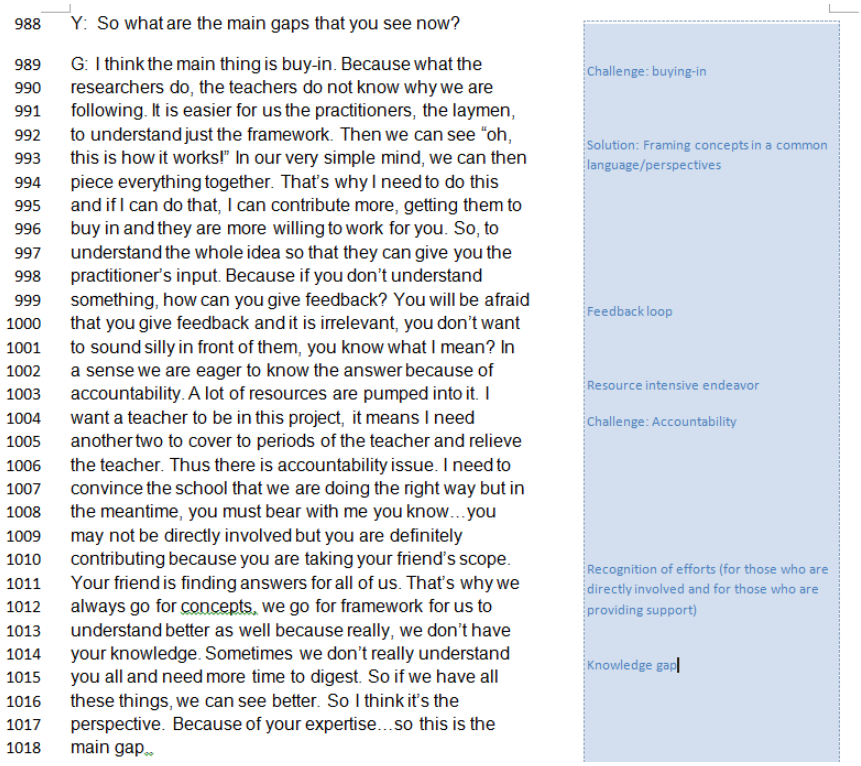

Figure 3.5 Excerpt of transcript and open coding

(Source: INGB 091106)

As my study involved multiple data sources, the data collected were clearly massive. To make the task of data reduction more manageable, I transferred my first round of open codes in word document to NVivo 9.0, the qualitative data analysis software to organise the fluid codes and categories that emerged from the repeated reviews

of data descriptions. This gave me a chance to revisit the codes and merge similar events under the same codes in the process. Codes (Nodes) that share similar traits were then subsumed under overarching categories. The next "quantum leap" in data analysis is the step from forming categories to developing a theory. Miles and Huberman (1994) refer this process metaphorically as connecting the observables and unobservable with "inferential glue" (p261). Propositions are then drawn and the specific research questions be addressed. Saldana's (2009) codes-to-theory model is especially useful in illuminating the process of theory building (Figure 3.6).

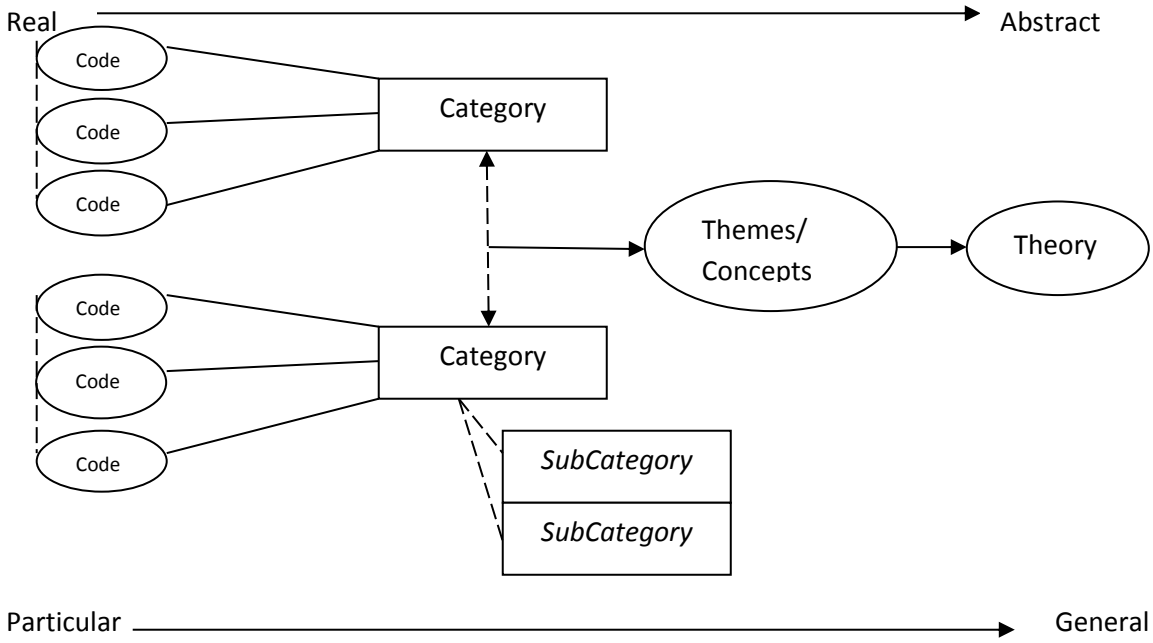

Figure 3.6 A streamlined codes-to-theory model for qualitative inquiry

Source: Saldana, 2009, p12

To further illustrate, Figure 3.7 shows how some of the open codes developed by me became themes/concepts.

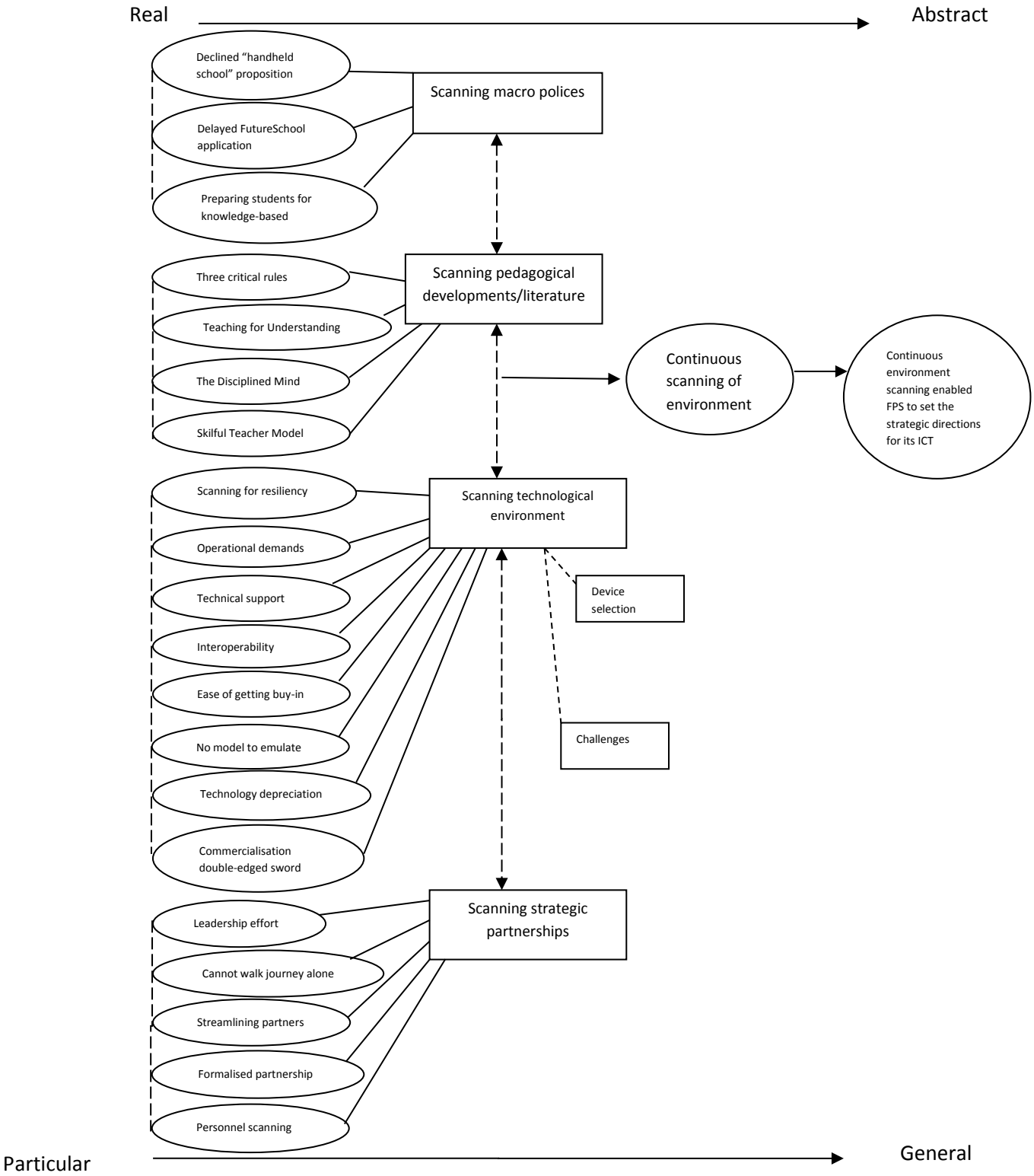

Figure 3.7 An example of how "inferential glue" is applied to categories

With reference to Figure 3.7, four categories emerged based on the open codes: Scanning macro polices, scanning pedagogical developments/scholarly literature, scanning technological environment and scanning strategic partnerships. As these scanning activities were carried out over time and not episodic in nature, they were subsumed under the theme of "continuous scanning of the environment". By looking at the multi-faceted considerations regarding the school's environment and its impact on the leaders' decisions, I made the following inference about the role of environment scanning in sustaining innovations:

> The scanning of environment had enabled FPS to set the strategic directions for its ICT development. Connecting to experts, understanding socio-political trends, making systemic evaluations regarding technology, assessing contextual readiness all add to create a better sense of mission in the usage of technology and attest to the fact that students' learning processes and outcomes were at the heart of decisions. (See Chapter 5.1)

Although the above coding scheme served me well in general, it had its limitations, especially in terms of fleshing out the change dynamics regarding the school's longitudinal ICT usage. As such, I conducted a second cycle of coding, known as "longitudinal coding" to attribute "selected change processes to qualitative data collected and compared across time" (Saldana, 2009, p173). The matrix was favoured as it was loosely structured to allow the study of emergent and dynamic

interactions to be traced without any disposition towards predefined codes. This was largely aligned with the spirit of complexity theory, thus enhancing the coherency of the paradigmatic, theoretical and analytical methods of this study. By conducting a second cycle of coding using a different method, I was also enhancing the robustness of my codes. Triangulation allowed me to see which strands of argument stood out prominently, not only for an episodic snapshot, but across the temporal dimension too. The following illustrates how I combined my first and second cycles of coding to map the trajectory of development.

In addition, four phases of development were demarcated according to FPS' key milestones and critical events, as expressed through interviews. For example, the first principal identified the year 2001 as the year where the school embarked on innovation ('Embarkation') and 2005 as the 'tipping point' in terms of quantitative and qualitative growth of champions as well as record number of failed demonstrations ('Entanglements'). The ex IT-HOD identified year 2008 as the year where more pedagogical frameworks were introduced under new stewardship ('Exposition'). Year 2011 was the year where FPS received the FutureSchool award, thereby shifting its priorities to innovation scaling ('Elevation'). These four phases became the four sets of data time pool depicted in the first row of Table 3.7. For illustration, an excerpt of longitudinal coding is provided here using two data pools (Embarkation 2001-2004; Elevation 2010-2011).

LONGITUDINAL QUALITATIVE DATA SUMMARY MATRIX

DATA TIME POOL/POND: FROM 2001 THROUGH 2004 (Embarkation Phase)							
	INCREASE/ EMERGE	CUMMULATIVE	SURGE/EPIPH/ TURN POINT	DECREASE/ CEASE	CONSTANT/ CONSISTENT	IDIOSYN CRATIC	MISSING
C		3 to 15 champions (Carl)			ICT department as champions (Nigel)	Confidence in departing from MOE's view (Gabriel)	
PH	Use technology for engaged and participatory learning (Carl) Continue innovations as long as students enjoyed the process (Carl; Han)		Inspired after attending an international conference (Carl)		Critical evaluation of the role of technology in enhancing learning and teaching (Carl) Not to be constrained by technology (Gabriel)		
PCS	Cross-school collaboration (Carl; project synopsis) Cross-subject collaboration (Carl; project synopsis) Awards received for some early experimentations (project synopsis)	Project-based ICT programmes (Gabriel) Development of learning model for mobile fieldtrips (Gabriel)	Kick-started ICT programme (Nigel) Embedded online learning environment (Nigel) Experiential learning framework (project synopsis)	Decrease in number of one-size-fits-all IT programmes (Gabriel)		Only few classes participated in cross-school ICT programme (Gabriel)	Decisions about curriculum not shared (Nigel); made between IT HOD & P (Gabriel) Roll-out impact was limited (Gabriel) No documentation & scientific data (Gabriel)
IP	Teachers tend to re-think the way they teach with technology (Carl)	Self-organised interest in exploring emergent technologies (Carl)	Introduced socio-constructivist model (Carl; Gabriel; research paper)		Portals mainly used for disseminating electronic worksheets (Han) No fundamental change in teaching practices in general (Han)	Unforeseen school events disrupt implementation schedule (Han)	Success only contained in experimental classes (Han)
AE	Monitor students' level of motivation and engagement (Gabriel)				High-stake summative examination		Minimal impact on learning (Gabriel) ICT profiling for teachers (Gabriel)
PD	Focused on introducing technology (Han)		Focus on action research (Gabriel)				
IN	Set up portal (Nigel) Bring technology into classroom (Nigel)	Creating learning packages (Han)					

DATA TIME POOL/POND: FROM 2011 THROUGH 2012 (Elevation Phase)							
	INCREASE/ EMERGE	CUMMULATIVE	SURGE/EPIPH/ TURN POINT	DECREASE/ CEASE	CONSTANT/ CONSISTENT	IDIOSYN CRATIC	MISSING
C	25-50% teachers champion-ready (Nigel) Buy-in (Nigel)	Continue to raise bar for forerunners, void filled by interested teachers (Nigel) Experimental teaches became mentor (Janis)	Nigel became IT HOD in 2011 (Nigel)				
PH	Serving as an example beyond FPS (Nigel)	Making successful innovations more pervasive (Terrence)	Became FutureSchool in 2011 (Nigel)		No penalization for laggards (Nigel, Gabriel) Don't just include technology for its sake (Gabriel) Philosophy and vision must be the same, process can change (Gabriel) Multiple perspectives valued (Gabriel, Nigel)		
PCS	Scaled up mobile learning programme to whole school (Nigel) Cross- department collaboration (Nigel) Pedagogical focus (Gabriel, Nigel) Projects with NIE (Gabriel) Integrating more projects into curriculum and scheme-of-work (Nigel)	Changes to content (Nigel) Projects gradually owned by IP instead of ICT dept (Nigel) Projects emphasise more on self-directed and collaborative learning; knowledge creation and learning across different spaces (project synopsis)	Re-look into curriculum and pedagogy (Nigel)		Constant review of projects. Decision made based on collective decision (Nigel, Gabriel) Proof of concept (Gabriel)	Logistical challenges of whole-level programme (Nigel) Energy diffused by administrative load of liaising with multiple stakeholders (Gavin)	Need to refine cyberwellness programme (Gabriel)
IP	Hire more teachers after becoming FS school (MOE policy)	Fewer cases of didactic usage. More teachers able to enact student-centred practices with technology (Amelia; Sheila)		Decreased teaching load of teachers involved in ICT projects (Nigel) Transient decrease in ICT support in classroom		Mass exodus of ICT staff in 2011, need to rebuild team (Nigel)	Not all IP heads have gone through shift of mindset (Nigel)
AE	Two lesson observations from 2011 (Nigel) Increased use of TfU framework in formative assessment (publicity poster)	Rubrics for profiling teachers in 2011 (Nigel) Shared decision in future direction of projects (Nigel)	Lesson observation include descriptors for self-directed and collaborative learning (Nigel)				Optimal balance between results and experimentation (Nigel)

PD	Escalate capacity building efforts (MOE proposal) Sharing platforms (Nigel) Nation-wide ICT mentor scheme (Jazz; Hannah)	Learning from researchers (Gabriel)	Small group coaching (Hannah)				
IN	Unstable connection due to intensive traffic flow (lesson observation) More demand for ICT support staff (journal record)		New working space for ICT support staff (Nigel)				
DIFFERNCES ABOVE FROM PREVIOUS DATA SUMMARY							
	Focus on sustainability and scalability	Shift of ownership	Emphasise FutureSchool curriculum and new pedagogy	Offloading teachers, more demand on ICT support	Coherence maintained but more emphasis on proof of concepts	Tensions happening at multi-level scales	More realisation of gaps, time needed for deep impact to occur
CONTEXTUAL/INTERVENING CONDITIONS INFULENCING/AFFECTING CHANGES ABOVE							
	More funding following the award of FutureSchool status	Desire for inclusive sharing	New stewardship and award of FutureSchool status	More funds to outsource some workload. Exit of IT HOD led to exit of ICT support staff.	Alignment of vision	Complexities arising from interfacing with many stakeholders	Culture of reflexivity on progress and gaps
PRELIMINARY ASSERTIONS AS DATA ANALSIS PROGRESSES Whilst there was deeper alignment between FPS' use of technology and the principles of student-centred learning over the years as a result of long-term enculturation, tensions that threatened the fidelity and adaptations of innovations did not abate correspondingly.							
					THROUGHLINE (in progress) Are there distinctive and linear phases of ICT development as posited by scholars?		

Table 3.7 An excerpt of longitudinal codes leading to assertions.

Source: Coding matrix adapted from Saldana's (2009) template (p174) for longitudinal coding method

The trajectory of FPS' ICT development was carefully mapped out by studying each of the seven categories across the seven columns of change processes that appeared within a data pool set. A conceptual theme was then developed based on the salient properties of the particular category. For example, the conceptual theme for the philosophy (PH) strand during embarkation phase was 'Affective Monitoring' as the school leaders focused more on affective development and outcomes. As for

the elevation phase, 'serving as exemplar' and 'making success pervasive' were the key philosophies, thus the theme 'prototype exemplifying' encapsulated these salient features. Refer to Table 4.1 for the complete themes of trajectory of growth. Assertions were drawn up based on the inter-relationship of themes and discussed using the complexity lens subsequently. For example, the theme of 'tensions' spanned across the four phases, and that led to the assertion of the existence of 'perpetual tensions' which did not abate even with more sophisticated resources.

Conflicts in data became apparent when using this method. To elaborate, during the 'entanglement phase', Han (ex-middle manager) critiqued that the school was award-driven; while the school leaders perceived those awards to be outcomes of documentation to sustain innovations instead of their philosophy of using technology. More triangulation work thus ensued. This was done by studying the transcripts of all other interviewees and also leveraging on the opportunity to probe further during the last round of member checking with the principal.

3.5 Trustworthiness

Maxwell (2002) describes trustworthiness as validity in terms of "descriptive" (factual accuracy of accounts), "interpretive" (accurately comprehending the participants' perspectives), "theoretical" (the validity of the concepts and their relationships in explaining actions and meanings) and "evaluative" (the judgement of the value of actions and meanings) validity. To enhance the trustworthiness of research, I

adopted Bassey's (2007) suggestion to be engaged in prolonged engagement, conduct longitudinal observations, constantly checking interpretation against original sources and get critical friends to challenge notions to improve the quality of research.

I had also attempted to establish credibility or internal/descriptive/interpretive validity by inviting participants to comment on the accuracy of their accounts and plausibility of the results. Interviews were recorded on tape to provide "highly detailed and publicly accessible representations of social interaction" (Peräkylä, 2004, p285). Interpretive/external validity can be achieved by providing thick description of the case, or what is known as "verisimilitude". Contextual completeness is important and the reasons are cogently expressed by Firestone (1987) who notes that qualitative studies provide readers with "a depiction in enough detail" to show that the author's conclusion is justifiable and that the onus is on the reader who will actively "check these details against personal experience" (p19). Related to the concept of thick description is "ecological validity" which focuses on accurate portrayals of social situations in their natural setting. This can be made possible by addressing in the research "as many characteristics in, and factors of, a given situation as possible" (Cohen, et al., 2007, p138). In terms of triangulation, multiple data collection methods were adopted. In addition, I also triangulated the findings with those found in literature reviews. To further keep bias in check, the paradigms and assumptions that frame this study were delineated in this chapter.

Lastly, as Cho & Trent (2006) contend, validity is a process and since reality is subject to changes and the perpetual re-interpretation of participants, keeping a reflective journal will "make transparent the subjective processes" (p327). Thus, I kept a small booklet with me and used it to record reflections, serendipitous (but non-confidential) information or epiphanies that I received. Self-reflexivity became an important tool to enhance validity.

3.6 Ethics

To ensure that my research endeavours were carried out in an ethical way, I paid extra attention to culture so as to be "sensitive to the socio-political contexts in which individuals live out their lives" (Busher & James, 2007, p109); avoided detachment during fieldwork and be aware of the possible harm I might be doing to the entire environment; engaged in responsive communication during reporting and to act responsibly when making public of what had been learnt (Flinders, 1992). Other more generic concerns of ethical issues include maintaining the privacy, anonymity and confidentiality of participants as well as granting them the freedom to withdraw from the research at any time. I also strove to maintain the confidentiality of participants by using pseudonyms for the school and interview subjects. All participants were also briefed on their rights.

As a researcher who belonged to a group of NIE research team that was exploring the use of smartphones in mediating students' learning both in and outside FPS, I

need to define the boundaries of the data collected. As the focus of this topic was on technology leadership, I had analysed the data from that perspective instead of collecting project-specific data. In this sense, there was a distinction between the data collected for professional and doctoral work. To maintain confidentiality, I would not disclose the raw data provided by my interviewees to any institution. It was made clear that the data would only reside with me. In addition, permission was sought from NIE, FPS and the University of Leicester Research Ethics Committee before I embarked on data collection.

3.7 Chapter Summary

This chapter delineates the implications of my ontological and epistemological beliefs on the choice of research paradigms and methodologies. I have argued that the paradigm of complexity theory and the methodology of holistic, qualitative case study research are most apt in addressing issues relating to how schools can possibly leverage on technology to transform and sustain its efforts to become a student-centred institution. Aligning the study's data collecting and analytical techniques with the overarching framework, a research plan detailing the selection of sites and participants is developed. Semi-structured interviews, unstructured classroom observations and documentary analysis are used to triangulate data. Subsequently, open coding, categorical aggregation and pattern establishment are used to analyse data. While doing so, I made attempts to enhance the

trustworthiness of the study and to observe ethical guidelines throughout the process.

Chapter 4. Findings Related to RQ1

4.1 Introduction

Although MOE had made it mandatory for all local schools to use ICT in the curriculum, different schools had pursued this cause with different degrees of fervour. Fortitude Primary School (FPS), which had been earmarked as a FutureSchool (prototype school which is using ICT across all levels and subjects) had worked relentlessly over the last decade to carve a niche in ICT, in particular, 1:1 computing where every student in the school will have the opportunity to be equipped with one device. This case study focused on the trajectory of how FPS had leveraged on technology to realise the pedagogical reform for student-centred learning. This chapter reports the findings of the first research question:

RQ1: What was the development trajectory of a Singapore ICT-enriched primary school that harnessed technology to meet the demands of pedagogical reform for student-centred learning?

4.2 Trajectory of FPS' ICT Development

To understand how FPS had been using technology for student-centred learning, I drew on data sources which composed interviews conducted with different personnel of FPS (see Table 3.2 for their profile), classroom observations and document analysis. From the synthesis of the corpus of data, FPS' process of using

technology for student-centred learning can be viewed as evolutionary with four phases which I established as: Embarkation, Entanglement, Exposition and Elevation (See Table 4.1). These four non-linear phases demarcated different milestones and foci of FPS' ICT implementation at an organisational level. However, they were not exclusive and could co-exist. For example, entanglement, which refers to a period of confusion from interaction with multiple agents could happen throughout the cycle but was most dominant during the earlier years of experimentation when expansion efforts placed pressure on infrastructural and capacity-building demands.

These four stages were identified based on the key events and milestones (See Chapter 3.8). The first round of coding produced seven categories about how ICT had been used to advance student-centred learning. They were namely: champions, philosophy of using technology, ICT programmes and curriculum structure, instructional practices, assessment strategies, professional development system and infrastructure. These categories were further analysed using the longitudinal coding method (See Table 3.7) which aided me in mapping out the key developments of FPS' ICT usage along the seven dimensions. Together, both rounds of coding led to the distillation of conceptual themes, depicted in the form of salient features and "Priorities", which was essentially a summary of the key concerns for each phase. Finally, three assertions were developed toward the end of this chapter.

4.2.1 Embarkation Phase

The embarkation phase refers to the infancy years of technology usage which spanned from years 2001-2004. FPS' attempt to explore technologies began as early as 2001. Initial success was palpable as the school won accolades for using equipment such as digital microscopes and data-loggers appropriately, resulting in the invitation from MOE to showcase its innovative projects in a nation-wide conference that marked the completion of the milestone of MP1 in 2002 and the recognition to be the first primary school in the world to use data flash logger competently for Science learning in 2003. The embarkation phase also saw an important turning event as Carl decided to explore the use of Palm (handheld organizer) as a teaching and learning tool after witnessing a demonstration in a workshop conducted by a renowned educational expert.

Said Carl:

> I thought the small size of the palm is good because is very conducive for the young children to use…….and MOE wanted schools to engage children in the learning and we saw the power of ICT being able to do that. (INCL 1003196094)

Gabriel interpreted Carl's move to implement the use of handhelds as forward-looking and daring (interview, INGB 091106660).

Phases/ Attributes	Embarkation (2001-2004)		Entanglement (2005-2008)		Exposition (2009-2010)		Elevation (2011-2012)	
	Rationale and actual use of technology for student-centred learning	**Salient Features**	**Rationale and actual use of technology for student-centred learning**	**Salient Features**	**Rationale and actual use of technology for student-centred learning**	**Salient Features**	**Rationale and actual use of technology for student-centred learning**	**Salient Features**
Priorities	Whether technology can engage and add value to learning.	Early reflection	Getting the fundamentals right.	Building foundation	Re-Clarification Accreditation Expansion	Consolidating gains	Scaling within and beyond FPS.	Extensive scaling
Champions	3 teachers in 2003 15 participating teachers in 2004.	Emergent forerunners	Growth in number of participants crossing the tipping point.	Expansive advocates	More than 50% of teachers were involved in projects.	Pervasive supporters	25-50% teachers were ready to champion.	Buoyant activists
Philosophy	Students should continue to use technology as long as they are enjoying the process. Engaged learning is the key.	Affective monitoring	Strategic re-positioning to focus on 1:1 computing.	Strategic repositioning	Everyone can learn and technology would be able to cater to the differentiated needs of learners.	Humanistic anchoring	Serving as an exemplar for other schools.	Prototype exemplifying
ICT Programmes and Curriculum structures	Early pockets of success in experimenting cutting-edge technology to promote active learning. In general, programmes had limited impact.	Nascent Pioneering	Emphasis was on socio-constructivist practices. However, the ICT projects were mainly ad-hoc and piecemeal involving very few classes. No incorporation of projects into the scheme of work.	Pedagogical Seeding Piecemeal trialling	Curriculum innovation anchored in pedagogical research. Projects emphasized bridging of formal & informal learning, Re-designed learning journeys based on systemic considerations.	Pedagogical framing Holistic integration	More projects with proof of concepts were integrated into SOW. More cross-departmental collaborations can also be observed.	Pedagogical translation Inclusive Collaboration
Instructional practices	Predominant use of electronic worksheets disseminated through LMS. No fundamental change in instructional practices.	Passive consumption	Tensions due to technical glitches, implementation incompatibilities and limited understanding of pedagogical implications.	Systemic tensions	Broad consensus on expanding use of ICT for student-centred learning. However, incongruence between espoused and actual enactment could be observed as teachers struggled to internalise new frameworks.	Pedagogical consensus Incongruent internalization	Majority of the teachers were able to enact constructivist practices when using ICT. Technology was perceived as a catalyst for changing teaching practices at a larger scale than embarkation phase.	Catalytic transformation

Phases/ Attributes	Embarkation (2001-2004)		Entanglement (2005-2008)		Exposition (2009-2010)		Elevation (2011-2012)	
	Rationale and actual use of technology for student-centred learning	**Salient Features**	**Rationale and actual use of technology for student-centred learning**	**Salient Features**	**Rationale and actual use of technology for student-centred learning**	**Salient Features**	**Rationale and actual use of technology for student-centred learning**	**Salient Features**
Assessment strategies	Traditional assessment and grading practices were especially rigid to changes.	Status-quo maintenance	Not many changes were introduced during this period. High incongruence between grading practices and principles of student-centred learning.	Widening divergence	Isolated evidence of students learning how to assess their own or peer's work. Some attempts at making formative assessment more varied and just-in-time. Drill and practice was still the dominant strategy for summative assessment.	Incremental diversification	New appraisal system for teachers that emphasized collective voice. For assessing projects, a more formal and collective evaluation was introduced.	Collective evaluation
Professional development system	Training is more technically driven in nature, for example, the teachers are trained in the use of the school's LMS or certain softwares.	Technology induction	A few interested teachers explored technologies together but these efforts were not integrated into the professional development system.	Isolated exploration	Covers wide-ranging formal and informal aspects such as encouraging curriculum innovation, ironing out implementation issues, improving instructional practices for student-centred learning, providing upgrading opportunities, connecting to experts and mentoring colleagues.	Encompassing enculturation	PD sessions were also more customized. Time-tabled time, small-group handholding were implemented.	Customized iteration
Infrastructure	LMS and school portal ready. IT department designed lesson packages.	Building fundamentals	Unstable connection and long log in time. Low battery life of devices and option for charging is not readily available.	Variable operating conditions	Futuristic Computer Lab for collaborative learning and classroom observation. P3 classrooms rewired for device charging.	Pedagogic focus	Wireless coverage higher but highly unstable. More demand on ICT support.	Sub-optimal connectivity

Table 4.1 Salient themes for FPS' ICT trajectory of growth

FPS' experiments caught the attention of MOE and subsequently in 2005, it was regarded by MOE as the epitome of "handheld school" (Gabriel, interview, INGB 091106405). When first introduced in 2003 in FPS, the handhelds were used to enhance the learning of primary two English, Mathematics, Chinese and Music. Activities included using interactive programmes for self-learning spelling, downloading software from the internet, recording schedule, inputting data like compositions and homework, exchanging information, using drill and practice Math software and playing virtual musical keyboard (project brief, PBPDA 111018).

In terms of the philosophy of using technology, the school's focus was on the affective aspects of learning. Carl felt that experiments should be continued as long as the children were enjoying the process. Engaged learning was the key:

> For children, the important thing is not to force it on them. Important thing is that as we are looking at them, do we see excitement in what they are doing? (Carl, interview, INCL 100319975)

Han made a similar comment about Carl's motivation to introduce technology:

> During [Carl's] time, his concern, for what I feel, is that students will be more interested in the lessons… Both [Carl] and I felt that as long as the students like it, we will pursue the projects……we always focus on the students, we look at the students. If students like it, we will do it. (interview, INHN 100531554)

Carl commented that students must enjoy the process of learning and also experience a qualitative transformation as a person. He felt that the use of technology was "about the person you are", and its usage was not just about improving academic results, but more a stage of becoming to get to know and discover oneself. He thought that educators should ponder hard on whether the use of technology had made students "exciting and curious" people. On the latter, he confidently postulated that FPS' use of technology had "planted that good fire (of curiosity)" in students. He believed that technology can add joy to learning and change the way students frame their knowledge. Said Carl, "We want to teach the children to learn, rather than you know, teach them what we know." (INCL 100319475)

Carl also reiterated the importance of thinking critically about the use of technology in FPS:

> A proposition that I've had even before [Gabriel] came was that whenever we (Carl and the first IT HOD) are talking about the use of ICT, before anybody can challenge us, we must always be very critical of what we are doing. The question was, and the question always will be, can it be done without? So we must always be ready to answer this question. And that was something that we thought was a good way to get things started, so we know that we are our worst critic. (interview, INCL 1003191203)

Thus, the embarkation phase involved the leaders' critical reflection of why technology was being used. Carl's intention rested on his belief that technology provided a unique affordance to add exponential value to learning. To Carl, justifications of using technology encompassed reasons such as actualising participatory learning through networked technology as it could give students access to esoteric knowledge that could not be found in textbooks. He felt that the online discussion mode favoured the social construction rather than transmission of knowledge and gave students access to experts who would otherwise be inaccessible. He provided many accounts of how students were able to construct their knowledge spontaneously with technology and how they in turn, could teach their peers and teachers their newly acquired knowledge (Carl, interview, INCL 1003191559). Learning independently and co-constructing knowledge collaboratively were affordances which Carl highly valued:

> That's the kind of powerful learning that we want to learn from the children you see. That I don't have to teach you, and your learning is so impactful, you can actually teach me you know. (interview, INCL 100319460)

At the heart of his epistemic belief was that ICT could play an important role in disintegrating the power divide between teachers and students in a profound way by democratising access to education and fundamentally challenging the traditional perspective of relying on the teacher to impart knowledge.

Carl also noted how using technology in classrooms, computer laboratories or during fieldtrips that involved the use of mobile technologies can effect changes in pedagogy:

> One thing that I see, when we use ICT, my teachers tend to teach differently. They tend not to, just teach in one direction, that means I talk they listen. Somehow ICT lessons don't allow you to do that……It's very hard to do an ICT lesson when you do that. And that's why for me, that's the beauty of ICT lesson. In itself, the way it is structured, forces the teacher to rethink the way the lesson is conducted. (interview, INCL 100319524)

Carl attributed the reasons of non-didactic instruction to the inherent affordance of mobile technology and the socio-cultural factors in educational settings. During these fieldtrips, the emergent process of experiential learning via physical and virtual interactions exemplified the incompatibilities of didactic instruction.

Shelia, one of FPS' ICT champions, attested to the same belief. She explained that when the students had a device in their hand, both teachers and students would strive to leverage on the affordances. She explained:

> I got the children to work in groups so they were excited. It is like lesson outside of the classroom. So they were going round with this and I told them a list of preposition that they can choose from and then they were supposed

> to go out, whether in the library or the canteen or basketball court, to take pictures and from there come up with prepositions. (interview, INSL 100602205)

Shelia also elaborated that the activity allowed students to interpret and apply what they had learnt through their own lens. In another example, one of the resident researchers who had been observing Janis' class two to three times a week also noticed that her classroom management style had changed drastically with the introduction of mobile devices. Notably, she facilitated more. Conversely, Janis tends to lose control of the class when without the handheld (meeting minutes, MM090416; MM100305). In this sense, technology gave students more voice and can be seen as playing a catalytic role in restructuring teacher-student discourse.

During this phase, the number of ICT champions started from a modest number of 3 teachers in 2003 to about 15 teachers in 2004. Carl emphasised that the teachers invested in themselves the time to explore emergent technologies, after being inspired by what the pioneering colleagues had done:

> It was not something that I had instituted, something that I wanted to structure, something that I said I want to do. It was among the teachers themselves. As they were talking about it, they wanted to be part of this. (interview, INCL 100319331)

He added that his highest achievement is "not knowing what to tell the teachers" and the teachers "know what it is that they must continue to do". Admitting that he was not a technology person, he was glad that the teachers did not wait for him as if they did, they would also become a "dinosaur" like him (interview, INCL 1003191120).

A retrospective examination of the synopsis of IT projects undertaken during this period indicated that notions of active, mobile and cross-disciplinary learning were incorporated for key projects, which was a very forward-looking stance as most of the schools were still ingrained in traditional teaching practices. However, these successes were relatively insular phenomena revolving around key projects. The predominant use of technology during this phase was to disseminate electronic worksheets through the school's Learning Management System (Han, interview, INHN 100531289). The IT department also worked at creating learning packages and placed them in the repository so that teachers can download and assign to students readily. One of the teachers, Jazz recalled planning her lessons according to what ICT device was made available instead of pedagogical principles (interview, INJZ 10090671). This evidence suggested that technology-centric planning was the norm during this embarkation phase. Trainings were also more technically driven in nature (Han, interview, INHN 100531248), indicating rudimentary capacity building efforts that focused mainly on technology induction. As Gabriel mentioned in his interview, due to the very small number of participants, the mobile learning journeys

conducted by FPS in the early years had limited impact although they involved participation across the five affiliated sister schools, signalling a lack of depth. Changes in assessment strategies were also not explored.

Despite these areas of lacklustre performance, the motivation for using ICT was primarily student-centred, gathering from the interviewees (Carl, Han, Gabriel, Sheila) who reiterated the importance of using ICT to advance the affective development of the students. The main criterion to decide whether a project should be continued rested not on the quantitative evaluation of learning gains, but more on the affective monitoring of students, which could be distilled from their level of engagement. There was also evidence of self-organising efforts amongst interested teachers to explore how technologies could be best used to engage the students (Carl, interview, INCL 1003191120; Han, interview, INCL 100531778).

Towards the end of 2004, FPS called for a review of its ICT initiatives (Gabriel, interview, INGB 091106262). The planning committee, in consultation with researchers from the National Institute of Education (NIE) decided to anchor its primary four curriculum within the social-constructivist model of teaching and learning. In parallel to social constructivism, the school also promoted the idea of using action research. Gabriel explained the rationale:

> We have nothing to fall back on, so rather than build on some framework or theory, why not start from scratch and we go through cycles and cycles to

improve our practice. That was our thinking at that time. (interview, INGB 0911106295)

This new initiative paved way for using ICT in an even more meaningful way to meet the imperatives of student-centred learning.

4.2.2 Entanglement Phase

The entanglement phase spanned mainly from 2005-2008 and involved several key milestones. The year 2005 was perceived by Gabriel as a watershed year as that was when MOE really started to look to FPS for ideas on how technology could be infused in teaching and learning (interview, INGB 091106360). The school was acknowledged by MOE for its effort to move in tandem with the changes prompted by the government to "Teach Less, Learn More" (TLLM). The ideology highlighted quality, rather than quantity and looked at creating more space for schools to introduce quality programmes that nurture students holistically.

Carl defined the period of 2005-2006 as "crossing the tipping point" that saw both qualitative and quantitative growth in the number of ICT champions (Carl, interview, INCL 100319354). In 2006, FPS achieved a school-based excellence award in ICT for encouraging greater diversity in its programme. To date, only two primary schools had been given this prestigious award. A six-year grant of $200, 000 was disbursed to support the further development of ICT programmes. In the same year, FPS became a LEAD school. With these continued thrusts, the school received a nation-

wide award for its excellent standards in innovation in 2007. Areas of evaluation include leadership, planning, implementation processes and results. The school perceived this as an attestation of its "competencies for managing and sustaining innovation", as well as "constant experimentation" and "commitment towards innovation excellence" (FPS newsletter, 2010).

When Gabriel came on board as IT HOD in 2006, he was cognizant about the wide range of technologies available and suggested to Carl that the school needs a focus. The discussion culminated in the decision to focus on 1:1 computing. Said Gabriel:

> I told [Carl] we need to focus. I know of schools which have videoconferencing, video production and in the end only focus on students' drawing. I feel that is not the way to go so I told [Carl] that. We had a conversation and I told [Carl] 1:1 computing. So all these years, since 06, we have 1:1 computing. I also told [Carl] that we will not focus on the equipment. Because at that time, we feel that at the equipment available is not created for the sake of education…… we will focus on learning. It is the thinking behind how we can use 1:1 computing to drive more effective learning outcomes. (interview, INGB 091106420)

On why the school had pursued 1:1 computing in particular, Gabriel explained that 1:1 computing is a "field-levelling" tool where introverts and students who suffered

from "inferior complexity" could share ideas without inhibitions. It also helped that each student had a tool and could learn independently:

> I feel that 1:1 can actually level the playing ground. So what happened now is you communicate directly with the teacher, if you think that you need more help, you can explore on your own, because now you have the tool, the skill to do so, you can seek help on your own, directly from the teacher as well. You can talk to friends you are very comfortable with. You will not worry that people will laugh at you. You work at your own pace. (interview, INGB 091106728)

Carl also rationalized that "technology is not about waiting for somebody, or we wait for the technology, it must be relatively available for us" (INCL 100319747). Thus, immediate access and ubiquitous presence for learning anytime and anywhere were important considerations. Carl remarked that with immediate access, it would then be possible to integrate technology into the curriculum more cohesively. There was no need to book the labs in advance and to use technology only during pre-determined time slots, which in Carl's eyes, was "artificial" and a "staged" way of learning (Carl, interview, INCL 100319753).

As the school moved away from the ad-hoc ICT project model to the whole-school programme, several flaws in execution became more apparent:

> In that one year, 2005, many teachers came in and experimented. Many lessons failed. Infrastructure will fail us as well. You can go to the classroom, sit for 20 min, and still cannot log on. These are the things we learn. (Gabriel, interview, INGB 091106225)

Carl also remembered vividly the pressure placed on infrastructural demands:

> I think in 05 06, when we were doing some of the piloting, the sets that came out at that time had a very low battery life. So an hour and a half, the things go flat so we got to plug in power points. Those were the technical problems. But we didn't want the technical issues to stop us. (interview, INCL 100319791)

Besides challenges stemming from the instability of infrastructure, there were also other structural rigidities that affected the use of ICT for student-centred learning, especially after the initial expansion phase from 2007-2008. Han, an ex-ICT champion and middle manager, who was tasked to ensure teachers met the targeted level of LMS usage, described his frustrations. He said that timetable conflicts and other school priorities often got into the way and technology-enhanced lessons could not be carried out as planned (interview, INHN 100531274). He also felt that many teachers were still not fully harnessing the power of technology for collaboration, production or creative learning. LMS was still mainly utilized for disseminating electronic worksheets. Fundamental changes in classroom instructional practises were not evident (Han, interview, INHN 100531290).

The analysis of projects undertaken during this phase revealed common characteristics:

1) The projects started to focus on personalised learning and cognitive development, allowing students to take more ownership of their learning. For example, one of the Mathematics project leveraged on artificial intelligence to allow students to choose heuristics or model drawing when they encountered learning difficulties, attesting to what Gabriel had elaborated about providing multi-modalities, points of entry and catering to differentiated cognitive dispositions (project brief, PBGW10; Gabriel, interview, INGB 101129217; Hannah, interview, INHA 11080259);
2) Making sense of multiple perspectives through networking platforms was also highlighted in several projects. For example, Sheila, a middle manager recalled how her students learned about the different perspectives of protagonists in the literature book, "Charlotte's Web" by discussing their stances with students from the United States (Sheila, interview, INSL 100602897);
3) There was more focus on collaborative learning where students learned to discuss, negotiate and produce artefacts collectively (project brief, PBGW10; interview, Amelia, INAM 110114105).

Although promising, Han's view was that these positive developments were confined mainly to the experimental classes. He had reservations about the arrangement of having "always the same experimental classes" (Han, interview, INHN 100531570). Triangulation with other interview sources seemed to be aligned with Han's observation. As inferred from the separate interviews with Carl, Terrence, Gabriel and Nigel, it was a deliberate policy by the upper management to contain more demanding research-based innovations within a few pilot classes to be led by experienced and willing champions, especially during early years of expansion where capacity building had not made widespread impact yet.

Whilst the use of technology for student-centred learning in classrooms was still not prolific and frequently hampered by institutional constraints, the use of mobile devices for fieldtrips had undergone positive developments:

1) The fieldtrips incorporated the framework of experiential learning to encourage inquiry and data collection (published conference paper, PCP 0705);
2) Projects effectively married the affordances of mobile devices and open-source tools such as Wiki to enable learning on the move (Gabriel, interview, INGB 091106458, PBGW10 LM5);

3) The teacher-initiated project was rolled out to Primary Four level in 2006 and Primary Three, Five and Six levels in 2008 (project brief PBGW10; interviews from Gabriel, Carl and Han), indicating a stable state of expansion;
4) The learning model provided a generic framework that could be adapted for different subject areas and catered to different spectrum of learning abilities (published conference paper, PCP 0705).

However, the fieldtrips also revealed other structural rigidities; one of which revolved the employment of assessment strategies. An examination of lesson plans and project briefs suggested that the assessment modes of these projects remained largely traditional. They were predominantly worksheet driven with close-ended questions. Students' collaborative or meaning-making process was not woven into the assessment component. Electronic worksheets remained the primary, if not, sole yardstick for testing students' understanding and charting their achievement (lesson plans, PCP 0705, PBPDA 111018; project briefs PBGW10).

The arrival of Terrence, the successor to Carl, in the last quarter of 2007, brought new perspectives which enhanced FPS' strong fundamentals in ICT development as well as challenged existing practices. This period of early expansion witnessed a flurry of emerging activities that exemplified polemic positions amongst leaders toward the use of technology, exposed some of the weaker links in the system, consolidated key developments, accentuated tensions and reinforced compatible

practices. For example, Terrence, while recognising his predecessors' great foresight in kick-starting the fieldtrips with good theoretical underpinnings, continued to fine-tune the programme by downplaying the use of electronic worksheets and bulky ultra-mobile portable computers (UMPCs) as he felt that mobility and the spirit of constructivism may be undermined. He also ensured that the fieldtrips were not implemented near examination period when the teachers were facing mounting pressure to complete the syllabus (Terrence, interview, INTE 110331231). The learning journeys were also re-designed such that students' learning experiences were more aligned with the national syllabus. The choice of tools used for these fieldtrips was changed to mobile phones subsequently. However, the procurement of equipment was also another source of contention. Han, for example, thought that the use of UMPC was powerful and mobile enough and it was therefore unnecessary to change the device (Han, interview, INHN 100531644).

Another tangible change felt by Han was the new emphasis on the sustainability of projects which saw Terrence expending energy on documentation to ensure the viability of projects in the face of staffing changes; and on accreditation in order to secure more funds. Han expressed his views about the shift of focus in implementation:

> [In the past], we are not aiming for certain award. We are not aiming for certain certificates, so we do not care about the documentation. We do not

> do the research, which way is not working well, which way is not good…we don't do the research. We just try it and if the students feel excited, we will just do it…… But now, it appears that if the methodology is useful, they will do it. Perhaps the students do not like it, but the decision lies in whether the thing is useful. The advantage now is that, perhaps students really can learn something, although I am not sure if the students are happy? (interview, INHN 100531P319)

Prior to 2008, assessment on the learning gains associated with ICT innovations was informal. Results of the experimental classes were tracked and compared with other classes of the cohort but there was no formal documentation or action research conducted. Han recalled conducting short and informal surveys in class to elicit students' feedback on the innovations, mainly to see if students enjoyed the lessons and used that as yardstick to decide whether innovation should be continued (Han, interview, INHN 100531P398).

During Terrence's stewardship, due to his focus on "teachers as researchers", all ICT innovations were considered action research projects to be grounded in pedagogical principles. Results had to be tracked consistently either by teachers or researchers to distil the learning gains. The latter usually involved a more elaborate comparison of the learning gains across different time scales (Gabriel, interview, INGB 0911061144). Survey instruments were validated by researchers, teachers and HODs before disseminating them to the students to ensure their robustness,

reliability and validity. The findings usually culminated into research briefs and action research papers (meeting minutes, MM100324; MM100518). Such new emphasis on documentation, measurement and accreditation accentuated the tensions between new and old practices, which led to the next phase of exposition, where there was proactive effort from the management to re-articulate their vision and re-clarify the mission of using ICT for student-centred learning.

4.2.3 Exposition Phase

The period between 2009 and 2010 was mainly expositional as there were pronounced attempts by Terrence to re-clarify and re-establish the purpose of using ICT. With the school's fast pace of winning a string of awards in recent years, there were questions raised as in whether the school was award driven. In the meeting room of the general office, there was a diagram which showed the awards that the school hoped to attain by 2015. Han had suggested that the school could be hankering after awards, because "it wanted to be famous" (Han, interview, INHN 100531P2558). Both Gabriel and Terrence were aware of such sentiments on the ground and offered their perspective to the award-centric interpretations:

> You can go and win the award. It's good! But your underlying objective, your KPI (Key Performance Indicator), what is it? Is it just to go for that thing? Or is it a natural outcome? Because you have improved, you have spent time thinking through how you want to improve your teaching and learning

> process, you got it right, then you document it, and you present it at a conference, that's alright…It's always back to that same, fundamental question. What is my motive? (Terrence, interview, INTE 1103311182)

Terrence seemed to point to the fact that some teachers may be extrinsically motivated and he did not agree with such award-winning mentality. He anchored his philosophy of using ICT within the praxis of teaching and learning. The emphasis was still on reflexivity of teaching practices, as exemplified by his contemplation to pull out from awards which FPS had already had a strong foothold but did not impact teaching and learning directly (interview, INTEMC 120712). Sharing this view was Jazz, a teacher who is proficient in using technology and has good pedagogical skills. She believed that children's learning should be fore-grounded:

> We do not want to do things because we want to have a good name for the school but forgot about children's learning. It's like if you bring in (technology), and the children did not learn in the end, it defeats the purpose. (interview, INJZ 100906910)

Here, Jazz demonstrated caution in not allowing commercialisation and aggrandisement to derail educators from employing strategies that truly benefit student learning.

Gabriel also explained why the school decided to apply for Microsoft's Pathfinder school award:

> We wanted to be a Pathfinder school because we want to reach out to a network of experts that Microsoft has. The whole idea is to help build our ICT leadership…….understanding what is the trend now……It gave us the opportunity to reach out to the network of schools under the programme and we can actually learn from them. (interview, INGB10091282)

The intention of applying for awards was driven by the desire to be connected to experts who would share invaluable experiences with regard to ICT leadership and to receive funding to continue research. Technology was only a means to an end and the school had set its longer-range goals on achieving excellence in teaching and learning (Terrence, interview, INTE 1103311296).

In terms of the vision of learning, Terrence also focused on humanistic aspects, as with his predecessor, Carl. He believed firmly:

> 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. (interview, INTE 1103311104)

On one of the new wall posters placed in the meeting room of FPS, it was stated that the school's essential belief is: "Every child can learn and their learning is determined by their effective efforts and use of appropriate strategies. Every child is different and hence has different needs." (PH VS11 110210) On the same wall is another display of Dr. William Glasser's "Choice theory" which expounded on the five basic and universal needs which affected students' choices: survival, love and belonging, power, freedom and fun (PH VS12 110210).

In the interview with Terrence, he also talked about the purported benefits of technology in meeting different needs. He believed that technology can provide customized scaffolds and transform students' knowledge base. This constituted a compelling need for educators to re-examine their epistemological beliefs:

> I remember when I was young, your access to knowledge base is the encyclopaedia, books in the library…….you got to travel that physical distance to get your sources of knowledge……And you know that has already changed. We can find information from the internet, and of course not all information is reliable. But you can at least get something now and 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 have also changed…….When students can get so many sources 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 now, we really have to change. (interview, INTE 110313379)

To Terrence, the most prominent affordance of technology was that it enabled the students to "reach out to knowledge spaces" and acted as a "springboard to larger body of knowledge". He believed there was "no end to the latest knowledge", and technology was an easier platform to reach out to current knowledge that would be subjected to revision constantly, as compared to traditional sources of information such as books. He emphasised that "we are not all the knowledge base". There was however some leadership anxiety here as Terrence was aware of the tension between the imperative and inertia to change. Knowledge bases are going through rapid re-organisation but schools are changing at a slower rate when compared to the socio-cultural trends happening beyond the school ecology. He saw the dialectical role of technology to shape or be shaped by the epistemological beliefs of those involved. The epistemological beliefs articulated showed high congruence with the principles of student-centred learning which underscored the importance of self-agency and autonomy.

As part of Terrence's effort to re-establish the purpose and ways of using ICT for student-centred learning, he held meetings with Gabriel, the then IT HOD, who served as the conduit between Carl's and Terrence's reign soon after he came on

board. Gabriel remarked that he could still recount the questions Terrence posed to him:

> What pedagogy, framework, and concept are the mobile learning trips built on? What are the research findings? How do we know this is much grounded? How do you know this is the right way to go? Do you have the research to back you up? (interview, INGB 0911061143)

Gabriel reckoned these were pertinent questions and became acquainted with the idea of teachers as researchers, a concept which Terrence had enthusiastically promoted and incorporated into the school's cornerstone philosophy (Gabriel, interview, INGB 0911061148). Interviews with Nigel, Yolanda, Sheila and Jazz also echoed Gabriel's view that pedagogical frameworks were foregrounded in FPS' current ICT curriculum, as compared to Carl's time.

Prior to 2010, FPS had an emergent learning framework (social constructivism) but it did not emphasise the need to devise a pedagogical and instructional framework for the school. It was not until recently that these were put in place, so much so that Hannah commented: "There are many frameworks used in this school." (interview, INHN 11080271). There were attempts by Terrence to institutionalise the instructional framework. For example, for teaching and learning, FPS adopted the "The Skilful Teacher" model first articulated by Saphier and Gower (1997) as the cornerstone framework. The model comprised a generic four-tier pyramid (Figure

4.1). FPS customized the second tier of instructional strategies further by specifying the National Research Council's meta-analysis of "How Human Learn" as principles of learning, strategies from Marzano's "Art and Science of Teaching" and the Teaching for Understanding (TfU) framework which was mooted by the Harvard University as models of teaching.

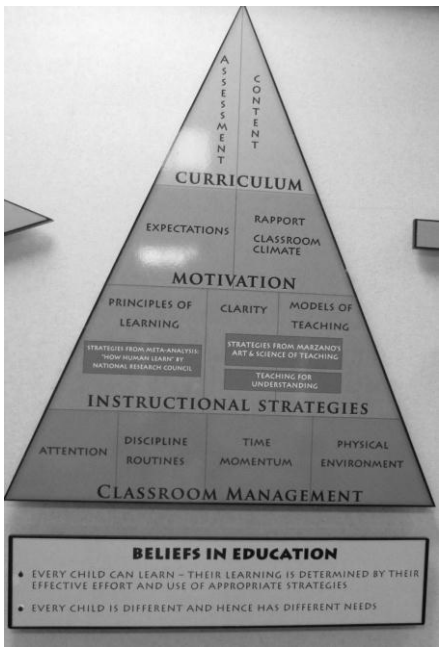

Figure 4.1 The "Skilful Teacher Model" of FPS

Source: Wall poster of FPS, Code: PH VS11 110210BW

Terrence thought it was essential for teachers to "understand the mechanics of lesson delivery and the ultimate purpose of education before any change in mindset can happen" (interview, INTEMC 120712). However, he also felt that the mapping of these theories to the actual use of ICT can be further enhanced so that there would be more consistency across the frameworks (interview, INTEMC 120712).

Terrence put forward the reasons for emphasising TfU:

> I find it very logical. And I hope to find an answer in TfU to solve a problem that I am encountering, and that is, to prepare for PSLE (Primary Six Leaving Examination). We teach our students whatever we can, we even give them as many questions to solve so that they can learn. Then when comes to the actual PSLE, maths and science papers, they cannot do it. Why? Because they don't understand at all……I mean thinking that kids have already understood the concept is very wrong……There are different levels of understanding……And I don't think anybody can understand everything about anything……I hope TfU will be a teaching methodology that will, when teacher plans and delivers the lesson, be very mindful I am teaching for my students to understand. (interview, INTE 1103131477)

Terrence had promoted TfU as a vehicle to realise differentiated learning. He observed that the teachers in the top classes were teaching the same way and using the same worksheet to teach as the weakest class. Thus, he proposed the use of TfU for the top class so that the high ability students would be spurred to think more deeply about understanding (interview, INTE 1103311542).

The use of instructional framework could perhaps be seen as an attempt of coherence-making but it also created frustrations in the process. For example, Amelia who had been working along with teachers to plan TfU lessons was well

aware of the challenges that teachers faced. To design good TfU lessons required niche skills which could not be acquired over a short span of time. Moreover, the need to marry the TfU framework with mobilized curriculum added more complexity to instructional planning, especially Mathematics, as the subject was predominantly taught in drill-and-practice way which "did not require students to articulate their understanding through words but more needing to know the steps" (Hannah, interview, INHA 110802102). These constituted additional tensions even though there was an elevated awareness for the use of ICT to realise constructivist practices. Time constrain also remained as one of the impediments to the effective management of technology-enhanced lessons, as underscored by Sherry, the beginning teacher (Sherry, interview, INSH 100823521) and other P3 Science teachers whom had a go with the piloted mobilized curriculum (fieldnotes, "whitespace" observation, FNWS100401).

In an attempt to further understand FPS' instructional practices involving the use of mobile technologies during this phase, I observed two school-led fieldtrips to Chinatown (a tourist attraction rich with Chinese heritage) in October 2010 and conducted an interview with Janis, the teacher-in-charge. 4 classes participated during those two days of observation. The Chinatown trip was selected for observation as this was entirely a teacher-led initiative implemented across all Primary Four classes. No researchers were involved in the planning. Another reason was that the Chinatown trip was very established and any changes to the design

could reflect the changing priorities of curriculum planning and instruction over the years.

The interview with Janis indicated that the current fieldtrip had merged two different routes to save students travelling time and to reduce manpower (FNJA 101008). Other changes to the trip included:

1) the use of jig-saw cooperative strategies that required students to explore different parts of the learning journey. This was to encourage active learning from every student in the team;
2) the use of student ambassadors to act as tour guides;
3) the use of Google Maps and the option of inputting open-ended comments on the electronic discussion board;
4) removing the museum tour to focus more on the actual historical artefacts at Chinatown.

These were measures that the participating teachers thought would enhance the student-centred principles of using technology as students now need to be active learners and observe shared accountability. The use of student ambassadors gave students a voice and was a departure from the conventional teacher-led instruction. Online open-ended reflections instead of worksheets were used as part of the attempt to encourage spontaneous sharing and knowledge creation. Although the mobilized curriculum structure was re-designed for student-centred learning

(meeting minutes, MM101013), observations of the fieldtrip and post-fieldtrip activities signalled challenging problems that departed from the original intentionality of teachers who were involved in the re-design:

1) Firstly, electronic worksheet was still included as part of the assessment. Students became task-oriented and exhibited low levels of self-directed learning, as shown in their desire for quick fixes by demanding answers from the student ambassadors.
2) Students had to access different platforms for different parts of the tour as the school did not have enough time to integrate the platforms which were previously under the charge of different departments.
3) Students had difficulty using the electronic platforms as they were not familiar with using them prior to the fieldtrips.
4) The use of the discussion board for knowledge exchange was tokenistic. 111 students posted their comments but there were no replies. This suggested that both teachers and students did not favour the use of discussion board for advancing discourse.
5) Very few students understood the essence of reflections and merely reproduced what the teacher had said at each station of the learning journey.

To sum up what I had observed from the fieldtrip, while the instructional design of the mobile fieldtrip was embedded with strong elements of student-centred

learning, the actual instructional strategies had yet to keep pace with the espoused principles. Students did not demonstrate reflective thinking and peer sharing based on the artefacts posted to discussion forum. Thus, even when technological platforms were proffered, the affordances were not fully exploited by both the students and teachers.

To gain insights about FPS' classroom instructional practices during the consolidation phase, the fieldnotes of the six classroom observations were analysed. Due to the intensity of ICT usage in FPS, there were no non-technology using teachers in the school. The criteria underlying the selection process of the 6 teachers was detailed in the methodology chapter (Chapter 3).

Several striking features were observed across the six lessons:

A significant amount of time was allocated for group work and students were generally quick in initiating discussion amongst themselves (amid some bickering for less efficient classes).

1) Although the duration of teacher-led discourse varied across the six lessons, students' voices were heard and respected.
2) There was customisation of lessons even though some of the teachers were using the same supplementary materials. This was especially evident from

Gavin's lessons where he pared down some lesson activities to cater to his low-ability students.

3) A broad-stroke analysis of the fieldnotes showed wide disparity in facilitation styles: Janis (level 3 teacher who was competent in action research and use of ICT in the classroom) being the most adept in extending students' emergent train of thought and Sherry (beginning teacher) being the most structured in terms of facilitating discussion; Jazz's (level 2 teacher with good knowledge of use of ICT in teaching and learning) lesson being the most exploratory in terms of allowing students to figure out the rules of a new technological application by themselves and Sheila's (level 4 affirmed teacher who wish to pursue higher qualifications in the area of educational technology) lesson being the most reflective in terms of consolidating the students' insights.

The lesson observations confirmed that the basic tenets of student-centred learning were present across the six technology-using teachers: both the students' affective and cognitive development were emphasized, students had opportunities to air their views; had space for exploration and were engaged in their learning. Teachers were also reflective about the students' needs. As an example, Jazz displayed her student-centric considerations by critically examining which technological platform would meet her students' needs and her pedagogical goal of fostering peer sharing on a Science topic. She rationalized that the school's electronic forum was a little

cumbersome to be used and previous attempts to ask students to post on the Forum were met with limited success. She also evaluated another popular application that used concept maps. However to use the application, Jazz had to set up accounts for students and there was age restriction of usage which was set at the mark of above 13 years old. After much contemplation, she believed Linoit (interactive post-it tags) was the best choice as it encouraged instantaneous feedback, active participation and could integrate different media types (FNLO JA101119). Post-lesson reflection also showed that she was aware of the competency gaps of students. She felt that although the students were actively posting, collaboration was generally absent, and she thus would like to look into how collaborative learning can be fostered in future lessons (FNLO JA101119). She also reviewed the changes in how she integrated technology in classrooms over the years:

> Last time, it is more of the teacher telling the students, ok, I give you this thing, then you are supposed to do this. So they basically just follow. But now, especially with seamless learning, it's very different. It's very student centred. I felt that last time in 2003, it's like I have that ICT equipment so I plan according to that equipment. But now it's like the other way round. (interview, INJZ 10090667)

When probed on what student-centred practices meant to her, she readily replied that it meant giving students more space to think instead of telling them the

answers straight away. Jazz also noted how students of varying competencies were all focusing on exploring technical tips amongst themselves without the need of her explicitly going through the functions of the application. From this example, Jazz had departed from didactic teaching; and lesson planning had evolved from technology-centred to student-centred considerations. Gavin also expressed similar views of how emergent technologies had enabled him to include more interactivity in his lessons. He started using PowerPoint in a show-and-tell way in the early years and gradually advanced to using discussion forum and Linoit after receiving ideas from colleagues during professional development sessions (interview, INGV 11081677).

The six lesson observations also showed some of the weaker links of enacting student-centred learning. Not all teachers were comfortable with giving students the freedom to explore as well as holding back the right answers. Sherry articulated the initial tension of enacting constructivist practices:

> (In the beginning), I don't conclude. I don't do anything. So when the children come, I was lost. I don't know what I am supposed to do. You know, supply information or don't supply? So it's only after that, I go and think about it, then I reassure them for this term 3, you go ahead and look for the information that you think is right or wrong. I will tell you the answer later. So maybe this motivated them to really go and experience the activities that we

have designed for them and also to search for information. (interview, INSH 100826534)

Sherry, a beginning teacher, had to grapple with content, pedagogical and technological issues. She realised from the conversations with resident researchers that she had the tendency to subconsciously tell, hint, or pigeon-hole the students to provide the pre-conceived answer she had in mind. Both Sherry and her students faced transitional challenges with the change of instructional style. The change from didactic instruction to constructivist practices invited mixed reactions from the students initially. According to the interview with Sherry, some students were enthusiastic about searching more information from the mobile tool they had in their hand while others who used to be passive recipients were insecure and waiting for her to provide them with a "right" answer. Her response to such diverse demands was to give students ample room to explore but reassured them she would validate their answers at the end of every thematic topic (interview, INSH 100826539). Therefore, the constructivist use of technology was seemed to be both explicitly creating a "culture shock" for Sherry as well as supporting her transition to new pedagogic approaches.

By studying the ICT programmes undertaken during this phase, the mobile learning fieldtrips which started from a modest scale in 2001 witnessed another major milestone by 2010: the initiative had been scaled up to the whole school and incorporated into the scheme of work across all six levels. Nigel provided reasons for

the resiliency of this programme, which included the school seeing "the value of merging technology", the potential to "bring the learning of the students more alive" and gaining multiple sources of knowledge via "venues with rich resources" (interview, INNL 11082599). Other projects implemented during this phase experienced a shift from classroom-based learning to the bridging of formal and informal learning, both in and out of the classroom context to create a dynamic and seamless learning environment for the students.

During this phase, the school started to re-think about assessment strategies related to the use technology for student-centred learning. In terms of assessment, although rigidity in grading practices was evident due to the macro socio-political environment of emphasising high-stake national examinations, the school was trying to diversify its assessment modes for other less examination-critical levels. For example, in 2010, the Science department devised more open-ended and higher-order thinking questions for primary three level. There was also more room for discussion among the markers of the examination paper instead of strictly marking according to the key words in the marking scheme (meeting minutes, MM101124). However, students' work done on electronic platforms was not incorporated into the summative assessment. The reason provided by Gabriel was that equity must be observed across the whole level. Most ICT projects were still contained within two or three experimental classes per level then, thus making radical changes to summative assessment a tall order (meeting minutes, MM090429).

Another issue related to the formative assessment of students' work in electronic media was raised during one of the professional development meetings with the vice principal, HOD from Sciences department, external consultants, NIE researchers and participating teachers of the project on the use of mobile phones for learning in and out of class. The Vice-principal and the HOD were concerned that students' electronic artefacts were not monitored and misconceptions could easily go unnoticed. They felt the need for digital artefacts to be validated and mistakes rectified, as with traditional media. However, the Vice-Principal was also aware that it would be difficult to monitor and grade every single artefact submitted online. Nonetheless, she highlighted the need to engender a more watertight relationship between the mobilized curriculum and accompanying assessment strategies (fieldnotes, FNPD 091109).

Professional development during this exposition phase also became more encompassing and diversified. According to the synthesis of interviews from Terrence, Gabriel, Nigel, Shelia and Amelia, the professional development practices were more elaborate and structured during this phase, covering areas such as curriculum innovation, project discussion, instructional practices and the exploration of emerging technologies (Amelia, interview, INAM 110114163; Sheila, interview, INSL 100602955). Terrence also highlighted how FPS had worked with external partners to conduct professional development courses. Examples of courses conducted by external partners include: 1) Master-level modules such as using ICT

for inquiry learning conducted by NIE professors for the key office holders on-site (Hannah, interview, INHA 11080274); 2) Microsoft online classes which connects key office holders to IT experts (Gabriel, interview, INGB 10120990); 3) discussion on lesson co-design between teachers and researchers (fieldnotes, FNPD100301) and 4) MOE-facilitated synchronous online classes conducted for the ICT mentors of every school (Jazz, interview, INJZ 100906733). Teachers such as Janis and Jazz benefited from the professional development courses: Janis worked with the researchers to enhance her competency in student-centred facilitation (interview, INJA 100412467) and Jazz gathered useful lesson ideas from the nation-wide ICT mentorship scheme (interview, INJZ 100906752).

In terms of infrastructure, the futuristic classroom and micro Lab were established. The planning committee had gone through protracted period of careful planning when conceptualising the new space for student-centred learning. Modelled after the futuristic classroom that is showcased at the National Institute of Education, the new air-conditioned classroom boasts of portable tables and chairs that can be readily re-configured into different group formations. The school also arrived at the conclusion that for a more immersive experience, the projections should be contiguous (Gabriel, orientation for delegates, December 6, 2010, JR101206). As such, three huge screens were mounted side by side so that all students, regardless of where they sat in the room, would be able to see the projections clearly. There were ample power points that were dispersed and concealed under the floor tiles so

that students could charge their mobile equipment conveniently. To enliven the learning atmosphere, three colourful bean bags were placed at the back of the room to encourage informal exchanges.

The one-way mirror in the lab also catered to non-participant observation where observers can be unobtrusive. This is a non-standard facility in Singapore's primary school. Gabriel commented, "We know that is not an authentic classroom environment, but I guess for professional development, to observe the teachers or to try out ICT pedagogy, that environment may be able to give us a better insight." (Gabriel, interview, INGB 0911061086) Researchers and teachers can record what is going on in class from behind the mirror partition. The only drawback of the design was that the video recorders are placed too far to pick up the utterances of the students, especially during collaborative learning. This hampered the ability for both teachers and researchers to obtain a better grasp of the classroom discourse (journal record, JR101206). Both the futuristic and micro labs were heavily utilised when teachers need to conduct ICT lessons as the internet connection was more stable at the two locations (journal record, JR101019).

In 2010, as FPS planned to implement level-wide 1:1 mobile computing for all P3 classes, it added new infrastructural provisions so that individual students can charge their devices anytime. As it was logistically challenging to re-wire the cables, the school improvised by aligning the wires within the cable pipes so that they ran all

the way from the floor to the adapter located at each individual student's desk (Gabriel, presentation to Finnish delegates, December 6, 2010, JR101206). This solved the problem of device charging but presented other problems: the mobility of the students was compromised as the fixed cables restrict the students' ability to join their tables for group discussion (fieldnotes, FNLOJA 101119). FPS was aware about the problem but found it a lesser evil when compared to the non-functionality of devices (journal record, JR101206).

During this phase, the school continued to grow from strength to strength and won two large-scale national level projects under the phase of ICT Masterplan 3. One of the projects was to work with MOE to "explore, articulate and prototype usable pedagogical principles and implementation strategies for self-directed learning and collaborative learning" (ICT Connection, 2010). The other project was a four-year collaboration between MOE, Infocomm Development Authority of Singapore (IDA) and Microsoft, also to develop students' competencies in self-directed learning and collaborative learning.

In 2010, FPS reached yet another pinnacle in their ICT milestone when MOE awarded the school with the status of Centre of Excellence for ICT. As a leader in this area, FPS was tasked to lead schools in achieving the goals of Masterplan 3. To achieve this mission, FPS had pledged to enable the following: "setting up structures to harness technology to drive curriculum innovation in the schools", "developing

leaders and champions in technology planning and implementation" and "setting up a national platform for sharing of best practices" (FPS newsletter, 2010, p2).

FPS was also recognised on the global front for its innovative use of technology when Microsoft accredited it as a "mentor school", the highest accolade given to schools for developing ICT programmes that could serve as world-wide exemplars. The FPS leaders recounted that they actually applied for the status of "Pathfinder school" (entry level of the programme), but was "accelerated directly to be a mentor school due to the maturity of the school's ICT programmes" (FPS newsletter, 2010, p8).

Overall, for this phase, curriculum innovation must be anchored in pedagogical research. Due to the emphasis on pedagogical principles, Terrence had encouraged FPS teachers to work with NIE researchers for better grounding of research methodologies (Terrence, interview, INTE 110331832). There was broad consensus on using technology for student-centred learning. However, incongruence could still be observed during enactment. Didactic worksheets were still used in some instances and not all teachers were using technology to advance discussion.

Teachers also struggled to internalise new frameworks so as to translate them into instructional practices that were aligned with the philosophical underpinnings of the frameworks suggested by leaders. There was also incremental diversification in terms of formative assessment. However, drill and practice was still the dominant

strategy for preparing students for summative assessment. Professional development sessions covered wide-ranging areas to build up teachers' capacity to enact student-centred practices with technology. Teacher's involvement in ICT projects had also increased in this expositional phase. Table 4.2 shows the involvement rate of teachers in ICT projects, as of 2010.

Level	Technological tools/Rationale	Affordances of technological tool	No. of Projects/How technology is used to enhance teaching and learning	Percentage of teachers involved Per Level
P1/2	iPod Touch (access information instead of creating content)	• Personal learning tool • Contextualized learning tool • Cognitive tool	3 projects, all teacher-initiated A simple tool for lower primary students to view digital books and to play audio/video recordings.	P1 – 10 teachers, 50% P2 – 12 teachers, 60%
P3/4	Smartphone (use of smartphone allows access to information anytime, anywhere. Allows content creation through powerful suite of application)	• Personal learning tool • Contextualized learning tool • Collaboration tool • Data Collection tool • Cognitive tool	4 projects, 1 teacher-initiated; 3 research studies in collaboration with NIE A simple mobile learning tool to support extension of learning outside the school, anytime, anywhere.	P3 – 8 teachers, 47% P4 – 11 teachers, 55%
P5/6	Netbooks (prepare students for collaboration in secondary schools)	• Personal learning tool • Contextualized learning tool • Collaboration tool • Cognitive tool	2 projects, 1 teacher-initiated, 1 research study with MOE A simple computing device to support higher level learning needs of upper primary students such as collaborative learning and research on the internet.	P5 – 12 teachers, 60% P6 – 6 teachers, 25%

Table 4.2 Teacher's involvement in key ICT projects in 2010

Source: FPS documentation to support FutureSchool application

Based on the table, the high participation rate of teachers in projects, be it emanating from bottom-up or researcher-led initiatives across all levels, suggested a buoyant culture in using technology to drive curriculum innovation. Technology was positioned as a personalised, contextualised, collaborative and cognitive tool for learning.

4.2.4 Elevation Phase

In 2011, the school received the FutureSchool award, signalling its commitment to deepen the use of ICT for student-centred learning by scaling projects to the whole-school level, thus the labelling of this phase as "elevation". After becoming a FutureSchool, FPS was allowed to hire more teachers than other schools to develop pedagogically sound ICT programmes and to provide better technical support. This gave FPS more capacity to deal with the complexities of managing and coordinating the number of projects that have grown exponentially over the years. Figure 4.2 gave an overview of the timeline of key ICT-related awards that FPS had received:

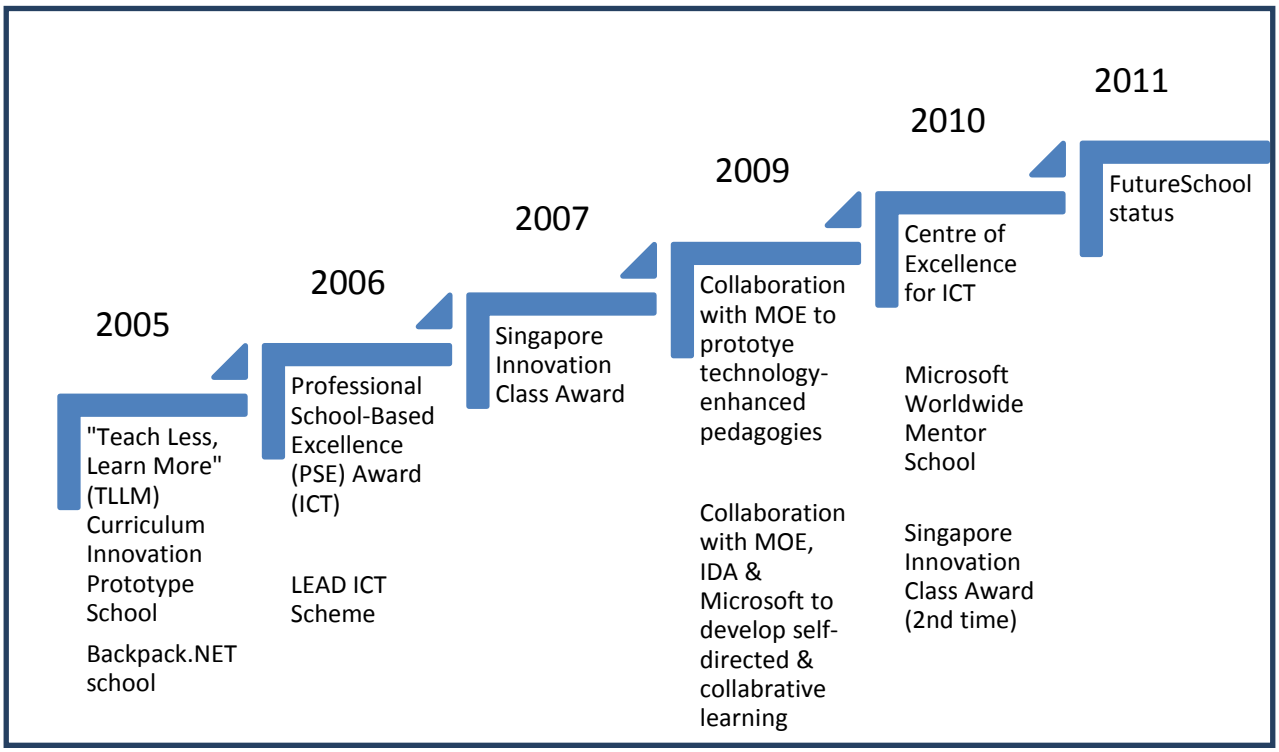

Figure 4.2 Key milestones in FPS' ICT journey

During this phase, sustaining and scaling successful innovations were of paramount importance, not only because both aspects were requirements spelt out by MOE for FutureSchools, but because it was also the belief of FPS leaders that innovations should not be episodic endeavours. This can be seen from the school's effort to successfully roll out 3 ICT programmes across different levels and 5 ICT projects across the same level (FutureSchool proposal, FSPRP 110714; presentation slides, PPFS 110216). Terrence had explicitly mentioned about the desire for and challenges of scaling up success:

> In the sense that after you have started with one or two experimental classes, are there (further) opportunities? I mean definitely with the help of research, to continue into the rest of the classes. Because to me, yes, it has benefitted one or two classes, that's one thing. But you also know it's a total different ball game to roll out to whole level and make it more pervasive because you will face another set of challenges, another set of issues……(interview, INTE 1103311355)

Terrence indicated his intention to extend the benefits of innovations beyond one or two experimental classes, and was cognisant of the demands. He sought the help of researchers to provide expertise during the scaling process. In the proposal submitted to MOE for application of FutureSchool status, FPS wrote:

> (Leaders) have adopted management systems to systematically put in place processes and forged partnership in key areas to sustain teaching and

> learning initiatives as well as to escalate capacity building efforts in curriculum design and research. (FutureSchool proposal, FSPRP 110714)

The goal of FPS during this phase is to train teachers not only to implement, but also to design lessons for ICT integration and subsequently at a more advanced stage, "re-design curriculum to extend students' learning experience in school across varying context of learning to enable learning anywhere, anytime" (FS proposal, FSPRP 110714). By 2012, more experimental teachers were able to hold their own fort and drive ICT programmes without intensive handholding from researchers. For example, Janis was able to conduct training sessions to colleagues and teachers from cluster schools on the enactment of technology-enhanced lessons, demonstrating the gradual shift of ownership from researchers to school. As Nigel remarked, one out of every three or four teachers in FPS was actively involved in ICT projects or programmes and would be ready to champion ICT initiatives (Nigel, interview, INNL 110825277).

Compared to the other three phases, the focus of development was more macro in nature: It had shifted from within-school milestones to developing prototypes for the nation. Nigel talked about how FPS' use of technology could serve as a living example for other schools, especially in terms of transcending the technology-centric perspective:

> Yes, technology will be always there, because it (FPS) is tagged with ICT but it is not just technology, it is how we want to make the school into a successful model for others to follow. And that model would include the curriculum, the pedagogy behind that is you know, driven with ICT. And we want the teachers to know that it is not all just a product of technology. It's about how we relook into the curriculum, the teaching pedagogy. (interview, INNL 110825607)

A meta-analysis of the projects undertaken during the 4 phases indicated a few trends about FPS' attempts to integrate technology into its curriculum:

1) Whilst FPS' perennial cornerstone had always been 1:1 computing, there was a shift in the emphasis of the ICT projects from enabling self-learning to nurturing self-directed and collaborative learners; and from classroom-based projects to projects that leveraged on different learning spaces. This shift could be perceived as both a top-down and bottom-up responses to the nation's changing priorities (ICT Masterplans);
2) There was "coming of age" of the ICT projects as the school entered the consolidation phase to scale up and sustain successful projects. The ICT projects had undergone constant reviews and a new lease of life was injected into promising projects so that they can be fine-tuned to benefit more students;

3) The learning objectives of the projects had become less technology centric and more contextualised and anchored in pedagogical framework;
4) As articulated by Hannah, the school's emphasis had "moved beyond motivation and engaging students to knowledge creation" (Hannah, interview, INHA 11080295);

Nigel also reflected on the changes to the usage pattern of ICT in FPS:

> And I think many schools then, many years ago weren't ready or even had the foresight to have an online environment where learning could take place. So with that, it really put in motion a lot of things. How you want to bring in technology not just into a portal but within our classroom itself. So that really kick-started a lot of things. But again, those were infrastructure issues. In time to come, we got the IP (core instructional programmes) department involved……but the IT department was still championing few of these projects. So now, we are getting them more involved by letting them take over the autonomy or the ownership of the project. Put it into their curriculum and scheme of work. So with that, we can see more synergy and integration. (interview, INNL 110825643)

Here, the emphasis of ICT integration had shifted from information structure to social structure, from piecemeal to integrated approach by having more cross-departmental fertilization of ideas accompanied by joint effort in implementation.

However, infrastructural issues seem to resurface again during this elevation phase, especially in 2011, probably due to unstable wireless connection when large cohort of students were logging in. Teachers had to resort to having mobilised lessons in the computer labs where connection was more stable, although theoretically, mobile devices should be used anywhere on campus.

In terms of instructional practices, interviews with Sheila and Amelia, both of whom had observed many lessons for the purpose of appraisal, commented that very few teachers were using ICT in a didactic manner. They emphasised that there was an elevated awareness of using ICT for constructivist practices due to the numerous professional training sessions the teachers had attended. However, Amelia interestingly noted that when teachers did not have the ICT tools with them, they tend to revert to traditional teaching (interview, INAM 11011498), thus supporting the view that technology can promote changes in pedagogic practices and expand teachers' repertoire of teaching strategies.

Insights from classroom observations seemed to be in congruence with the proposition that technology could potentially change teaching practices, especially for conducting formative assessment. Gavin, one of the participating teachers explored the use of a new language learning portal for peer learning where students were encouraged to learn from, critique and correct one another's mistakes. He consolidated learning points and shared sentence-making strategies in class based

on students' online posts, which was aligned with the notion of just-in-time feedback (lesson observation, FNGV 110826). This suggested that experimental teachers like Gavin had become increasingly aware about the importance of student agency and refrained himself from becoming "Sage on the stage".

Another breakthrough in formative assessment was the increased use of TfU framework in formative assessment (publicity poster, PHFCP1 110210) for P5 Science experimental classes. This nascent effort was considered very forward looking as the deliberate effort to allow demonstration of students' understanding was not widely practised in primary schools. This stance represented a break away from the rigidity and stability of traditional assessment.

Assessment of teachers had also gone through changes during the elevation phase. First, teachers were profiled based on the results of their self-reported surveys. It had also become mandatory for teachers to use technology during at least one of the observed lessons conducted twice a year (Nigel, interview, INNL110825257; Amelia, interview, INAM 11011481). The rubrics of appraisal revolved around tenets of student-centred skills of self-directed and collaborative learning, both of which were competencies emphasised in ICT Masterplan 3. The reporting officer would evaluate based on whether the descriptors of the skills were observable during the lesson (Nigel, interview, INNL 110825451). According to Nigel, there would be a

pre- and post-lesson conference between the teacher and reporting officer. He commented on this appraisal system:

> It gives the teacher a chance to clarify certain things, it allows the reporting officer to value add, to help improve the lesson so that on the day of the lesson observation, it is something that I would say, one of the better lessons that the teacher can offer. At the end of it, we will review and see what we have found. (interview, INNL110825467)

The new appraisal system enabled the leaders to monitor the usage of technology for student-centred learning and to also build teacher competency. This was important as the elevation phase placed greater demand for curriculum experts and the need for more sophisticated professional development system.

From the interviews with Hannah and Jazz, the benefits of nation-wide ICT mentoring scheme, which was part of MOE' s effort to enhance capacity building, had begun to cascade down to school. In FPS, the 4 designated ICT mentors would share ICT lesson ideas or organisational tools with staff every quarterly, each time lasting for 3-4 hours. Hannah commented:

> Teachers are generally busy and have no time to explore technologies. ICT mentors can explore and test out tools which can be used in the classroom. We can get ideas from friends, course mates or educational technology

officers from MOE. We will usually do internal testing first before sharing with our staff. (interview, INHA 11080228)

According to Hannah, although there was feedback that the ideas shared was feasible and useful, jam-packing the introduction of various tools in a compressed timeframe of 3-4 hours was overkill. Teachers prefer to have smaller 1:1 coaching at a slower pace. The ICT department acted on the teachers' feedback and encouraged teachers who shared similar interest to form groups of 2-5 persons. The ICT mentor can then spend one hour walking through the steps with teachers. The direction of breaking out into "mini ICT PD sessions" (Hannah, interview, INHA 11080241) showed that the professional development sessions were now more personalized than before.

Lastly, due to the emphasis on the roll-out of projects and programmes at a much wider scale, the administrative load had increased manifold. Anecdotal evidences from resident researchers revealed that the demand for ICT support staff to maintain the equipment and to troubleshoot technical problems in the classrooms had been overwhelming (journal record, JR 110330). The interview with Gavin also offered insights that middle managers had to negotiate with multiple stakeholders such as parents, researchers and commercial vendors which required nuanced skills beyond his core scope of teaching and learning (INGV 110816216).

The mapping of the ICT development trajectory of FPS over the four phases was an attempt to provide a rich historical account of what happened to the school as it harnessed technology to meet the pedagogical reform for student-centred learning. Several assertions can be made based on the school's longitudinal use of technology:

Assertion 1: Whilst there was deeper alignment between FPS' use of technology and the principles of student-centred learning over the years as a result of long-term enculturation, tensions that threatened the fidelity and adaptations of innovations did not abate correspondingly.

Over the four phases of development, there was anchoring of student-centred learning principles. This could be seen from the humanistic belief of both principals, pedagogical grounding, systemic integration for promising programmes, heightened awareness for using technology to realise constructivist practices, incremental diversification for formative assessment and grading practices and the encompassing enculturation for professional development practices. However, there were other tensions that proved to be more tenacious, such as the tensions between new instructional emphasis (e.g. TfU) and the rigidity of national examination format which called for the need to design a generic but validated instrument for evaluating students' competency across levels and subjects.

Although broad pedagogical consensus to infuse socio-constructivism as one of the important teaching strategies had been achieved, the abovementioned tensions

gave rise to incongruent internalization of pedagogical principles and the gulf between espoused and actual enactment of student-centred practices. Interactions with stakeholders were also fraught with tensions throughout the four phases. The empirical evidence that arose from FPS' case study allowed me to depart from Tong and Trinidad's (2005) view that many favourable conditions can be fulfilled and constraints be eliminated as the school advances in its ICT journey. In fact, for FPS, living with perpetual and multi-faceted tensions was part and parcel of their innovative culture.

Assertion 2: The continuous perturbations during the decade-long use of technology were discernible from the entanglements between technologies, pedagogies, learning theories and bureaucracies. These entanglements, however, could lead to the crystallisation of strategic direction.

Entanglements, which could be interpreted as a state of "becoming", were intertwined with the specificities of technologies, rise of pedagogies and learning theories as well as bureaucracies, most often experienced as logistical challenges such as top-down directives or structural rigidities of schooling. As seen in FPS' case, these entanglements could be productive as they led to the crystallisation of values and future directions. The expositions of learning and teaching framework and the strategic positioning of focusing on 1:1 mobile learning were responses to such entanglements. The introduction of these frameworks may create perturbations at first but can subsequently serve as a unifying principle for lesson planning. The

teacher's ability to enumerate the imperative of aligning their teaching practices to sound pedagogical principles during interviews was an example of common understanding shared among the diverse group.

Assertion 3: Formal leaders of FPS (Principals and HODs) tend to articulate multi-dimensional motivations for using technology whereas teachers focused primarily on pedagogical reasons. These motivations helped to sustain the fraternity's interest in using ICT in education, as manifested in how formal leaders were committed to creating conducive conditions for ICT integration and champion teachers in continuing their pedagogical innovations.

As gathered from the interviews, FPS leaders had cited a confluence of considerations in relation to the use of ICT, ranging from epistemological, ideological, instrumental and pedagogical motivations. Epistemological motivations include the belief in participatory learning and the need to expand students' sources of knowledge. Interestingly, only the two principals had made explicit references to epistemological aspect during the semi-structured interviews. Altruistic motivation refers to the belief that technology can democratise classroom participation, enable one to discover oneself and serve as living example for other aspiring schools. Instrumental reasons include chasing award, reviving students' ailing interest in particular subject areas, pragmatic utilization of resources and leveraging on the fact that the use of technology had not compromised FPS' academic results. Pedagogical motivation include the perception of seeing technology as a catalyst for changing teaching practices and an enabler for engaged, cognitive and extended

learning. The difference in outlook between leaders and teachers could perhaps be attributed to the fact that leaders have to be more encompassing in their outlook, especially in terms of internalising and justifying the use of ICT to multiple stakeholders.

These multi-dimensional motivations added as impetus for the fraternity, especially the formal leaders and champion teachers, to continue the use of ICT in teaching and learning over the decade. Based on the narratives and development history of the school outlined in this chapter, it can be established that organisational aspects have a part to play in creating conducive conditions for the prolonged use of ICT. Predicated on this assertion, the next chapter will explore the essence of these conditions in depth.

4.3 Chapter Summary

This chapter traced the trajectory of FPS' ICT development over a decade by looking at a variety of aspects: levels of usage, number of champions, motivation to use technology, instructional practices, curriculum structure, project nature and professional development design. The preponderance of evidence suggests that FPS had been using technology to promote student-centred learning, specifically in promulgating social constructivist learning, tapping on student agency and giving students more voice. Their ICT curriculum had advanced from piecemeal projects to systemic whole-school program; the evaluation of projects from a more laissez-faire

approach to a more critical examination of learning gains; scaling of projects from sporadic championing by small group of teachers to whole-school participation in curriculum-related decision making. Infrastructure provision was also increasingly sophisticated. FPS' ICT implementation departs from the five-staged implementation model suggested by Mooij and Smeets' (2001) as most of the characteristics delineated in their sequential model can be observed throughout FPS' ICT cycle, suggesting a more iterative instead of linear and successive phases of ICT implementation. Thus, I made no claims that schools need to go through the 4 phases identified in this chapter in a sequential manner for effective ICT implementation. What I had attempted to do is to foreground FPS' different locus of concern over time as it powered up the use of technology at a whole school level.

The next chapter examines how FPS has created the favourable conditions for supporting the longitudinal use of technology as well as overcome the unfavourable conditions that affect the adoption of innovations over the four phases.

Chapter 5. Findings Related to RQ2

In the preceding chapter, I discussed how FPS had used technology for student-centred learning over the decade. This chapter reports the main findings with regard to the second research question:

> **How did the school organisation create the conditions that support the sustainable use of technology for student-centred learning?**

Five themes emerged from using Saldana's (2009) codes-to-theory model for qualitative inquiry (See Figure 3.7). They are: 1) Continuous scanning of environment; 2) Multi-pronged capacity-building strategies; 3) Reconciling systemic tensions amongst stakeholders; 4) Shared accountability and 5) Prudent spread of innovation. The data emerged mainly from interviews, document analysis and personal observations that arose from my three years' of prolonged engagement with the school.

5.1 Continuous scanning of environment

5.1.1 Scanning macro policies

Over the decade, the two principals of FPS had proactively scanned the macro environment to understand the global trends and national policies governing the usage of technology. As mentioned chapter 4, the germination of FPS' ICT journey started with Carl's decision to experiment with handhelds after he was being

introduced to the idea of mobile learning in an international conference. This was a critical point as it led to FPS to becoming a champion school that experimented with mobile devices, a very forward-looking disposition which caught the attention of both media and MOE alike, leading to the receipt of funds from MOE to continue its pedagogically-sound innovations. As a result of FPS' effort in advancing the use of handheld devices, MOE wanted to recognize and brand FPS as a "handheld school" in 2005. However, Carl felt that this branding may restrict the school's choice in exploring other devices. Moreover, FPS was just about to start levelling up the use of ICT to more classes instead of the whole school, thus declined the proposition (Carl, interview, INCL 100319312; Gabriel, interview INGB 091106405). This can be perceived as FPS' contextualized response after scanning both the macro policies and the school's ecology.

Such evaluation of national policies against the school's contextual needs can also be seen during MOE's first call for FutureSchool application in May 2007. FPS, which was widely viewed as a likely candidate decided to withdraw from this application after studying the model. Gabriel described:

> On reflection, I think for a school who pull out from such a big project because they believe that that is not the way to go shows the confidence the school has…that is something we are proud of. We wanted the flexibility then. Like I say our direction is 1:1, but I feel that they are not into 1:1 then, they

> are creating resources to be commercialized. You see, it also shows that we are very focused in our direction……I must thank (Carl)…when we pulled out that time; he also agreed with our explanation and supported it. (interview, INGB 0911061427)

Such was the school's confidence in their vision that it pulled out from the first round of application despite high expectations from both internal staff members and the public for it to become a prototype school. The second round of application focused more on the scaling of innovation within and across schools. Said Gabriel during the interview which took place in 2010 before the second call of application:

> We are working towards the next round because we believe the next round will be more aligned with our belief and we will embark on it. We still believe that it's our mission to deliver answer for MOE on 1:1 computing for primary schools. (interview, INGB 0911061456)

Thus, the school gave up the opportunity of acquiring more funds after mulling over the possible outcomes and patiently waited for the right alignment of conditions to appear.

Terrence also critiqued the current situation of international political economies, highlighting the vulnerabilities of Singapore as a small and open economy and the interconnectedness of the global system. Initially a sceptic about the use of ICT in

education, he became more convinced about the role technology can play in preparing the students for their future in the light of global emphasis on ICT skills in a knowledge-based economy (Terrence, interview, INTE 110331360). Such environmental scanning is akin to discovering possible blind spots leading to changed mindset and informed practices. In drawing up the policy paper of ICT development, FPS aligned its plans with national priorities such as anticipating human resource needs and building a resilient society with responsible citizens (policy paper, PP090428).

5.1.2 Scanning pedagogical developments and scholarly literature

Terrence also discussed contemporary theories that inspired and influenced his practices. He read extensively about the developments in ICT, learning theories and pedagogies as well as school improvements. He also connected himself with experts in the educational field to find out more about the purposive use of technologies. He elaborated how his literature scan had helped him shape the cornerstone philosophy of FPS:

> One is, you know, about what are critical success factor that sustain school improvement? And some of the articles I have gone through are actually meta-analysis of many studies that people have done……so from there, they list 14 to 20 important factors……NIE also invited Professor Viviane Robinson from University of Auckland during one of the curriculum forum to talk to us.

> And again she also shared what are the critical aspects…… I try to marry all these (teachers' inputs and literature) together, and that's how I come up with the 3 critical rules. (interview, INTE 1103311257)

Terrence elaborated that he often receives epiphanies through readings and would enthusiastically share them with his colleagues. During the interviews, he also recounted how important books had shaped his educational philosophy and made him re-think about the values of education (interview, INTE 110331923; 110331923451).

5.1.3 Scanning technological environment

Scanning the technological landscape is another vital part of the system. This was done collectively by the principals, IT HOD and the IT department staff members. Teachers' feedback, if any, was also taken into account. As an example, Shelia suggested to the IT department that the new handhelds should come with camera functions to facilitate data collection and this requirement was incorporated into next round's purchase (Sheila, interview, INSL 100602326). In deciding which mobile devices the school should get for specific projects, the school scanned the technologies for 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 and compatibility with students' own tools such as mobile phones

(Gabriel, interview, INGB 101129580). These suggested the adoption of systemic considerations in terms of procuring devices.

The school's upper management also went on overseas study trips to understand how technology was used in other educational contexts. Most notably, the trip to US in 2005 culminated in the realisation that there was no ready model to emulate as FPS was experimenting way ahead of its overseas counterparts in terms of using technology at the school level (Gabriel, interview, INGB 091106183). More recently in 2011, the trip to Microsoft Research Centre, Asia, Beijing to explore the use of their existing text-to-voice technologies led to the cementation of partnerships between the school and the research centre as FPS had the interntion to incorporate their technology into the school's language learning portal (Gavin, interview, INGV 11081678).

However, FPS' leaders' technology deployment was confounded by the conundrum of technology depreciation. As product cycles became shorter, FPS was caught in the situation of procuring obsolete equipment, knowing that the newer version of technology was to be released in the near horizon. One of the resident researchers at FPS puts it, "scaling up is challenging in the face of rapid change of technology, especially for mobile devices because it is the fastest evolving technology right now" (journal record, JR120716). Adding to the complexity is the double-edged nature of commercial partnership, where the selection of technological tools tends to be

skewed towards what partners could offer to avoid jeopardizing the relationship (journal record, JR120716). All these multi-level considerations could delay the whole decision-making process and the pace of scaling.

5.1.4 Scanning for strategic partnerships

Terrence highlighted the unique traits of FPS to forge collaborations with potential partners:

> I feel that the typical school structure in Singapore or even anywhere else is not prepared to collaborate with people. A lot depends on the principal, very frankly, to want to make that connection. There's no inherent structure within our system for schools to actually do that. The leadership must be convinced of the value. And it's always up to the leadership to make that effort to want to connect to people. And I mean we can't blame schools because there are so many things to do in school and the desire to collaborate with other people is often the last priority, but to me, I take a slightly different view to them. (interview, INTE 110331767)

Terrence placed a lot of value on partnership as he felt that when technology was involved, the issues were multi-faceted and the school cannot "walk the journey alone" (interview, INTE 110331815). Gabriel also attested to the distinctive value FPS placed on partnership even during his predecessor's time in 2003. During the early

years, FPS' collaborative partners were diversified, ranging from technical partners, researchers to peripheral sponsors who provided food items during students' fieldtrips. When Gabriel took over the helm as IT HOD, he felt that he should re-scan and streamline the list to maintain collaborations with selective partners whom he believed will "add value and create direct impact on teaching and learning". Gabriel noted the benefits of a streamlined coalition:

> While the list of names is smaller, we are closer. We share a common belief, or at least a shared direction on where to go, that is, to improve education. We want to go towards education. (interview, INGB 0911061357)

As a result, the nature of alliance had become more sophisticated. Ad-hoc collaborations were de-emphasised so that the school can expend more energy on building long-standing relationships with partners that can provide niche expertise to complement the school's strengths. The current list of partners comprised technical and research partners from institutes of higher learning whom Gabriel believed would be able to provide advice to the array of ICT projects. Carl, the principal then gave Gabriel the support to pursue the new direction of partnership. During Terrence's stewardship, more strategic partnerships were cemented. Memorandums of understanding (MOUs) were signed with research and commercial partners for more formalized and long-term collaboration.

Within FPS, there was also constant scanning of personnel in attempts to form strategic alliances. For example, before moving to FPS, Terrence was the Vice-Principal of another reputable primary school which also had strong emphasis on Chinese culture. He had to be interviewed by both the MOE and the Clan Association to ensure that he would continue to promote the Chinese tradition before the new posting was cast in stone. This measure was designed to ensure the continued growth of the school and a common vision. Gabriel noted that both principals share the same philosophy of exploring 1:1 computing and are "visionaries in their own right" (interview, INGB 0911061136), with Carl knowing the right opportunity to act and Terrence knowing how to implement the reforms that the school has envisaged. He remarked that he was thankful that the school "always get the right people" (interview, INGB 0911061498).

The scanning of environment had enabled FPS to set the strategic directions for its ICT development. Connecting to experts, understanding socio-political trends, making systemic evaluations regarding technology, assessing contextual readiness all add to create a better sense of mission in the usage of technology and attest to the fact that students' learning processes and outcomes were at the heart of decisions. The next section detailed the capacity building strategies of FPS.

5.2 Multi-pronged capacity-building strategies

FPS had adopted an elaborate multi-pronged approach to build the capacity of

teachers to use technology effectively for student-centred learning. The four strategies are to: 1) work with research partners to develop teachers as researchers, 2) foster innovation culture; 3) identify teachers' PD needs and 4) create a mechanism for reflexivity.

5.2.1 Developing teacher-researchers

Terrence had shown commitment towards developing teachers as researchers and had incorporated this goal as one of the expectations for FPS teachers. He elucidated that being a teacher-researcher was not about being adept at conducting formal studies or publishing academic papers, but to perpetually read, search and "re-search" for better and more effective ways of teaching and learning (interview, INTE 110331861). As part of his effort to develop teachers' capacity in research, he established an in-house research centre in collaboration with NIE to sustain school-based research, setting a precedent for other primary schools. The strategic coalition also ensured that the formal studies conducted in the school would not be episodic in nature but deepen over time with many spin-off projects involving more teacher-researchers, thus building up a critical mass of champions (Terrence, interview, INTE 110331304). The school also engaged internationally renowned consultants in 1:1 mobile learning field to conduct workshops and give keynote speeches to both FPS and cluster schools, thereby providing teachers with another avenue to widen their horizon (policy paper, PP090428).

5.2.2 Fostering innovation culture

The literature review suggests that to achieve sustainable improvement, schools would have to live with uncertainty. During the period of 2005-2007, the school focused mainly on their mobile fieldtrip programme and did not actively explore other models. Gabriel perceived this as the "complacent stage of hitting a plateau" and therefore the need to "renew practices" (Gabriel, interview, INGB0911061111). Terrence also demonstrated the thinking that a school needs to be "messy" if it wants to develop a culture for innovation:

> Innovation cannot be so neat and tidy. Sometimes when I see, out of the messiness, the important thing is how then do we sieve the more implementable innovation versus those that we may not be ready yet and plug into the school system. (interview, INTE 110331897)

What could be inferred here is that FPS leaders were not averse to "messiness" and "untidiness" that accompany innovation. To Terrence, the more pressing need is to match the feasibility of ideas to the existing capacity of the school.

Gabriel also recounted the type of "messiness" associated with early years of experimenting with technology. Technical glitches happened during several high profile lesson demonstrations conducted by HODs:

> Yes, they (HODs) did the innovation with the teachers. And they actually showcased their lesson. So some of the lessons actually failed. The HOD was

> doing the demo but the message at that time was: Look, it's alright to fail because HOD failed as well and they were not ashamed of it. And the most important thing was that they went back and see what was wrong and they tried again. (Gabriel, interview, INGB 091106240)

To encourage the uptake of technology integration, the upper management of FPS acted as vanguards and instilled confidence in teachers during the embarkation journey. Shelia, one of the pioneer teachers and middle manager recalled the insecurities she had when did not see expected outcomes in the initial phase of innovation. Carl, the principal then told Shelia to be more patient as the students could be adjusting to the new way of learning. Shelia persevered and the efforts paid off as children were engaged and displayed depth in their deliverables by the time the intervention ended (Shelia, interview, INSL 100602159). The accounts suggested that a tolerant and patient culture for accepting "failures" and awaiting results could create psychological safety for innovations.

In Chapter 4, I mentioned that FPS was awarded twice by national accreditation bodies for fostering innovation culture. Nigel attributed FPS' success in sustaining the use of ICT for student-centred learning to this deeply entrenched culture and mechanism for innovation put in place since 2003:

> Project group creation adopts both a centralised and de-centralised approach. Centrally, school leaders have key school projects so groups are

> formed to work on those projects. Also, in departments, KPs (key personnel) see if there are areas of concern that require teachers to work on as a project. Those teachers not down through the central approach will form their own groups (de-centralised). This is then subject to school's approval. (member checking, INNL MC120327)

Amelia also noted FPS' unique emphasis on innovation. She highlighted that for other schools which would like to replicate FPS' success, the critical thing would be to structure time for innovation:

> In other schools, innovation time is ad-hoc. Here in FPS, all teachers have to be involved in projects and the meeting is scheduled into their calendar. They are divided into many small groups and in each mini group, there will be one activist who will lead the project. The accommodation for innovation time is more of top-down approach in FPS and at one time, there could be as many as 10-20 projects going on. (interview, INAM 110114216)

What Amelia highlighted was that the school leaders need to create the conditions for innovation by institutionalising innovation time into teachers' schedule. For example, on a monthly basis, there are 4 sessions of one-hourly contact time, a standard feature for all schools in Singapore for the principal to disseminate information or for the teaching fraternity to conduct professional development matters. Terrence went a step ahead and gave up two sessions of his contact time

so that the teachers could use one hour per month on innovation projects and another one hour of white space to form learning circles to discuss issues related to teaching and learning with colleagues teaching the same level. Terrence emphasised:

> I always want to free up a certain portion of my staff's time and we put in the space, we create the space, we create the structures to free them, to be able to innovate. (interview, INTE 110331846)

In addition, on a termly basis, there is a Staff Learning Day scheduled during the one-week school holiday for teachers to attend workshops and finally, on a yearly basis, teachers convene to share findings of innovation projects. This are ways to foster the culture of innovation without creating extra load on the teachers who already found it hard to squeeze time for additional discussion (Terrence, interview, INTE 110331876). These measures undertaken are in congruent with Hazy et al.'s (2007) call for formal leaders to "enact formal organizational policies and processes for emergence and self-organisation to happen" (p95).

FPS also rewarded experimental teachers who invested their time and energy in the various ICT projects as they are "creating new value in teaching and learning" (Terrence, interview, INTE 110331614). They had to grapple with the design of curriculum, gain proficiency in technology and implement classroom management strategies, thus incentivizing the process (Terrence, interview, INTE 110331612)

would be necessary. Janis, a teacher involved in a challenging two-year research project, was promoted to the subject head of ICT programmes towards the end of the intervention. She had evolved from a teacher unfamiliar with student-centred facilitation to a mentor adept in designing mobilized curriculum (meeting minutes, MM100305). Thus, the school sent a strong signal that hard work would be rewarded. Gabriel mentioned that teachers who contributed indirectly by offloading their colleague's workload were also recognized as they made the journey possible while their colleagues were trying to find the "answers" (Gabriel, interview, INGB 0911061020). This helped in spreading innovation as recognized teachers would become more empowered, motivated and confident to mentor other colleagues and continue to spearhead more projects.

5.2.3 Identifying PD needs

FPS had an elaborate structure for identifying teachers' PD needs. Teachers were carefully profiled and a corresponding capacity building plan was mapped out to help teachers build up their competencies.

Table 5.1 shows the relationship between teachers' profile and the school's devised capacity-building plan for teachers. In particular, it showed how the school valued the development of human capital by thinking through possible progression paths that teachers could embark to upgrade themselves. Teachers were divided into 4 levels according to dual-track criteria: competency in action research and

knowledge in integrating ICT into lessons. The bases of profiling were derived from teachers' self-reported survey results. Data compiled by FPS showed that only 7% of FPS the teachers were not trained in action research and of the 93% of who were trained, 38% participated in action research indirectly by being a member of innovation teams, 37% were experimental teachers of action research projects which they initiated and another 18% actually partnered with researchers from institutes of higher learning or MOE to conduct formal studies.

Profiling	Capacity building plan
Level 1 Beginning teachers/ Affirmed teachers not trained in Action Research (AR) and need basic ICT skills.	• Conduct ICT-enabled lessons (Peer observation, mentorship by senior teachers) • Use of available software & hardware
Level 2 Affirmed teachers who are trained in AR and can use ICT in Teaching and Learning (T&L) sometimes.	• Involvement in innovation teams to improve current classroom practices (Learning Circles, InnoWits) • Use of IQC (International Quality Circle) tools to evaluate effectiveness of ICT-enabled lessons
Level 3 Affirmed Teachers who are competent in AR and can use ICT in T&L most of the times.	• Conduct of research studies on ICT-enabled curriculum and pedagogies • Translation of research findings in the classroom
Level 4 Affirmed Teachers who partnered researchers in studies or wish to pursue higher qualifications in the area of educational technology and can effectively integrate ICT in T&L.	• Research-based programmes and teaching modules for the Masters Programme • Translation of research findings in the classroom

Table 5.1 Profiling and capacity building plans for FPS teachers

(Source: FPS, 2011, proposal to support application of FutureSchool status, FSPRP 110714)

As for ICT skills, only 4% of the teachers need intensive handholding and at the top of pinnacle, 11% of teachers had sophisticated skills in integrating lessons effectively (FPS, 2011, proposal for FutureSchool application, FSPRP 110714). According to

Amelia, the undergirding principle of this school-wide profiling was to ensure that all teachers gain the competency to evaluate their ICT lessons and constantly upgrade themselves (Amelia, interview, INAM 110114112).

In Amelia's words, Terrence had "left no stone unturned" in terms of putting in place a systemic structure. But her concern was how to spin off from the current stage. Having a structure may not be enough, as progress need to be monitored too. She felt that some of the one-off professional development sessions that the teachers had attended may not create the multiplier effect as envisaged as these were akin to fleeting touch-and-go moments which were of limited help in terms of internalising espoused practices. She suggested more on-going hands-on opportunities for the staff members to design, enact and reflect on the ICT lessons. The efficacies of the training sessions should be tracked more robustly to enhance FPS' capacity-building competencies (interview, INAM 11011451).

Nigel also pointed out that the capacity building structure in FPS was appropriate but its success could be hampered by many issues. He provided a metaphorical description:

> If a teacher has a certain readiness and has the right mindset, then I think the plant will grow very well, the seeds are there. You know, it's optimized for growth. But of course if the mindset is not there, synergy is not there, of

> course you know the plant will not grow very well. Takes a whole lot of communication and stuff like that. (interview, INNL 110825221)

In other words, the readiness, mindset, synergy and communication pattern of the group all played a role in the viability of professional development sessions.

Figure 5.1 shows the dynamics of the taskforce that was selected to create a new "mobilised" learning package that involved the routine use of smartphones in cross-disciplinary curriculum. The figure shows that when actors in the taskforces had no direct stake in the project but were brought in to co-design lessons in the name of cross-subject integration, their level of disengagement can be high (meeting minutes, MM090826, MM090923, MM100331, MM100707; journal record, JR100705). Janis explained how earlier attempts to integrate all subjects during weekly learning circles "failed":

> Initially when they wanted integration for English, Maths and Science, each of us will actually play a big role, but then now I think it comes to a point whereby English and Maths teachers will deploy and write the science curriculum. So it's sort of made them wondered why am I writing the science curriculum? You know that mentality? And we do not want this to happen because we want them to know that actually all the subjects are equally important. (interview, INJA 100412756)

With displeasure of playing the second fiddle building up, the participating teachers eventually voiced their opinion to the upper management and conveyed their wish to exit from this particular professional development programme. Janis added:

> The management asked the teachers how are things going on and they provided feedback on this and I think the management also felt maybe this shouldn't be the case, so they decided to actually conduct (the sessions) separately (for different subjects) . (interview, INJA 100412773)

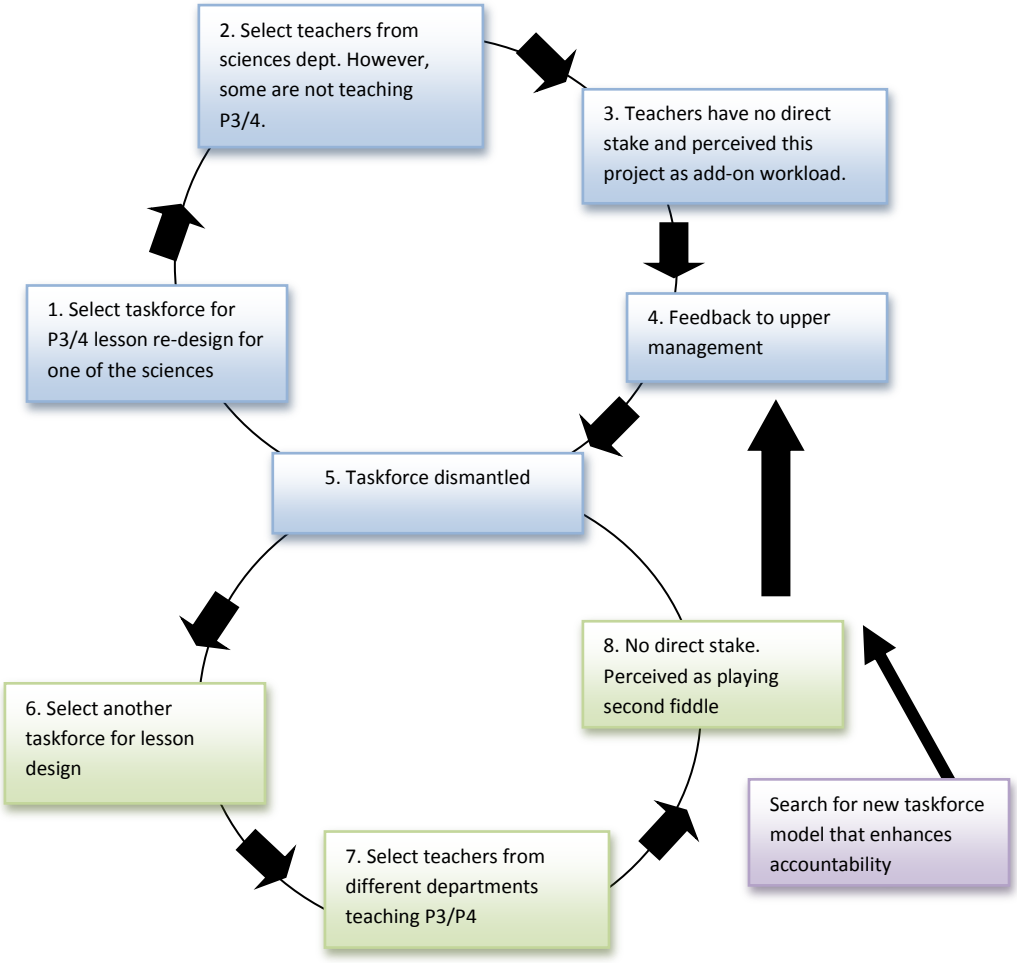

Figure 5.1 Feedback loop on taskforce configuration

Both leaders and teachers learned to respond more intelligently to the situation through iterative corrections and the results of local interactions. The management learnt that it would be an imperative to identify both the participating teachers for pilot studies and the teachers who would be running the programme right before the intervention so that teachers can feel a sense of belonging and the pragmatic need to be involved (meeting minutes, MM100707). By exemplifying what worked and what did not, successful projects can take a foothold in the school and be refined over the years in a logical fashion, as seen in Fullan's (2009) call for organisation to be clear about what works at all levels of the system.

Lastly, Nigel summed up the essential conditions for capacity building. These include the need to focus on: 1) developing role models to create blueprints through mistakes and successes; 2) perpetually raising the bar for forerunners; 3) ensuring the void left by teachers who had moved on to forerunners were filled up by initially reluctant but now interested teachers; 4) continuing to refine the PD structure and 5) empowering middle managers (interview, INNL 110825240).

5.2.4 Mechanism for reflexivity

Forming the backbone of capacity building model was FPS' ability to put in place a systemic mechanism for reflexivity through providing platforms for discussions. However, being cautious about the fact that unstructured discussion may not be

purposeful, Terrence wanted these discussions to be imbued with "more purposeful creativity" (INTE 110331925). Therefore, other than the white space, the rest of the sessions were more structured. They were anchored in the methodology of action research. Gabriel explained the rationale:

> We insist that everybody has to do research because we want the rigour. We want the teachers to go through the rigour of constantly reviewing their lessons, improving their lessons, rather than investigating certain areas. (interview, INGB 091106251)

The findings of RQ1 suggested that the school had advanced from merely using AR as a guide for implementing projects to incorporating more sophisticated theoretical framework such as TfU to frame their research study.

The "whitespace" constituted another important platform for collective reflexivity. According to Amelia, the teachers were most vocal during white spaces as teachers teaching the same subject at the same level would come together to discuss pertinent issues faced. The group was small and thus the climate was more conducive for in-depth discussion. As the school culture encouraged transparency, any concerns about the on-going projects would be openly discussed during the meetings to collectively decide how additional support could be given (Amelia, interview, INAM110114530). Jazz attested to the importance of the whitespace as a platform for fleshing out ambiguities, displeasures and epiphanies:

> During whitespaces, one of the teachers shared how she addressed children's misconception……Her children managed to share, research more on whatever things that she's doing in class. We hear a lot of positive accounts from her compared to before she started out. She actually was very sceptical and said: "huh a lot of time wasted, you know, got to do this (X3), my class is very big you know, I don't think I can implement this". But after she came on board, it seems like I don't hear so much complaints from her, but it's more like oh my class did this this this, I did this this this with my class. You know my children do this. I can sense a lot of positiveness from her. (interview, INJZ 100906401)

Based on the synthesis of interview data and observational fieldnotes, the whitespace served as an intimate space for teachers to make frank exchanges about their apprehension and aspirations. There was veracity in the teachers' opinion about the use of various technologies, which encouraged critical reflections.

The reflexivity mechanism also includes Terrence's meetings with the planning committee which are developmental in nature. He made use of the opportunities to share with the key personnel articles that inspired him. These were usually case studies and he would invite the team to share the rationale of the actions taken. He wanted to socially construct the meaning of actions taken, rather than simply disseminating articles via email. This measure inevitably meant that the team would

spend a lot of time "talking" and these "talks" were supposed to enculturate the planning committee to make decisions, especially during Terrence's absence (Terrence, interview, INTE 1103311558).

Overall, every interviewee agreed that the school had given a lot of support to help staff integrate ICT into their lessons. As an example, Gavin stressed that the avenues to pick up ICT skills were aplenty and he felt it would be unacceptable if a teacher in FPS were to say he/she had no idea about how to use technology at all (interview, INGV 110816196). Even Han, the ex-middle manager who was critical about the school's use of ICT, shared mutual sentiments on the wide array of professional development opportunities available (INHN 110531P2810). According to the data that emerged from an anonymous internal survey conducted by FPS, 85% of the teachers in FPS agreed that the school had an effective staff development programme for capacity building and 95% agreed on the effectiveness of the school's teaching and learning framework in developing 21st century skills. All these spoke very favourably of FPS' multi-pronged capacity building approaches.

5.3 Mitigating systemic tensions amongst stakeholders

In chapter 4, I mentioned the multi-faceted tensions of using ICT during the 4 phases of development. This section focused on the systemic tensions amongst stakeholders and can be summarized as tensions between research, practice,

industry and bureaucracies. The first part of this section explores the sources of followed by delineating the leadership practices in reconciling these tensions.

5.3.1 Sources of tensions

5.3.1.1 Mismatched expectations between researchers and practitioners

The first source of tension pertained mainly to the mismatched expectations between researchers (in particular the academics from NIE) and practitioners (the leaders and teachers from FPS). These tensions stemmed from several factors such as: 1) inadequate communications of research protocols; 2) shortfall of results; 3) lack of common language; 4) time pressure and 5) pace of shift in ownership.

Tensions that arose from inadequate communication of research protocols include the need to seek both experimental and control groups to ensure the robustness of research findings related to the learning gains of specific interventions. However, the practice of finding control groups at times placed the teachers of these classes in a defensive mode, as their practices may be perceived as inferior compared to the experimental classes that were getting interventionist support from the researchers. Experimental teachers who were in the process of transforming their teaching practices also experienced tensions initially when their teaching were deemed not student-centred enough by researchers. In addition, researchers often require quantitative analysis of examination results across the whole cohort, which may be

deemed as confidential data by the school management (meeting minutes, MM090826, interview, Gabriel, INGB 101129386). Gabriel also expressed disappointment over experimental classes' performance as despite investing hefty resources and time into the project, these students did not make it to the top 10% of the cohort during one of the intervention years. He attributed the shortfall to a change in research focus and interventionist strategies (Gabriel, interview, INGB101129399). Gabriel also felt that there was "a divorce" between the intentionality of school and researchers. In particular, he thought the researchers were prescribing what was right and failed to take into account the school's perspective (journal record, JR 100705).

There was also feedback from teachers that some of the professional development sessions conducted by researchers were too demanding, either because intensive participation was required of them or that those sessions were perceived to be laden with too many academic lexicons which the teachers or administrators found abstract for laymen's comprehension. Gabriel explicitly mentioned: "Sometimes we don't really understand you all and need more time to digest" (interview, INGB 0911061026).

Time pressure constituted another source of tension as experimental teachers need more time to enact the student-centred curriculum while having to complete the same prescribed scheme of work as other non-experimental teachers. For example,

Janis had to meet the inter-departmental goals of various HODs and requirements of the research team, which were "not fundamentally compatible" (meeting minutes, MM 090429, MM090826).

Researchers and practitioners also have different expectations about the pace of ownership shift. For FPS, Terrence would like the researchers to continue to assist with the scaling up of projects. However, he was also mindful about the need to strike a balance and avoid being too dependent on partners, which could undermine the school's ability to build up real capacity to take over the ownership of projects in the longer term (interview, INTE 110331791).

5.3.1.2 Conflict between ideology and reality

In FPS, all key personnel believe that the appropriate use of technology can enhance learning but not every key personnel supported the essential use of technology in classrooms. For example, the HOD from the Sciences department queried the benefits of the routine use of technology in class (fieldnotes, FNPD 101109). Her concern was that such practices could destabilise work progress and jeopardise results. Teachers usually need at least two periods (one hour) for meaningful discourse to take place. This placed tremendous pressure on the existing structural constraints of fixed time-tabled periods. Moreover, staff members who were advocating drill and practice methods found little value in co-designing lessons

with researchers (journal record, JR100705; meeting minutes, MM100331; MM100707).

In one of the "white space" meetings which I had attended, the teachers were raising concerns about the implementation of an across-the-board mobilised curriculum which had been successfully piloted in one of the experimental classes in the previous year. The non-experimental teachers thought they were ill-prepared to use the device and were not convinced that the students, especially those from lower-ability classes, would be able to follow the demanding curriculum. They were also apprehensive about the trade-off in the time used for mobilised lessons and the time needed to complete the mandated drill-and-practice worksheets (fieldnotes FNWS 100401; meeting minutes, MM090225).

5.3.1.3 Incompatibilities undergirding the education-research-industry partnership

To sustain the use of ICT for large cohort of students, FPS leaders need to be more resourceful and nuanced in their negotiation with telecommunications companies (telcos) for subscription of data plans, technology partners for procurement of devices, parents on the rationale of using technology and intellectual partners on issues related to intellectual ownership. There were also constraints around how money could be spent and how tenders should be awarded, making the whole process a very challenging affair. For example, the protracted negotiation with

several telcos that took place in the later half of 2011 affected the progress of research projects as the stakeholders (school, telcos and NIE) need time to clear the red tape (emails, EM110520). The selection, procurement and delivery of mobile devices for the project were also delayed. Confounding the problem was that the teachers involved in those projects were not able to accomplish much while waiting for the resources to arrive, thus affecting their morale. Communication with vendors also proved to be exigent as design-based research often surfaced emergent user requirements and vendors would only incorporate them in the next round of development cycle by increasing development costs (meeting minutes, MM120220). These incidents exposed the underlying vulnerabilities in the procurement system (journal record, JR 110330) and the misalignment between hardware, funds and human resources (journal record, JR100707).

5.3.2 Dealing with tensions

Due to the complexity of the issues, it was not possible to eradicate the tensions but there were attempts to mitigate these problems. These include maintaining a climate of openness, unifying competing agendas and ensuring alignment of resources.

5.3.2.1 Climate of openness

Although FPS faced pressure to perform as an ICT prototype school, the school had managed to nurture an open climate for experimentation without using iron-fisted

measures to ensure compliance. The school embraced heterogeneous views and abilities, used soft persuasion, ensured transparency and practiced non-egocentric leadership.

Amelia, who just joined FPS three years ago, appreciated the open climate and strong leadership she experienced here. Coming from a previous school where she perceived leadership to be elusive, she did not take FPS' open climate for granted. She felt that although there was an imperative to get more buy-in, the school did not exert top-down pressure for these changes to take place. The school was receptive to different views. For example, Terrence respected the independent mindedness of the Sciences HOD whom can serve to check his thinking (interview, INTE 1103311437). In a similar vein, Gabriel also asserted:

> For the change to occur, we need these people. If everybody buys in, you will be very worried if you make the transition properly or not. Whenever these people stand up and say "No" to our programme, we will go up and ask them..not so much as to challenge them you know but to find out what is their underlying fear…the thing they are not comfortable with…and from there, only when we can settle this, we can know that we are slowly paving the building blocks. You have to embrace these people. If you are serious about change, you have to embrace them. These are the ones…they are like your checks and balances. (interview, INGB0911061556)

From the above, we can infer that the school valued the views of dissidents and welcomed the confluence of thoughts to ensure a more robust and critical reflection on the use of technology. Gabriel added:

> I think these people have an important role to play, if not more important. You cannot go too far and run ahead and forget your building blocks. Because at the end of the day, this is about sustainability and it is only when you arrest these fears that you have that sustainability. (interview, INGB 0911061578)

Herein, Gabriel had suggested that the "naysayers" played a vital role in enhancing the sustainability of the ICT programmes. To him, soft persuasion, embracing contrary views and paving building blocks were keys to long term success. Changes should be introduced in an evolutionary, rather than revolutionary manner so as to include everyone in the reforms. FPS maintained the position that no teachers would be penalized because they held different views towards technology integration. This principle of inclusiveness was also adopted during Carl's time. He would not impose projects on teachers "who do not want to be converted" (interview, INCL 100319281). In his language, he always looked for "ready converts" who have exhibited readiness and willingness to lead projects. For those who were not ready, Carl would appreciate whatever baby steps they could take. He said:

> There was never any fear put into anybody that we are doing ICT you know, and if you don't do ICT, we don't want you. We never make anybody feel that way. (interview, INCL 100319382)

Leaders such as Carl empathised with the sceptics as using technology intensively required a great leap of faith (Carl, interview, INCL 100319411). FPS, therefore, to date, had chosen to use soft persuasion and focused more on informal sharing of exemplars through the numerous sharing platforms that the school had created (Terrence, interview, INTE 110331609; Carl, INCL 100319391).

Another form of soft persuasion manifested in the form of non-egocentric leadership. For example, Gabriel displayed such disposition during an observation of a PD session which was conducted to examine the outcomes of an on-going project. When the vice-principal sought evidence of learning benefits of the project which his subordinate (Janis) participated, Gabriel explicitly mentioned that her experimental class (mid-ability) outshone his control class which comprised high-ability students, even though this may portray his own teaching ability in a negative light. Many middle managers were also not afraid of "failing" when championing new initiatives. Such non-egocentric leadership is important in a research-based school such as FPS as any subtle conflicts in interest or power issues could be abated if the leaders adopt an open-minded attitude and allow subordinates to excel.

Soft persuasion was also evident by examining the power dynamics of the school. According to the resident researchers, the power of influence at FPS appeared to be centred on the notion of friendship. If the middle managers were perceived as 'friends" by the teachers, they would be more willing to expedite the necessary changes (journal record, JR 100707). This gave the middle managers a lot of room to exercise their soft power, but it could also be a double-edged sword. One of the middle managers was a little concerned that her popularity will drop if she were to exert more pressure on the teachers even though that may be a necessary evil, especially during the elevation phase. The middle managers thus were in the predicament of ensuring teachers could deliver but at the same time, trapped in the school ethos where they could only patiently change mindsets. This is similar to Leithwood et al.'s (2009b) notion of a leader who needs to possess both expertise and prototypicality to earn trust and shorten the buy-in time of the teachers but not to be trapped in group think.

Besides using soft persuasion, ensuring the transparency of data collection methods also formed a vital part of psychological safety. Amelia stressed that since FPS is a research-based school, the leaders need to create trust by ensuring transparency in how the data will be dealt with. According to her, leaders had so far, emphasised that the videos of ICT lesson observations were created solely for them and the record would be deleted by the technician a few months later (interview, INAM 110114587). This helped in giving teachers the assurance that the videos were not a

form of surveillance or appraisal tool but a reflective tool which they could use to improve their teaching. Teachers could also be involved in data analysis to have a clearer idea of how the data are being used. Amelia remarked that it would be important for leaders to "to stay true to their words" regarding transparency to "avoid spreading fears" (interview, INAM 110114123).

5.3.2.2 Unifying competing agendas

In the preceding section, I mentioned the multi-faceted nature of tensions such as discrepancy between actual and espoused usage of technologies, researchers' protocols, HODs' priority of guarding results and commercial firms' profit-maximizing motives. Terrence had to deal with these conflicts frequently and coordinate the competing demands. He articulated his philosophy:

> At the end of the day I feel that we got to be very clear what the overarching goals are. We are not a R&D centre, we are very clear. We don't do research, we don't collaborate with researchers because we want to publish paper, we want to come up with a product… And there is something about the ways we align our people. We work with researchers because we want to try out new methods of teaching and learning. But at the same time, we also want to learn from our partners, what is that about? And if we see value in that new thing being applied in our curriculum, let's do it. If not, let's tweak it a little bit, to see whether it works. (interview, INTE 110331832)

Thus, adding value to teaching and learning was the yardstick used for unifying different stakeholders. Nigel also attested to the fact that Terrence was able to articulate the shared agenda effectively when working with different stakeholders:

> When we have agreed on that shared agenda and always make it as a point of reference, many things can move forward because the moment that is not made clear to the different parties, then we are going in different directions. And when that happens, it's going to be challenging and tiring to bring them back, to tell them again why we are here. So it takes a strong head to do that. I think (Terrence) is able to do it quite well so far. (interview, INNL 110825697)

Gavin also added that there were times where intricate negotiations entailed more inter-meshing of responsibilities. As an example, working with commercial vendor on the roll-out of new portal required inputs from the subject department, ICT department and NIE researchers on issues related to infrastructural demands, tender bidding, contract crafting, demarcation of intellectual property rights, user requirements and pedagogical design (interview, INGV 110816226). Thus, the early involvement of all stakeholders is crucial in mitigating conflicts in the process.

One interesting remark Terrence mentioned during interview was: "As a principal, I cannot offend people." (INTE 1103311448) Indeed, true to his word, Terrence did employ a lot of diplomacy, evident from his emails and face-to-face communications with different stakeholders. His style was assertive but non-

confrontational. However, that would also mean more time would be needed to mitigate the deadlocks that appear during negotiations, especially internally (journal record JR 110707). Examples of strategies which FPS leaders used to circumvent the deadlocks with internal stakeholders include: 1) entrusting the ICT department to roll out programmes in the interim until the respective instructional departments were ready to do so (Gabriel, interview, INGB 091106313; Nigel, interview, INNL 110825315); 2) having middle managers of the respective departments to act as enablers and conduits to motivate departmental colleagues and to keep the HODs and principal in the loop about project progress (journal record, JR100707).

The HODs in general supported the participating teachers by giving them the latitude to innovate within bounded limits, using the sustainability of students' results as a "psychological baseline" that must be met (meeting minutes, MM100305; email, EM091003). The school adopted a twin strategy where HODs would be the last line of defence to guard performance while middle managers would be the drivers of ICT projects (Nigel, interview, INNL 110825327; Amelia, interview, INAM 110114231). The unifying principle was not to include technology for the sake of including if it did not add value to teaching and learning, a recurrent theme that was surfaced in many interviews conducted (interviews of Terrence, Carl, Gabriel, Nigel, Jazz, Sheila, Amelia, Gavin, Katherine).

The school also made efforts to maintain coherency by creating a shared identity. Nigel explained:

> Traditionally, we are a Huay Kuan (Clan Association) school, regardless of anything; we will always be a Huay Kuan school. That will be our main family. But with FutureSchool status, it provides us a different angle to how the public view us, so not only are we a clan school or a school that is very much into the Chinese culture, we are also very forward thinking. (interview, INNL 110825724)

In this sense, the new branding of FPS as a niche school in technology extended the school's identity and fostered a shared imperative.

5.3.2.3 Ensuring alignment of resources

Leaders of FPS also played an important role in aligning resources, especially in terms of aligning funds, staffing needs and availability of time. To ensure the sustainability of projects, leaders of FPS had to ensure a continuous inflow of funds. During the early embarkation and entanglement phase, funding was not a major issue.

Said Han:

> (FPS) can get a lot of money. That's the truth. We get a lot of money because the school is already very famous (for using ICT). So once they want to do it, they can easily get approval. (interview, INHN 100531897)

Securing early success was one of the strategies for obtaining more funds. Carl also recounted that "funding was never a problem" (Carl, interview, INCL 100319845). His foremost concern was how to use the monies meaningfully since he was accountable for the use of public funds. He should not be "wastefully using it" for frivolous ICT experiments and had to be clear about how and why he was using technology. He was heartened that opportunities knocked when interested collaborators who were aware of FPS' pursuit in ICT research expressed interest to work with the school and provided resources for the enactment of activities. Thus, FPS was able to carry out many activities without straining its limited pool of resources.

In addition to the standard ICT grant that was disbursed to all schools, Carl also canvassed for funds and sought the support of parents to pay for the PDAs that the school intended to use. The major breakthrough happened when FPS received a nation-wide ICT award in 2006, where a total of $200, 000 was disbursed to support FPS' key programmes from year 2007. The Chinese Clan Association also sponsored equipment and cost of portal development for activities that will be scaled to all

sister schools. The bulk of FPS' financial resources, especially in the early years, came mainly from the string of awards that the school had won by proving its success in integrating technology into curriculum. FPS' story suggests that it is possible to embark on the ICT journey even with inadequate financial resources. The inception of a good idea, predicated on sound pedagogical knowledge and research methodology, is what it matters to secure funds for further exploration in Singapore's context. The more challenging part, perhaps, is to seed a nurturing and sustainable environment for creativity and learning culture to flourish.

During the elevation phase however, funding became one of the centrepieces of discussion due to the massive scaling up. Just days before the MOE officials arrived to inspect and assess the school's potential for FutureSchool, Terrence told the teachers:

> I'll be frank. We have not rolled out many of our ICT programmes to many levels yet. The issue is funding. It is not easy to find money to support some of our programmes. I hope that with FutureSchool funding, we are able to do more. (video, VIDFS 110211)

FPS' successful application resulted in a fresh injection of $3, 000,000 that could be used for the purchase of devices and recruitment of personnel to drive the projects. The leaders also leveraged on their academic consultants' network to successfully

obtain additional sponsorship for students' mobile handsets from a renowned international chipset manufacturer.

Handling human resource issues effectively was also one of the ways to ensure the sustainability of student-centred uses of technology. In 2011, Gabriel's resignation from the teaching service to pursue personal interests and a mass exodus of ICT support team members left a temporary power vacuum in terms of technology leadership. The school later appointed Nigel as the successor to Gabriel as he had been involved in many ICT projects since 2006. The immediate challenge which Nigel faced was to rebuild the ICT support staff structure again:

> I thought the support staff was one critical thing that I wanted to rectify because I can't have a department with ICT projects without the support staff coming in to help. So immediately, I spoke to my Principal and I told him we need to do this quickly. So I engaged my admin executive to liaise with the different manpower agencies to line up a lot of interviews and to identify suitable candidates so from there, the support staff team reshaped, this is, I got a chance to handpick the people that I want. So immediately the trust is there…..I told them where the school's direction is and how to be part of it. And from there I thought, what's also important is to provide the right environment for them to work because in the past, they didn't have that cosy room that you see in that lab. (interview, INNL 110825563)

Besides quickly rebuilding a team, Nigel also strove to assimilate new ICT support staff into the environment in the shortest span of time (Nigel, interview, INNL110825568). The ICT support staff played a pivotal role in sustaining FPS' ICT endeavours, as mentioned by interviewees such as Jazz, Sherry, Nigel, Gabriel, Shelia and Frederick. These non-teaching staff members helped the teachers to troubleshoot problems in the classrooms, maintain the system and prepare the equipment in advance, which in turn allowed teachers to focus more on the core role of teaching.

One of the more radical measures that FPS had adopted to enhance the sustainability of ICT projects was to "manufacture time" for teachers and students. Terrence incorporated professional development sessions within teacher's curriculum time so that they did not have to find time after school hours for that purpose. Teachers who were involved in the same project were allocated three common consecutive free periods per week to discuss matters pertaining to their project. Terrence and Gabriel also created three extra Science periods for the experimental classes on a fortnightly basis in the form of supplementary classes (meeting minutes, MM 110621; Gabriel, interview, INTE 101129547). This was to resolve the issue of time constraint for enactment of student-centred lessons. Routine worksheets were placed in the school's Learning Management System as homework. Non-critical activities were postponed and non-essential worksheets

removed. However, practice papers which were deemed critical to prepare students for examinations had to be retained. Jazz explained:

> We cut down some of the worksheets, then we look through the activities for the MLE (mobile learning environment). We also cut down on maybe one or two here and there. Certain worksheets which we have to complete but not so urgent were deferred until we finish the mock test, then we go back to those worksheet. Then there are some activities in the activity book, we tell teachers to get their children to do it at home instead of in class. So a lot of things are so called like push it, you know to home or after the mock test. (interview, INJZ 110906487)

According to Jazz, the mandatory assignments comprised activities designed by the MOE and the topical worksheets which served to equip students with nuanced skills to answer examination questions. Teacher-produced worksheets which were deemed to be vague and irrelevant after collective review by the teachers were removed. However, as the department's measure was to largely defer instead of substituting the activities with the new student-centred activities, teachers still find difficulty keeping to the schedule of SOW. Jamie, the level head, imparted to the teachers time-saving tips to circumvent the problem of time constrain. Examples include suggesting what could be done in and out of class, recommending the use of peer coaching to save time, focusing on common errors when going through the

worksheet answers, getting students to see teachers individually for less common errors as well as using pockets of time for giving students feedback (interview, INJM 110423). This partially diffused the tensions between the "worksheet culture" and the philosophy of student-centred learning, one of the persistent impediments of research progress as reported by the NIE researchers.

Some HODs also supported the experimental teachers by creating blocks of successive time for their enactment of technology-enabled lessons. For example, Katherine, the HOD of Arts department explained that one of the experimental teachers from her department reflected it would be more feasible to use three instead of two successive periods to run her student-centred ICT lessons. To create that extra successive period for her, Katherine actually co-taught another of her non-experimental class so that the experimental teacher could run the three-period lessons for her experimental class. Such pairing scheme had been planned one year in advance as the HOD had an overview of the staffing needs and nature of projects in the department (Katherine, interview, INKN 11080391).

Amelia also added that FPS teachers with key ICT projects only taught about 20 periods, compared to the normal teaching load of 38-40 periods a week. The management would also engage part-time helpers to perform administrative tasks such as data entry of student results, creation of data banks and collection of school fees. Amelia highlighted that such "offloading" was unheard of in other schools. The

norm was that the form teacher would have to perform all these administrative duties (Amelia, interview, INAM110114143). The multitude of approaches showed that the upper management was committed in sustaining the use of technology for student-centred learning by making structural changes to the teacher's timetable.

5.4 Shared accountability

Collective vision and distributed leadership, which are manifested in the form of decentralisation of decision-making process and shared accountability, are prominent features of FPS' leadership.

5.4.1 Collective Vision

To ensure shared accountability, Terrence placed a lot of emphasis on collective vision. Shortly after he came on board, he invited a group of teachers to brainstorm what effective teaching and learning meant to them. The group comprised young and experienced teachers as well as key personnel. Their collective inputs became part of the 3 critical dispositions which every FPS teacher should strive to possess in order to promote student-centred development (interview, INTE 110331267).

Creating collective vision goes in tandem with sharing future directions. In an attempt to prepare FPS for the application of FutureSchool status, Terrence addressed what the future curriculum entailed: new learning spaces, knowledge creation, diverse pathways and more formative assessment. He also impressed upon

the teachers that teacher development and school leadership would be the enablers to manifest the vision of FutureSchool. He rallied the teachers for support:

> Leadership must be in sync with what the teachers are doing. The school leaders must support what the school is doing……With the change in our curriculum, it will lead to a change in learning outcomes. Our learning outcomes may not be in the form of worksheets, may not be in the form of paper and pen, and assessments or exercises. It may take the form of PiCoMap (Concept Map), GoogleDocs, KWL (I know-I Wonder – I Learned), Wiki and Sketchy (animation)…… This is not a project that I like to do, or planning committee like to do. This is a project which we all like to do. Each and everyone will be in it. All of us will play a role. (video, VIDFS 110211)

Lexicons such as "a project we all like to do", "each and everyone will be in it", "all of us will play a role" instilled a sense of collective ownership. As described by Nigel, the notion of collective ownership was so ingrained in the psyche of Terrence that he would frequently remind everyone: "This is not my school, this is our school." Nigel said he thought that was a very strong message to the middle managers and teachers (Nigel, interview, INNL110825678). Such efforts to create shared visions and new directions through continuous dialogue were important means to maintain coherency in ICT implementation.

5.4.2 Distributed leadership

Distributed leadership can be observed across a spectrum of activities taking place in FPS. In terms of curriculum innovation, the school espoused a whole-school approach which underscored the importance of bottom-up initiatives and top-down support. For top-down support, leaders provided visionary and strategic leadership, curriculum framework and promoted research and translation of effective programs. Teachers, on the other hand, were empowered to provide instructional leadership, enact curriculum innovation and improve teaching and learning practices (publicity poster, PH FCP9 110210).

Bottom-up ownership was also highly valued in terms of ICT implementation. Explained Gabriel:

> ICT innovations are run by the ICT department, so in terms of sustainability, I guess our creative juices will run out sooner or later. So in terms of sustainability and ownership, he (Terrence) wants it to come from bottom-up…… For this change to happen, we cannot rely on one person, we have to be very realistic, it has to go through change of leadership. (interview, INGB 0911061526)

Gabriel highlighted that for sustainable change to happen, there must be psychological ownership of programmes from all actors in the system so that there

were sources of leverage points at every level. Gavin elaborated how the responsibilities were shared between the subject and ICT departments typically:

> The subject (IP) department provides curriculum and pedagogical expertise, what to teach and what strategies to use. The ICT department will provide technological expertise. For example, they will provide advice on which model of equipment to use and troubleshoot technological problems. ICT personnel will need to ensure both hardware and applications are "operation-ready" when the lessons are implemented. (interview, INGV 11081681)

That said, the ICT department also championed some of the more technologically demanding projects (Gabriel, interview, INGB 0911061226; Nigel, interview, INNL 110825324). By the end of the intervention, the planning committee would review the programme and collectively decide the next course of action. If the programme was to be scaled up to the whole level, the instructional leaders of the respective departments would step in to integrate it into the curriculum and SOW. Gabriel pointed out the merits of such shared accountability:

> Because of all these structures he (Terrence) put in place, the ICT department can focus what we do best, which is to explore and to bring in ICT pedagogy…….We used to be in charged of the roll out too. It's very taxing on the department. In the meantime, we may lose out opportunities to develop

> further because of the roll out. The IPs take over, it actually helps a lot. While these, on paper sounds very easy, but then in reality it is very difficult because many schools cannot even do this. (interview, INGB 0911061244)

Nigel also explicated that such an approach can allow the school to "see more synergy and integration" (interview, INNL 110825648). As Gabriel described, implementing such a systematic screening process was no easy feat. The initiative was a result of gradual metamorphosis; with the switch of ownership back to the core departments "been done recently" (Nigel, interview, INNL 110825323).

The longest-standing ICT programme was the whole-school mobilized fieldtrips which involved cross-department collaborations in terms of planning. These ideas usually arose from innovation groups comprising members from various departments. If the mobilized trip was more Science-related, members of the innovation circles who were not from the department would be involved in other areas such as data collection or coordinating the fieldtrip itself. Such an arrangement can bring a slew of benefits, as articulated by Nigel:

> 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 mean why not, because if you can have a single programme and have multiple outcomes and products, that would be fantastic…..I guess from the organizational perspective, it broadens their

> awareness. It is kind of like, make them more involved in the school's operation. 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 within the 4 IP departments (English, Science, Mathematics and Chinese) or even for the non-IP departments, be it PE, art, music and stuff like that. (interview, INNL 110825168)

Herein, shared accountability brings the benefits of multiple perspectives, outcomes, products and enhances awareness of organizational goals and complementariness of expertise amongst staff. Terrence also expressed his confidence in his ability to coordinate different demands because of this structure:

> I'm not so worried because I think, that's where 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. (interview, INTE 110331839)

Nigel also attested that the structure of shared accountability led to higher level of "buy-in" and ownership as many personnel, including upper management and teachers were involved in the decision-making process and thus shaped a "shared vision". Nigel noted: "The net is cast further and not localized to only a few (decision makers)" (INTE 110331675). In short, shared accountability was also one of the

avenues that a school could use to enhance the sustainability of their ICT programmes.

5.5 Prudent innovation spread

Both Carl and Terrence were acutely aware that they had to answer to the public about the outcomes of their interventions. Carl talked about "the fear of wasting a lot of public money" (interview, INCL 100319114) and that leaders should tread prudently. FPS had thus adopted a judicious attitude towards scaling up. The strategies adopted can be broadly categorized as "systematic pacing", "consistent focus" and "customizing needs".

5.5.1 Systematic pacing

Carl spoke about the importance of pacing oneself when scaling up school innovations. There must be strong fundamentals and an ample window for critical reflection before pushing any frontier:

> ICT cannot be rushed. If you want to do it then you must give yourself the time to grow many things. One was we did not have an infrastructure in place, so it will take some time, and you certainly don't want to be too clever to start it tomorrow and put everything in place. You may not know exactly what is it that your school can do and what you want to do. So you got to

> give it some time. Maybe 2 years 3 years to see how as each year progresses, how things are and how to move on from first to second, second to third year. (interview, INCL 100319158)

Gabriel remarked sombrely that the transition period will take "many many years" (interview, INGB 0911061494). Carl's conception of innovation diffusion was to start small with one pilot class and subsequently ponder about how the project could be scaled up to another two more classes.

> Nobody can come to (FPS) and say we have seen this, now go back to school and you know, you cannot replicate. If you want, I would say replicate the process. You have to start off small. Decide what you think works in the school, who can help you to start it, who can get things going, which class can aid you get going and then slowly go for it. So I remember from then from 04 to 05, 05 to 06, I think by 06 07,we were already quite comfortable that entire levels would have come on board. (interview, INCL 100319307)

This also applies to the procurement of equipment. Carl mentioned that the school's approach was not to buy too many devices at one time as technology evolved over time and the school may have a clearer idea of how to align pedagogical knowledge with technological affordances after piloting the project for one year. In addition, the school was also going slower for Primary One and Two classes for reasons stated below:

> Actually we are trying to go into P1 and P2 as well, but we have some reservations because we feel they may be a little too young, especially for P1, the first year in school, the focus should not be ICT yet, it should be knowing what school is about first, get into the flow of things, and then what classroom, what classroom learning is about. So our idea now is to involve them in the use of ICT in the later part of the P1 year, term 3 and term 4, introduce to them IT, slowly get them involved. P2, we start our programme. (Gabriel, interview, INGB 091106473)

Thus, for the lower primary classes, the focus was still on the assimilation of the classroom culture before introducing additional learning tools.

To help teachers who may be ambivalent, Amelia pointed out that these teachers would first be allocated lower primary classes where the use of technology was not as intensive. By doing so, the school sent a subtle signal that they had a two-year time frame to get acquainted with technology. Amelia described this process with the metaphor: "Let it simmer." This strategy was part of the larger buying-in scheme as these teachers would be more ready to take on more ICT projects after the "incubation" period of two years (Amelia, interview, INAM 11011478).

Developing "proof of concept" was also important in terms of ameliorating fears of innovation, especially amongst respective HODs who were ultimately accountable

for the results of their department. Gabriel recounted how he managed to get the instructional leaders on board for the long-standing mobilized learning programme:

> In the beginning, we have to negotiate. I negotiated with the IP heads to allow them to allow me to "intrude" into their curriculum. The first year when we run mobile learning fieldtrips, we were very worried. Whatever the outcome is, let's say if it's bad, I may not get the support from the IP heads. So in the first year, we explored a lot with them…. I guess we managed to convince the IPs a bit in allowing us to extend another year. (interview, INGB 091106440)

Jazz also echoed the importance of starting small:

> Normally when we try, it's always with a small class or small group first. If it doesn't work then ok, then just stop there or you modify or you change it. Then if it's ok, you bring the innovation to a bigger scale. (interview, INJZ 100906572)

What could be inferred was that FPS had advocated systematic pacing in terms of starting with small-scale piloting and obtaining proof of concept to convince key personnel before scaling up the programmes to more classes.

For programmes that had already obtained the proof of concept, HODs may incorporate them formally into the curriculum structure. For example, Katherine, the HOD of the Arts department had integrated a successful ICT programme on Wiki

collaborative writing into the department's Scheme of Work (SOW). As Katherine felt that the results of pilot study had been encouraging, she made the bold move to substitute two out of eight traditional in-class essays with wiki essays. Now, all primary four and five students have to complete at least two essays using the Wiki platform per year (Katherine, interview, INKN 11080388). Gavin, the middle manager noted that every staff member had been supportive of this measure and met the target since its integration into the SOW two years ago. He attributed this success to effective training during whitespace where the teachers were handheld on the pedagogical and technological aspects. He added that the affordance of asynchronous collaborative writing meant that students' learning spaces were not confined to classrooms - they could always collaborate online anytime and anywhere, thus freeing up in-class time for other activities (Gavin, interview, INGV 110816108). The actions of substituting old practices and institutionalising new approaches spoke volume about the degree of buy-in for the wiki project.

5.5.2 Consistent innovation focus to achieve depth

Gabriel attributed the school's ability to achieve depth in 1:1 mobile computing to its consistent focus over the years. Carl explained that FPS' innovations were not episodic in nature. Unlike some schools which had a penchant for always trying something novel, FPS pursued innovations over several iterative cycles to perfect its implementation. Carl expounded:

> My challenge to them (teachers) was always that you don't want to move abruptly to something new and changes everything altogether. Then you cannot tap on the experience of that growing. So if I can track with you the history, you will find that in there is continuation as we move from 02 to 05. Move in a very logical manner so that the growing makes sense to people. (interview, INCL1003191132)

What Carl had illustrated here were his perceived merits of tapping on institutional memory and leveraging on collective wisdom brought about by consistent focus so that tacit knowledge or rather, innovation culture can be propagated. This is similar to Coppola's argument to foster culture coherence by building on the school's "honoured traditions" (p154). Due to FPS' consistent effort, the school was able to carve a niche. Gabriel proudly remarked:

> Because we are consistent, we have more depth. We are very curious about 1:1, in the beginning, we have failed many times, in terms of approach, curriculum design and even equipment. We have succeeded also and when we succeed, we see teachers grow over time. Over time, we managed to build many champions and we are not only concerned about ICT department, but spreading to other departments also. Every department will have a champion for 1:1. (interview, INGB10112915)

Gabriel made it explicit that consistent focus was important in order to achieve both

depth and spread as there was purposive channelling of resources. It also gave Gabriel the confidence to justify the embarkation of the ICT projects in the school. He cited that some projects provided insights on how students applied their understanding of knowledge, which was in line with the school's overarching pedagogical framework of using TfU. Other projects provided insights about curriculum design and allowed teachers to learn how to introduce formative assessment and integrate technology effectively in lessons. Gabriel explained:

> There is a reason why we want all these projects because there are others we don't want as well. So we are stretched but we are also very mindful that these projects have value for us. We can get some value back for school. (interview, INGB 101129138)

The interview suggested that the school had a clear direction on which projects to pursue and was wary about distractions that may diffuse their effort in scaling.

5.5.3 Customizing needs

To spread innovation, FPS ensured that the ICT activities were customized according to the needs of the school during subsequent rounds of implementation. For example, Jazz reiterated that the mobilized curriculum co-designed by the researchers and teachers during the pilot phase was subject to further customization after discussion with all teachers teaching the same level (interview, INJZ 100906592). The duration of some activities were reduced, and some activities that were

relatively challenging, especially those that involved parental participation were pared down for the low-ability classes. Gabriel explained why such customization was absolutely necessary:

> Sustainability…the way I look at it, what you all (researchers) did is research component, so you all come into school with a model and you all are helping us to determine way of doing, learning value and whether there is outcome. But for us, the school, if we want sustainability, we have to spend time to translate it back into the school's way of doing it. This is exactly what we did for P3 this year. We are not adapting it wholesale. (interview, INGB101129541)

Gabriel situated the evolvement of ICT activities within the broader context of the school culture. He was cognizant that supplanting recommendations without considering the unique ethos of the school culture would be futile. Likewise, the programmes such as mobilized fieldtrips that were developed entirely bottom-up by the school teachers were subject to revisions too. The core activities could change due to external factors such as changes to the physical sites or to the overarching ICT policies recommended by MOE; or internal factors such as the desire to overcome logistical challenges or acting on recommendations to suit the needs of different cohorts of students.

5.6 Chapter Summary

This chapter reports the findings of how FPS leaders have sustained the use of technology for student-centred learning. The five broad themes are: continuous scanning of environment, multi-pronged capacity building strategies, mitigating systemic tensions amongst stakeholders, shared accountability and prudent innovation spread. The success of sustaining pedagogical innovations is dependent on how well the school responds intelligently to the information that arises from the inter-meshing of the multiple contexts underpinning the five themes as well as creating the conditions that facilitate alignment through building critical connections. These shall be elaborated in the next chapter, which focuses on interpreting and extending the findings through the complexity lens; and situating the discussion in the literature surveyed.

Chapter 6. Discussion

6.1 Discussion

In this chapter of the thesis, I would like to examine the findings to the two research questions from the perspective of complexity theory and with respect to the literature reviewed. To reiterate, the research topic is: "Sustaining the use of ICT for student-centred learning: A case study of technology leadership in a Singapore ICT-enriched primary school". In Wheatley's words (2006), sustainability is never just about "critical mass" but more about "critical connections" (p45). I find this proposition very relevant to what I have observed over the three-year period of engagement with FPS. To put it succinctly, the success of sustainability depends on the organization's capacity to foster critical connections at all levels of systems, both spatially and temporally so that self-renewals can happen in a complex adaptive system.

Figure 6.1 maps out the inter-connectedness of the multi-level influences that shape FPS' ICT policies and implementation. To visualise the interrelationships of influences impacting the sustainability of FPS' ICT endeavours, I have adapted Bronfenbrenner's (1993) ecological model, which is first used to conceptualise human development, as an organising framework to explicate the mutually constituting factors in a complex adaptive system.

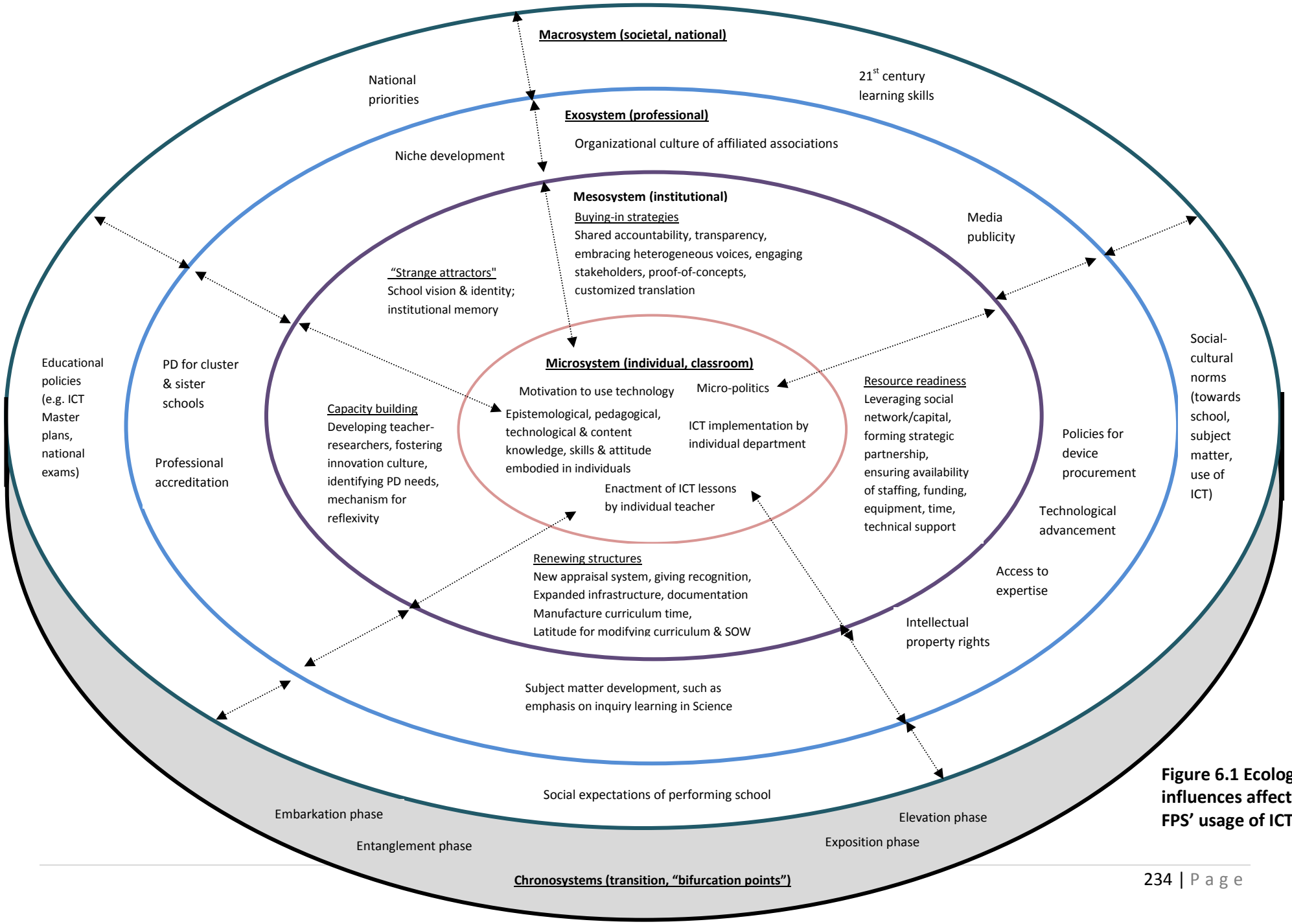

Figure 6.1 Ecological influences affecting FPS' usage of ICT

In this adapted model, Bronfenbrenner's five nested multi-scale sub-systems (microsystem, mesosystem, exosystem, macrosystem and chronosystem) are maintained. The concept of "nestedness" in this model complements the essence of complexity perspective where the relationship amongst multiple influences is not represented in a linear or reductionist manner, but nested to show how sub-systems can shape each other, thus providing a powerful visual metaphor for mapping ecological landscape. The content within each nested concentric circle, however, is contextualised based on FPS' unique landscape. The various influences which are now contained in each circle are extracted from the codes and themes arising from the data analysis of this study (See Table 6.1).

Levels of sub-system	Constructs	Data Source(s)
Microsystem (activities and relations as experienced by individuals in their immediate environment)	Motivation to use technology	Assertion 3 (Chapter 4) on motivation for using technology.
	Epistemological, pedagogical, technological & content knowledge, skills & attitude embodied in individuals	Interviews and observations of lessons, fieldtrips and professional development sessions. For example, Sherry who used to rely on transmission of knowledge went through a phase of "culture shock".
	Micro-politics	Dynamics between various departments. For example, the Arts department enjoyed greater synergy with the ICT department as compared to the Sciences department.
	ICT implementation by individual department	The contextual factors affecting individual department's ICT implementation. For example, the roll-out plan of Arts department and Sciences department varies (Figure 6.2).
	Enactment of ICT lessons by individual teacher	Six lesson observations. Fieldnotes showed that there were commonalities and variances across teachers' lesson enactment.

Mesosystem (pertains to institutional influences that shape the environment in which individuals participate in)	"Strange Attractors" School vision & identity, institutional memory	Chapter 5.3.2.2 "Unifying competing agendas" and 5.5.2 "Consistent innovation focus to achieve depth".
	Buying-in strategies Shared accountability, transparency, embracing heterogeneous voices, engaging stakeholders, proof-of-concepts, customized translation	Chapter 5.4 on "Shared Accountability", 5.3.2.1 on "Climate of Openness" and 5.5.3 on "Customizing needs".
	Resource readiness Leveraging social network/capital Forming strategic partnership Ensuring availability of staffing, funding, equipment, time, technical support	Chapter 5.3.2.3 on "Ensuring alignment of resources".
	Renewing structures New appraisal system, giving recognition, expanded infrastructure, documentation, manufacture curriculum time, latitude for modifying curriculum & SOW	Chapter 4 on "Elevation phase" and Chapter 5.3.2.2 on "Unifying competing agendas". Chapter 5.3.2.3 on "Ensuring alignment od resources".
	Capacity building Developing teacher-researchers, fostering innovation culture, identifying PD needs, mechanism for reflexivity	Chapter 5.2 on "Multi-pronged capacity-building strategies".
Exosystem (more distal influences that do not directly involve the school as active participant but still affect the way ICT is being implemented)	Organizational culture of affiliated associations	For FPS, it is the organisational culture of Chinese Clan Association, in terms of recruiting principals, defraying innovation cost and reviewing progress.
	Niche development	For FPS, it is the development to focus on 1:1 computing.
	PD for cluster & sister schools	Chapter 4.2.4 on scaling some innovations to sister schools and its mission to conduct PD for cluster schools as part of the mission for FutureSchool.
	Professional accreditation	Chapter 3 on the accreditations received by FPS and Chapter 4.3.3 on how "award-driven mentality"/"documentation" may influence ICT implementation.
	Subject matter development, such as emphasis on inquiry learning in Science	Vignette as described in 6.1.1.2.
	Intellectual property rights	Chapter 5.3.1.3 on "Incompatibilities undergirding the education-research-industry partnership".
	Technological advancement	Chapter 5.1.3 on "Scanning technological environment", in particular the systemic considerations when deciding on the type of mobile device to purchase and the constraints of commercial partnerships that influenced the options of device and operating systems.
	Policies for device procurement	Chapter 5.3.1.3 on "Incompatibilities undergirding the education-research-industry partnership".

	Media publicity	Chapter 5.1.1 on "Scanning macro policies". In particular, how media exposure caught MOE's attention and subsequently, the proposal to brand FPS as "handheld school".
Macrosystem (larger contextual environment that encompasses societal norms, ideologies, national governance, policies or socio-cultural trends)	National priorities	Chapter 5.1.1 on "Scanning macro policies".
	Educational policies (e.g. ICT Master plans, national exams)	Chapter 1 on backdrop of ICT Masterplans, Chapter 3 on context of the case school and Chapter 4 on FPS' "Assessment Strategies".
	Social expectations of performing school	Chapter 3 on the profile of FPS as a performing neighbourhood school and Chapter 5.3.2.2 on "psychological baseline" on maintenance of high-stake examination results.
	Social-cultural norms (towards school, subject matter, use of ICT)	Chapter 5.1.2 on "Scanning pedagogical developments", 5.1.3 and "Scanning technological environment".
	21st century learning skills	Chapter 1 on landscape of 21st century learning and its inter-relationship with Singapore's ICT Masterplans.
Chronosystem (the longitudinal changes made to the system)	Embarkation phase	Changes depicted in Chapter 4.2.1.
	Entanglement phase	Changes depicted in Chapter 4.2.2.
	Exposition phase	Changes depicted in Chapter 4.2.3.
	Elevation phase	Changes depicted in Chapter 4.2.4.

Table 6.1 Data sources to support constructs of multi-level ecological influences

The microsystem includes activities and relations as experienced by individuals in their immediate environment. For FPS, microsystem influences include personal, interpersonal and classroom-level factors such as the motivation to use technology; the knowledge, skills and attitude embodied in individuals; micro-politics or challenges faced by individuals, enactment of ICT lessons by teachers as well as ICT implementation carried out by individuals/individual department. The mesosystem pertains to institutional influences that shape the environment in which individuals participate in. These influences include historical developments, buying-in strategies, school connections, resource management, structure renewals, capacity building

efforts and presence of "strange attractors" (influences that keep a system at the edge of chaos). Exosystem, on the other hand, are more distal influences that do not directly involve the school as active participant but still affect the way ICT is being implemented. Here, the exosystem pertains more to professional affiliations, organisational culture of affiliated bodies such as the clan association, accreditation bodies or developments that affect the school. The macrosystem is yet another larger contextual environment that encompasses societal norms, ideologies, national governance, policies or socio-cultural trends.

Chronosystem involves the longitudinal changes made to the system. In Chapter 4, I have identified key influences that have occurred over the embarkation, entanglement, exposition and elevation phases (see Chapter 4). These are akin to "bifurcation points" which, in complexity terms, are critical choices that led to transformation. Some of these bifurcation points were responses to macro developments. These events, whether anticipated or otherwise, gave rise to disequilibrium and resulted in oscillation between steady states and chaos as they enfolded. To illustrate, the decision to embark on 1:1 mobile learning after Carl attended a workshop catapulted FPS into a niche school in this area. The decision to withdraw from first call of FutureSchool application gave FPS more time to build capacity and nurture readiness. The mass exit of ICT support staff was a form of internal perturbation and that was quickly rectified by re-configuring the internal structure and re-organizing the department.

In short, the school has to respond intelligently to a confluence of changes. All these are possible only if the leaders are adept at scanning the environment and interpreting the feedback to respond intelligently to changes (Morrison, 2002; Wheatley, 2006). Aligning with what Morrison (2002) has said, the school needs to do the following: "identifying, describing, sensing and scanning the environments in which they operate; defining the priorities within these environments; deciding their relationship with the environment; responding to and planning for the environment and self-organising for the environment" (p117).

Extending from Bronfenbrenner's model, the influences in the ecological environment are mutually-constituting, manifested in the form of lateral, top-down or bottom-up interactions within and across sub-systems, as depicted in the form of bidirectional arrows that cuts across all dynamics. Sub-systems tend to be more tightly coupled with their immediate sphere of influence and more loosely coupled with distal spheres. It suggests that technology leaders who are adept at fostering ecological coherence across sub-systems will be able to renew, adjust and sustain innovations in a complex environment. The following section expounds on the mechanism by elaborating critical events.

6.1.1 Inter-dependencies across all levels of systems

6.1.1.1 Ecological considerations regarding ICT implementation

As stated above, environmental scanning is an integral mechanism for technology leaders to understand the complex environment so as to create conditions for changes to happen. As the interpretation of information can be subjective, it warrants distributed leadership to co-scan and co-interpret what emerges from the changing dynamics. Truth, in a complexity sense, is socially constructed and emerges out of interactions with both actors and non-human factors in the system. No one has perfect information and the only way to respond intelligently is to gather multiple perspectives through feedback loops and to look out for coherence from seemingly contradictory views.

As an example, due to the impetus of ICT Masterplan *[macro]*, FPS had been moving towards the use of ICT for student-centred learning and encouraging teachers to propose projects that promote the cause. Socio-cultural trends *[macro]* such as students' ailing interest in the second language had prompted the teachers in the Arts department to look at ICT to revitalise the teaching of the subject. Pedagogical innovations *[exo]* such as the growing emphasis on inquiry learning had also provided impetus for the Sciences department to revamp their teaching practices. Students' feedback, in the form of formative assessment or behaviour *[micro]* over time *[chrono]* allowed teachers to adjust their practices accordingly.

Reform efforts can also be promoted or impeded by social expectations from parents *[meso]* and policymakers *[macro]*.

Nigel commented during the interview that at the school level *[meso]*, innovation ideas proposed by staff members *[micro]* would be evaluated against the school's overarching policies *[meso]* by the planning committee which comprised HODs from every department. Within the department, the middle managers were also involved in the selection process *[micro, meso]*. Gavin indicated that some projects had to be deferred or rejected based on the following grounds: 1) time constraints *[meso]*; 2) no feasible technology *[exo]*; 3) no suitable collaborative partner *[meso, exo]*; 4) collective perception (largely bottom-up) that the learning efficacies will be low *[micro, meso]* (interview, INGV 110816133). Such extensive evaluation exercise is similar to Blumenfeld et al.'s (2000) concept of gap analysis between demands of innovations and existing capacity of organisation by locating innovations along the dimensions of school culture, capability of practitioners and policy/management. In addition, the findings of this thesis foreground the process of shared decisions in conducting the gap analysis. The growing emphasis on shared accountability led to more buy-in and development *[meso]*, constituting positive *feedback loop;* and a healthy mechanism of checks and balances *[meso]*, constituting negative *feedback loop*.

In the event that a project was feasible, FPS will leverage on its social capital *[meso]* to ensure convergence of resources, such as funding. Gavin explained the significance of economic sustainability:

> For Carl's era, the use of ICT is still not so prevalent. Although there are learning circles, limited funds make it difficult to expand or scale up successful projects. Now with ample funding, there is more leverage for innovation. (interview, INGV 110816177)

FPS leaders, thus far, had secured funding from the clan association, government and commercial partners *[meso, exo, macro]*. Yee (2000) terms this kind of financial leverage as "Entrepreneurial Networking". This is also congruent to Kowch's (2004) proposition that leaders who have demonstrated success can exercise greater capacity to influence outcomes and have more opportunities to generate even greater social capital through its expanding network *[chrono]* and publicity *[exo]*. In FPS, this virtuous cycle, made possible by longitudinal use of technology, can be first observed during the entanglement phase and subsequently became more pronounced during the elevation phase *[chrono]*. However, the convergence of resources can be confounded by factors at the level of exosystem. For example, the procurement procedures *[exo]* which the school and collaborative agencies had to abide with were not compatible, resulting in delays in the arrival of equipment, which in turn affected pedagogical practices *[micro]* and shorten the timeframe for the project intervention *[meso]*.

6.1.1.2 Ecological influences affecting scaling efforts

Scaling up is another important aspect of FPS' ICT implementation, especially in the light of being accredited as a FutureSchool *[exo]*. When there was proof-of-concept, the project would be rolled out to a wider scale, leading to more intensive scrutiny and robust examination by all actors involved *[meso, exo]*. From the complexity theory point of view, having proof-of-concept is vital as any decision made can have ramifications on many inter-locking sub-systems *[meso, micro]*. Limiting new projects to a smaller-scale test beds is a way of cushioning possible shocks and provides a window for all stakeholders to objectively evaluate projects before committing too many resources prematurely *[meso, micro]*. The argument for proof-of-concept however departs from Law, Yuen and Fox's (2011) observation that having an innovation prototype is not a necessary condition for sustaining innovations.

In addition, emphasis on traditional examination *[macro]* and big student-teacher ratio *[micro]* were tenacious challenges that still threaten the sustainability of projects. My prolonged engagement with the school showed that projects that did not accentuate macro-level rigidities, namely those projects that: 1) did not require the essential use of technology for teaching; 2) were not in conflict with the requirements of national assessment; 3) did not require massive re-design of curriculum, can be scaled up rapidly. This was so as resources for these projects can be easily re-configured and made available way in advance.

One such example was the collaborative Wiki writing project to produce digital essays. Formally integrated into the SOW *[meso],* this project was successfully scaled up to two school levels within a year. Reasons include the project's feasibility to meet the national curriculum requirements of completing at least 8 essays a year *[macro]* and thus the general perception that this project was not an add-on burden for the teachers *[micro]* as well as the provision of adequate handholding sessions for teachers *[meso, micro]* (Gavin, interview, INGV 110816120).

Conversely, another project in Sciences department which started in year 2009 required more time for scaling up as it involved the convergence of physical, financial and intellectual resources *[meso]*, substantial curriculum re-design efforts, intensive integration of technology in routine lessons and shift of instructional focus from learning outcomes to processes. When the project was rolled out to one more pilot class in 2010, the champion teacher from the IT department instead of Sciences Department took a greater lead as the principle of routine use of technology did not resonate with the HOD of Sciences department. She viewed drilling students via worksheets as absolutely necessary to prepare students for standardized examinations and thus did not substitute worksheets with the mobilized activities *[macro, meso, micro]* (meeting minutes, MM091112, MM100305). As a result, the experimental teachers were facing time pressure to complete the stipulated worksheets on top of the enactment of student-centred lessons.

In 2011, the Sciences HOD decided to give the middle manager, Jamie more autonomy to make strategic decisions after witnessing that the two-year intervention had not done any harm to the results of experimental classes *[micro, macro]*. This was also considered a "bifurcation point" as Jamie, after spending one year to understand the essence of the project by attending all meetings with the pilot teachers and researchers took the risk to make more significant structural changes *[meso]*. She believed that if the fundamentals were laid in the right manner, it would create more impact in teaching and learning in future *[chrono]*. Jamie and the teachers also made a joint-decision not to acquire worksheets, partly to allow teachers more time to enact mobilised lessons and also in response to parents' feedback *[meso]* that worksheets bought were not completed during the pilot phase (journal record). The principal and the educational consultants *[meso]* supported the decision (journal record, JR120718). The tension that arose from the school's emphasis on worksheet was finally mitigated after a three-year deadlock *[chrono]*. In 2012, the project was scaled up across all primary three classes.

6.1.1.3 Coupling effects affecting capacity for self-organising

The coupling effect amongst sub-systems will be tighter between the neighboring spheres of influences and looser between distal sub-systems. For example, socio-polity at the micro level will be more inter-connected with components at the meso level, as compared to influences at the scales of exosystem or macrosystem. Figure 6.2 shows the different cross-departmental collaborative patterns between the

Sciences and Arts departments in year 2010 and illustrates how micro-polity can interface with meso-level organisational interventions to affect the respective department's capacity for self-organisation.

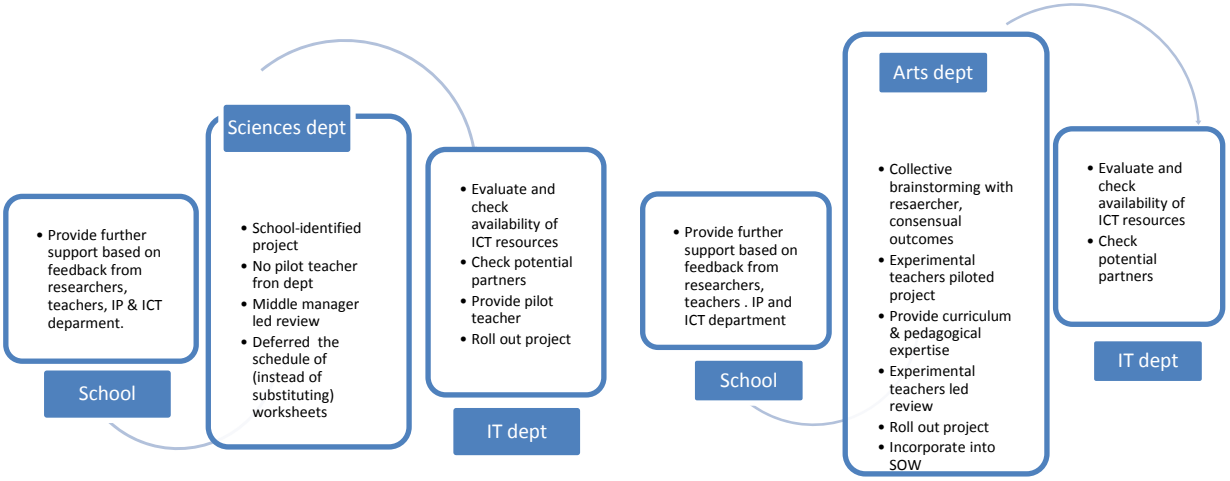

Figure 6.2 Dynamics of scaling up for researcher-initiated projects in year 2010

The figure shows the shift in the role of ICT department with regard to *inter-departmental* dynamics and the *intra-departmental* perception about the use of technology for teaching and learning. Compared to the Sciences department, the Arts department had exhibited a higher level of self-organisation and synergy. It leveraged on the members' expertise to spread innovation without top-down directives and was less reliant on the ICT department to sustain and scale up innovations. The cohesive department also saw the highest number of ICT champions. Synthesising the viewpoints of Katherine (Department HOD), Gavin (Subject Head) and Amelia (IT coordinator), the possible reasons for this

extraordinary collegiality were: 1) geographical proximity as the staff members were sitting close to one another; 2) more white space time together; 3) cognisance of the urgent need to inject new lease of life into the teaching and learning of the subject matter; 4) strong encouragement from the HOD to work with researchers and ICT department to deepen the use of technologies for engaged learning; 5) longstanding tradition of resource-sharing and camaraderie; 6) flat hierarchy as HOD worked alongside the teachers and adopted a very spirited stance and 7) presence of key ICT champions whose enthusiasm was contagious.

On the other hand, the Sciences department had fewer instances of self-organisation and experienced disjuncture in its scaling efforts. The reasons were: 1) a lack of shared imperative revolving the essential use of ICT to improve student outcomes; 2) the resultant effect of Sciences HOD working at "arms-length" with the IT department and researchers (meeting minutes, MM090429; MM090923, MM100305); 3) absence of proactive ICT champions. As there was no total buy-in, the middle manager became the sole conduit between what Uhl-Bein and Marion (2009) termed as bottom-up "adaptive leadership" and top-down "administrative leadership".

Propositions can be drawn up based on the micro-meso dynamics exhibited by the Sciences and Arts departments:

1) informal alliances or relational affinities such as friendship have more power than formal authority;
2) self-organisation is more apparent only when there is collegiality AND self-referential properties revolving around core identity;
3) attesting to what Morrison (2002) has suggested, it is easier for closely-coupled departments to achieve positive ramifications that reverberate throughout the system; on the other hand, negative sentiments about ICT tend to be isolated if the department is loosely coupled with other systems;
4) when there are conflicting agendas, existence of "attractors" which are elements in a system that would "hold our behaviour within a boundary and keep us from wandering into formlessness" (Wheatley, 2006, p132), will act as an impetus to re-create order and pattern. In FPS' case, the "strange attractors" are the unifying philosophies of using technologies to benefit students' learning.

Such micro-polity exhibited by the various departments however would have limited bottom-up impact on professional *[exo]* or societal developments *[macro]*. One implication of this diminishing coupling effect is that it is still important for leaders to foster ecological coherence even though actors at the micro scale can self-organise as leaders tend to have more access to information emanating from higher levels of sub-systems.

Figure 6.3 is drawn based on the vignettes described in this section. It describes how actors within the school system (bounded by circle) interact with actors beyond the school organisation to fulfil intertwining roles and how changes happen as a result of longitudinal neighbour interactions between all actors as they influence, clarify and shape one another's roles, mindsets and practices.

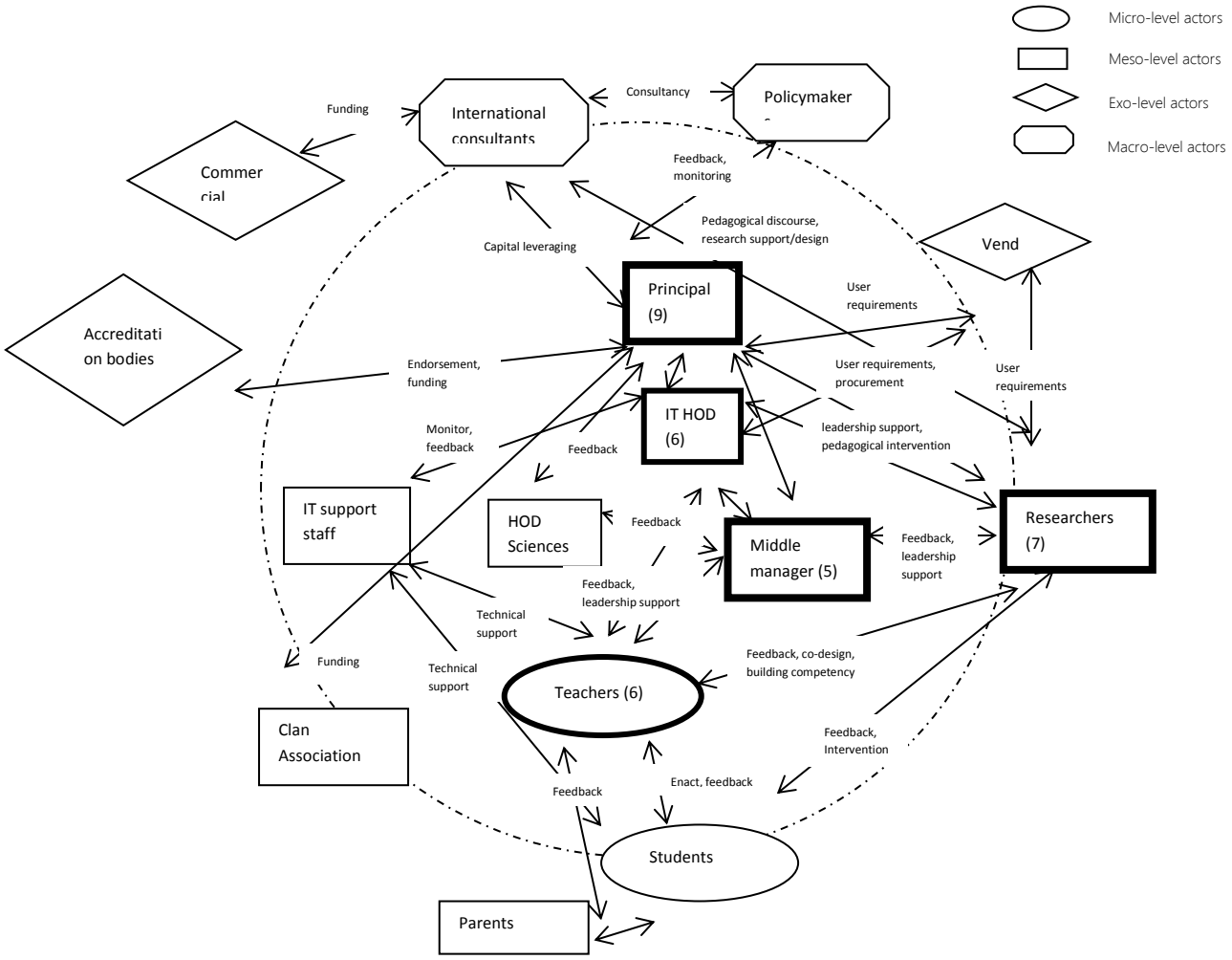

Figure 6.3 Dynamics amongst stakeholders

Based on the number of connecting nodes, the figure illustrates that teachers, middle managers, IT HOD, researchers and in particular the principal formed the

nexus of communication channels. This is in line with O'Day's (2002) argument about the concomitant emphasis of whole-school administrative and professional accountability to create meaningful and lasting reforms. Decisions made were premised on professional discretion distributed across various departments and different levels of hierarchy. However, the principal was still the main actor that interfaced with external parties, especially when social and financial capital were concerned, bolstering the fact that it would be important for key leaders to enhance ecological coherence due to their proximal connections with other sub-systems.

Owston (2006) and Fishman et al. (2004) remark that university partnership, if it exits, is a critical determinant of sustainability, which seems to hold true for FPS, according to interviews (with Gabriel, Terrence and Janis) and the high number of connection nodes (7) coalescing around researchers (See Figure 6.3) who worked as "recontextualizers" of "pedagogic discourse" (Looi et al., 2011, p11). Kowch's (2004) concepts of "bonding", "bridging" and "linking" can also be applied to FPS' context. The Arts department exhibited features of "bonding" with the inherent capacity to organise their own interests; the Sciences department leveraged on "bridging" (middle manager) to interface within same strata (IT department) and across strata (upper management). "Linking" happened when the IT department linked project members to external partners, attesting to the complexity of micro-politics and generation of social capital.

6.1.2 Inter-dependencies within same level of sub-system

Within the learning ecology of FPS, inter-dependencies between components can also happen laterally within the same level of sub-system. For example, at the meso level, policymaking needs to be supported by identity, vision and values *[strange attractors]* to unify competing agendas; effective communication channels to articulate vision *[buying-in strategies]* and convergence of resources *[resource management]* to make espoused usage a reality. Unwilling participation will hamper the school's identity-making process and lead to less champions. It can also impede policymaking if personnel distance themselves in the process. Providing support to mitigate structural rigidities *[structure renewal]* will reduce the resistance towards innovation. Fostering an innovation culture, enabling shared decision-making and encouraging professional upgrading *[capacity building]* in an environment that is tolerant of ambiguity *[meso]* may diffuse problems associated with staffing shortage as more personnel will be less fearful about change. FPS' professional development strategies *[meso]* and mechanisms for reflectivity *[meso]* helped teachers to build confidence in the transition to these new teaching practices. Even Lisa (interview, INLA 110825), a level 1 teacher who had been using technology only in an ad-hoc fashion *[micro]* had experimented with the use of a discussion forum for her lessons, an idea which she picked up from FPS' internal professional development session *[meso]*. This is synchronous to Wong and Li's (2006) proposition that successful

pedagogical and organisational intervention are those where teachers' training has progressed from piecemeal to the holistic social capital development approach.

Wong and Li's (2006) quantitative survey (See Chapter 2) also indicated that conditions such as risk-taking culture, shared vision, evaluation of school readiness and changes in assessment mode were relatively less important in sustaining the use of ICT for teaching and learning. However, an anomaly seems to exist when the findings are situated within the ecology of FPS. All the 17 FPS interviewees had unanimously perceived the innovation culture of the school as an important condition for the school's success in sustaining the use of technology for student-centred learning. Nigel specifically highlighted FPS' innovation culture *[capacity building]*, together with staff professional development *[capacity building]* and clear communication to stakeholders *[buying-in strategies]* as the three critical factors for sustainability (interview).

The transformation of the school into a FutureSchool *[identity making]* over the years can also be interpreted as a form of "autopoisies", which Morrison (2002) defines as meaning "each living system possesses its own unique characteristics and autonomous identity which enable the system to perpetuate and renew itself over time" (p15). This can be observed from the fact that the school made deliberate efforts to metamorphose into a centre of excellence for IT and subsequently a prototype school for the nation. The school achieved this self-referenced goal by re-

designing their curriculum, re-structuring their professional development models, re-furbishing infrastructure and re-formulating their time tables *[structure renewal]*. The school leaders also actively formalized partnerships with university researchers to provide complementary skills to the school and to create the branding of "research-based school" *[identity-making, capacity building]*.

The self-referential identity of FPS as a 1:1 learning school enabled the whole fraternity to remain focused on the core, reject peripheral ICT involvements, expand and later streamline its coalition as well as structure its school operations for student-centred learning *[strange attractors]*. Leaders developed FPS' niche longitudinally by ensuring systematic pacing, emphasising consistent focus, leveraging self-organised spread and customizing needs. Even in the change of leadership, these anchors and vision remained, resulting in a successful lineage of ICT usage *[strange attractors]*. This could be due to the fact that Terrence was carefully selected by the Clan Association and had understudied FPS before taking over the helm. This is akin to Hargreaves and Fink's (2004) exposition on preparing for leadership succession for continued success.

The following section will present how FPS' case relate to the three questions that arose from the literature review, paying special attention to how the case school is in congruence or dissonance with the body of existing knowledge.

1) *How important is the role of distributed leadership in sustaining the use of technology for student-centred learning?*

Distributed leadership was a vital mechanism in sustaining the use of technology for student-centred learning in FPS. Gabriel had specifically mentioned that "creative juices" would run out if the ICT department had to oversee the process of idea generation right up to the process of scaling. Both Nigel and Gabriel shared the sentiment that the previous model of putting ICT department at the forefront of pedagogical innovations was not sustainable (interview, Gabriel, INGB 09110961158; interview, Nigel, INNL 110825315). The school gradually gravitated towards the model of allowing departments to have "collective ownership", where the subject departments were more involved from the inception of idea to the scaling process after successful piloting. The merit of such an approach was to allow the ICT department to focus on conducting technological scanning, providing technical support and liaising with commercial partners so as to negotiate a more comprehensive learning solution for the students.

This model did not take shape in the earlier phases. Instead, the fine-tuning process was the result of iterative innovations and reflections amongst all actors, an attestation to how the school became a learning organisation through distributing leadership and enhancing collectivism at all levels of social interaction. The school's practices of distributing leadership roles and

encouraging collective ownership complemented the notion of "complexity leadership" where the direction of innovations was more bottom-up, with the sense-making process more emergent and inter-woven across different sub-scales of influences.

2) Is the traditional assumption that structural changes are not needed to maintain sustainability true?

A critical issue raised by Lemke and Sabelli (2008) is whether it is realistic to expect reform goals to manifest without accompanying changes to structural changes. FPS' story showed that localized efforts from the school management to address structural rigidities, such as revamping the appraisal system, manufacturing time for enactment of student-centred lessons, providing more infrastructures and giving departments the latitude to modify the curricula and SOWs, were integral in its effort to sustain the use of ICT for pedagogical innovations.

Interestingly, some of these re-structuring efforts were top-down responses to bottom-up suggestions. Notably, teachers reflected the pressing need to structure a common block of time within the curriculum timetable for project members to discuss matters pertaining to their innovation as well as continuous block of classroom time to enact student-centred lessons. Teachers also

suggested that professional development sessions could be more personalized and implemented in the format of small-group peer coaching. These measures increased efficiency as more time was freed up for constructive discussion rather than coordinating logistical demands. The leaders were swift in embedding these suggestions into the "grammar" of schooling.

When visualized in terms of interaction circles, FPS had provided teachers with many opportunities to create multi-layered integration, as manifested in the form of vertical interactions between individuals and upper management (contact time), lateral interactions between individuals and departmental colleagues (department meetings); individuals and like-minded colleagues linked by self-organised interests (communities of interests); individuals and project team members (time-tabled time) as well as individuals and colleagues from other departments teaching the same subject matter (white space meetings).

Concomitantly, top-down policies such as the introduction of new appraisal system and the re-structuring of classrooms and computer laboratories signaled the leaders' political will to promulgate change. Each of these structural changes constituted the building blocks for sustaining innovations. FPS' case, in this sense, demystified school's resistance to structural changes. In fact, lessons learnt from the case school reinforced the importance of re-structuring as it was used as a

means for re-culturing and promoting the spirit of innovation – an element which was very much underplayed in literature.

3) *Why is the case school an exceptional case against the backdrop of literature that reports on the limited role of technology in promoting pedagogical change?*

The rhetoric surrounding the use of technology in education evoked the view that technology had largely failed to transform teaching and learning – a disappointing reality check for unbridled enthusiasts. Against such a sombre backdrop, why was FPS able to sustain its efforts in using technology for student-centred practices?

Despite the school's phenomenal success, the challenges it faced were not radically different from those reported in literature. To illustrate, in FPS, most teachers were able to adopt a constructivist approach when technological devices were made available. However, there was a tendency for the teachers to revert to teacher-centred practices in the absence of such tools (Amelia, interview, INAM 11011498). These accounts demonstrated the affordances of technology to expand teachers' repertoire of teaching strategies and at the same time, the tenacity of transmissionist practices. This tenacity stemmed from

the push factor of time constraints and pull factor related to perceived merits of teacher-centred instruction.

As what Sherry had mentioned in the interview, if time constraint was not an issue, she would have made more use of the animation programmes and concept maps that were bundled together in the digital learning suite (interview, INSH 100826996). On the other hand, the HOD of Sciences department valued the drill and practice route highly in terms of preparing students for the high stake examinations – a scaffold aid which she believed could reinforce important scientific concepts in addition to other instructional methods (meeting minutes, MM091112, MM100305). Thus, both teacher-centred and student-centred learning co-exist, albeit awkwardly at times, even in a prototype school that had been widely acclaimed by both the local government and international bodies for its efforts to use ICT for student-centred learning. As the school embraced heterogeneous views about teaching and learning, it did not exercise top-down pressure and mandate pedagogical change. This brought forth Harris' (2005) call for "pedagogical plurality" (p121). What we could learn from FPS' case is that pedagogical transformation should be viewed in the light of expanding teachers' pedagogical strategies through leveraging the affordances of technology, and that traditional method of teaching and learning need not be demonised. This is aligned with what complexity advocates: Evolution is emergent and can perhaps be metaphorically described as an orchestration between the old and the new,

rather than the cannibalisation of the old by the new. The evolutionary rather than revolutionary changes witnessed in FPS' change management practices reduced angst related to reform and provided teachers with the much needed space to think about the various pedagogical approaches.

Notwithstanding the divergent views held by the fraternity regarding instructional means, the school was unified by the philosophy that students' welfare would take precedence and technology should not be used if it did not add value to students' learning. This philosophy remained consistent over the decade, even in face of leadership change. Such cornerstone then became a self-referential norm that FPS can identify with. Coupled with collective reflexivity, the whole organisation became more aware about the systemic influences at play and made shared decisions based on shared values.

The sustainability of innovations in FPS constituted another building block towards its success. Because of the school's efforts to sustain and scale up successful pilot projects, there were opportunities for institutional memory to become embodied tacit knowledge which was deepened over time. The tacit knowledge was subsequently transformed into knowledge capital that attracted more social and financial capital to sustain the innovations. Here, we see the formation of a virtuous cycle that had spun off from the school's early successes,

attesting to the fact that complex adaptive systems are indeed "sensitive to initial conditions".

Overall, the transformative journey of FPS was a result of collective intelligence, distributed across time and space. No singular innovation or sheer quantitative growth of innovations could make significant impact to teaching and learning. It was only when these innovations were situated in an organisation with sustained innovative and reflective culture (made possible with the help of re-structuring) that teachers' repertoire of teaching strategies could be expanded and harnessed according to the nature of learning contexts. The next chapter delves into what all these meant for policymakers, middle managers, teachers and future research directions.

Chapter 7. Implications and Conclusions

7.1 Implications on policymaking to promote the sustainability of innovations

As pointed out in the literature review, Jennings & Dooley (2007) refer to emergence as the natural tendency for agents to interact in a complex way to produce change, novel order and system-level adaptation through exchanging information, taking action and responding to feedback. Figure 7.1 is an attempt to elaborate the emergence of change by developing a framework for technology leadership, which emanates from reflections on the case study of FPS.

As sustainability depends on the perturbations a system can absorb without detracting from strange attractors as well as the degree to which the system is able to self-organise and build capacity for learning and adaptation (Folke, 2006), this framework focuses on the importance of indirect roles technology leaders can play in sustaining the use of technology which eventuates in student-centred learning. They are:

1) ensuring information that stems from the complex and dynamic cross-scale ecological interactions can reach locally interacting heterogeneous agents;

2) encouraging reflexivity on the abovementioned interplay of influences so that actors at the micro level can also be attuned to making decisions based on systemic considerations;
3) collectively create alignment among all nested sub-systems through constant adaptations so that dynamic needs at the individual, organisational, professional, national and global levels can be met.

The abovementioned alignment refers to making ecological coherence in philosophical, pedagogical, structural, political, technological and capital (social, human, financial, cultural) aspects (See Figure 6.1). As changes in the multi-level system over time (such as the 4 phases stated in Chapter 4) can have ramifications throughout the system, any alignment is transient. It is therefore important that the school as a complex adaptive system keeps itself nimble based on the nature of changes.

The "novel order" that could emerge from the above indirect interventions of coherence-making include: a pervading culture of self-renewals and creative adaptations, as manifested in Dede (2006) and Coburn's (2003) argument for "depth" (teachers changing practices), "sustainability" (sustained scale growth), "spread" (more classes coming on board), "shift" (change in ownership) and "evolution" (original designers rethink model based on adopter's feedback); increased capacity for learning and collective sense-making across a whole spectrum of re-design work:

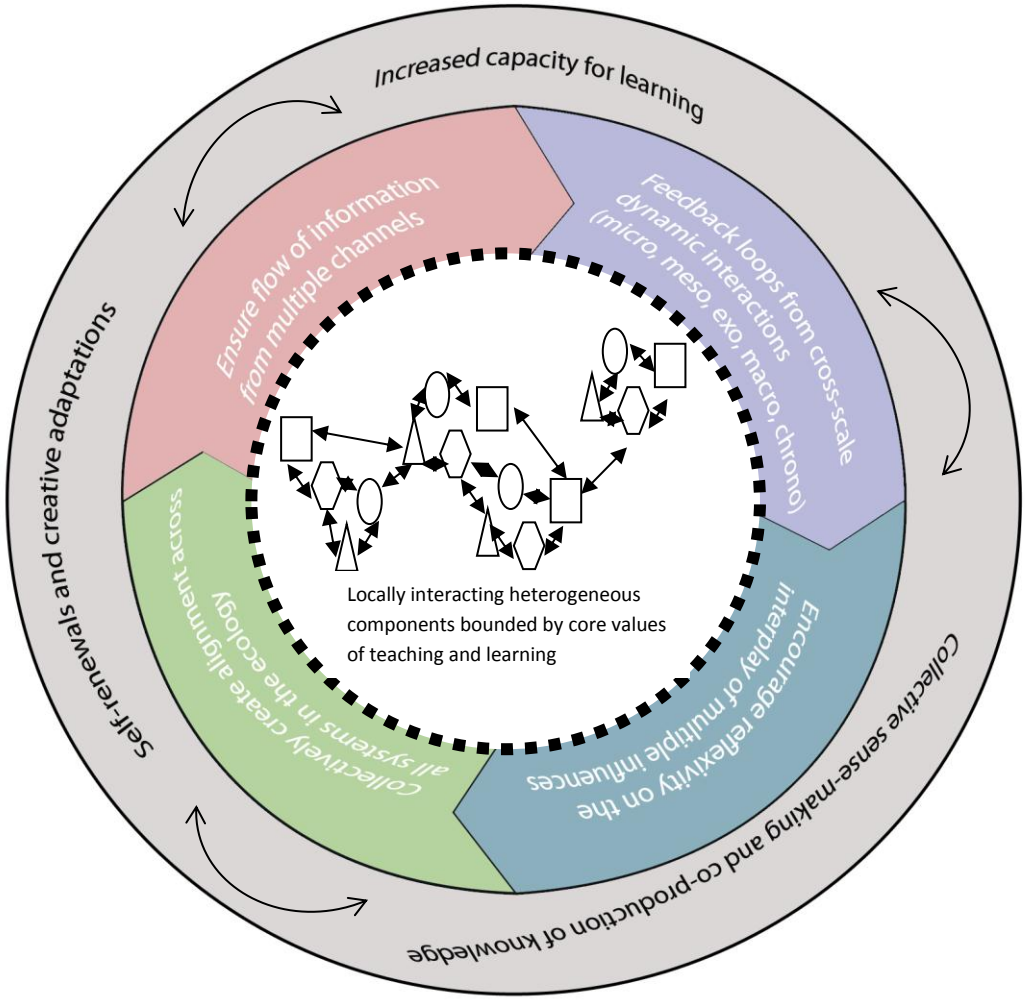

Figure 7.1 A complexity-informed framework for sustaining ICT innovations

planning, designing, executing and evaluating instructional and organisational practices. These three outcomes form a virtuous learning loop: collective sense-making and knowledge co-production can help a system as a whole respond to the environment more intelligently; such knowledge augments the system's capacity for learning and injects buoyant energy for self-renewals, leading to the sustainability of using ICT for student-centred learning. Although the framework can be used for non-ICT innovations, it stands out in greater relief in the domain of technology

leadership due to the constant need to monitor for right fit between fast-changing technology, resource readiness and new pedagogies.

Although FPS had sustained the use of ICT for student-centred learning, high visibility and exposure to media due to its success had created a strain on school resources. Teachers and administrators had to spend additional time for high-profile publicity endeavours, which were not directly relevant to teaching and learning – a new challenge that needs to be addressed as diffused energy can undermine the clarity of purpose that led to FPS' achievement in the first place. In addition, the professional development sessions, although encompassing in terms of covering the technicalities of lesson delivery, did not emphasise enough the pedagogical rationale of the ICT-based innovations in schools which could affect teachers' motivation level and fidelity of innovations (meeting minutes, MM110629).

Overall, FPS' trajectory of ICT development shows how "chaos" brought about by perturbations of ICT usage can co-exist with the "order" of focusing on teaching and learning actualized by 1:1 computing and making structural changes. It also shows how sub-systems with "bounded instability" can self-organise, albeit to different degree (Arts and Sciences department). The interactions between multi-scale systems demonstrate the co-evolution of environment, structure and nature of collaboration amongst actors. The general guiding principles for policymaking can be arranged according to the three principles of complexity theory, as depicted in

Table 7.1.

Principles of complexity theory	Implications on sustaining innovations as informed by complexity theory
Both order and chaos co-exist in a complex system	• Change should be embraced and ambiguities tolerated as the system undergoes re-organization. • Chaos at the edge of the system can create "creative tensions" and lead to new perspectives.
Complexity depicts the world as self-organizing, non-linear and interconnected	• When problems challenge the sustainability of projects, it has to be examined from the systemic perspective. • Foster as many "ecological coherence" as possible so that the sustainability of the projects can create profound impact on teaching and learning. • Monitor and follow-up on bottom-up and top-down actions as one action may have unexpected ramifications on other aspects of operation. • Building collegial people-oriented relationships can facilitate self-organisation as consensual outcomes can be reached alongside with prompt re-configuration of the system.
Co-evolution of both actors and more-than-human context (technology, structure of schooling etc)	• Being cognizant of institutional memory and co-scanning the external environment can help the school understand its bounded context and develop its potential. • Ensure there is healthy feedback mechanism both within and beyond the school context. Encourage heterogeneous voices at multiple levels of the systems. • Innovation can be "messy" but clear lines of communication needs to be established to expose weaker links timely. • Inter-dependence is the key word so that all parties can sustain the collaboration. Over-reliance may drain partners and threaten the sustainability of projects. Working in isolation may impede flow of critical information which affects survival of project. Wheatley (2006) talks about having both "emotional investment" and "psychological ownership" to make innovations become a personal reality (p68). • Capacity-building is one potent way to change the dynamics or power imbalance present in the evolutionary process.

Table 7.1 Implications on sustainability of innovations informed by complexity theory

The three principles included in Table 7.1 can be condensed into the salient theme of "understanding and working with change". Taking FPS as an example, the transformation happened over time based on the emergent and iterative feedbacks along the trajectory. Neither the first nor current principal had a very clear ecological view of what the transformation would or should looked like. In the early years, innovations were discrete and small-scale. If there was an important turning point, it would be year 2005 when the then-and-new IT HOD, together with Carl reviewed FPS' IT roadmap and realised the school had to be: 1) more focused in its IT pursuits and 2) create more impact on learning and teaching (instead of just containing benefits of IT innovations within experimental classes). With that insight, the school decided to focus on 1:1 computing and develop whole-school mobile learning fieldtrip programme. Even so, there was a lack of clear pedagogical direction during that time. It was only recently in 2010 that an overarching curriculum and pedagogical framework (TfU and Skilful Teacher Model) were established. Thus, the school did not start with a very coherent map in the first place. The trajectory was shaped along the way by multi-level influences: national policies, distributed leadership, researchers' evidence-based inputs, parents' expectations and teachers' agency. The vision became clearer only during the exposition phase.

Although there was no "fixed" plan in the beginning, one common thing ran through the whole trajectory: School leaders made decisions based on students' welfare, and technology should not supersede teaching and learning. However, that

did not mean FPS' development was entirely "serendipitous" as the leaders still played a vital role in providing the right conditions for effective feedback mechanisms as well as innovation and reflective culture to be established. In particular, the leaders, having proximal access to external knowledge had to ensure actors in school would have access to such knowledge. The school as an organisation can then collectively internalise and co-produce knowledge in the form of providing a response that best fit the in-situ contextual needs of the school.

7.2 Implications for middle managers and teachers

The literature on sustainable leadership highlights the importance of "making what works explicit and by enabling more and more leaders at all levels of the system to be aware of the conditions that energize themselves and those with whom they work" (Fullan and Sharratt, 2009, p176-177). In other words, policymakers in schools have to strive to ensure ecological awareness rests not only within the upper echelons of hierarchy, but distributed throughout the system.

In FPS, this ecological awareness was fostered through collective sense-making endeavours facilitated by principals, HODs and in particular, middle managers who were empowered by HODs to make decisions and acted as conduits between teachers and upper management. With empowerment comes accountability. Whilst distributed leadership and shared accountability can be observed in the aspect of decision-making process coalescing around innovations, the middle manager had

to be accountable when departmental goals were not met (Han, interview, INHN 100531P2280). This placed middle managers in a predicament, perhaps best exemplified by Jamie, the middle manager of Sciences department. She was concerned that her collegial relationship with colleagues would be corroded if she regulated the teachers too much, leading to the loss of "soft" powers to move things forward (journal record, JR 110708).

Such concerns can be mitigated if the whole school adopts the consultative approach. Whilst the school may hold the middle managers accountable, this accountability should manifest in the form of allowing them to flesh out the ecological conditions that impeded the department from reaching the goals, rather than in the form of penalisation. Affirmations should be given to middle managers who are able to connect ground sentiments, identify gaps and propose ways to achieve ecological coherence. In the spirit of emergence, the middle managers should strive to understand what would intrinsically motivate the teachers to self-organise into communities of shared interests, instead of mandating changes or policing activities. The focal points are on enabling communication and promoting respectful sharing of multiple perspectives instead of perpetuating groupthink. These of course, have to be synergistically supported by an upper management who believes in empowering people and not merely passing the buck. They should have genuine interest in finding out the various influences underpinning teachers' actions and subsequently provide further resources to support the teachers.

One of the assertions that arose from Chapter 4 is that teachers are mainly driven by pedagogical motivation when using technology. However, teachers' pedagogical and epistemological beliefs tend to differ widely in a school. Some may have limited knowledge or reservations about student-centred learning and thus are not able or willing to incorporate this pedagogy into their repertoire of teaching strategies when using technology. The question then would be should we "wait for the stars to line up" and ensure mindsets are changed, culture established and elaborate professional development sessions put in place before teachers use technology for student-centred learning? More importantly, will all these efforts still be futile since Cuban (2008) contends that if marked changes in teachers' pedagogy should occur, it is because teacher beliefs are predisposed towards student-centred learning and not that technology promotes pedagogical changes?

The empirical evidence provided by FPS however showed that teachers such as Janis and Sherry were not equipped with rich technological, pedagogical or content knowledge when they embarked on projects. Their journey to incorporate student-centred learning was fraught with tensions. Their doubts, fears, interaction patterns and instructional strategies in classroom both shaped and were shaped constantly by the feedback from students, colleagues and researchers. During interview, Sherry whom was initially highly sceptical articulated that she witnessed for herself the power of student-centred learning as some of the students who were labelled as low achievers shone when given opportunities to construct meanings through

science experiments and other activities that allowed them to demonstrate their prowess of reasoning. They were also more independent in terms of sourcing for information with their technological tools and reconciling the different perspectives they surfaced from the search. As students started to immerse themselves in the new inquiry mode, they also built Sherry's confidence in the pedagogy (interview, INSH 100826566). Janis, who started the journey one year earlier than Sherry was also very positive about how the use of technology had changed students' learning and her own teaching practices (interview, INJA 10041223). This contradicted Cuban's (2008) argument that it would be unlikely for technology to promote pedagogical change.

The implication is that it is not necessary to wait for change of mindset before teachers make attempts to enact student-centred lessons. Both Janis and Sherry adopted the "just-do-it" mentality and were transformed during the journey of co-evolution with students. They were constantly aware of how the pedagogical changes affected their students' learning and the resulting impact on their pedagogical beliefs. All these entailed retrospective examination. However, teachers still need support in terms of receiving feedback on their teaching practices either from colleagues or evidence-based research. Herein lies the roles of key leaders which is to enable these mechanisms for intellectual debate.

7.3 Conclusion and future research

This thesis revolves around the study of how FPS had responded longitudinally to the movement of using ICT for student-centred learning. Despite the ephemeral nature of technology development, the use of technological tools in the school had not exhibited signs of languish over the decade. What emerged from FPS' ecology as a result of the school's effort to build cumulative critical connections can be broadly categorized as such: enhanced self-renewal capacity for adaptations and learning, more buy-in for reforms and sustained use of ICT for student-centred learning. The success story of FPS bespoke the importance of adopting a "holistic, connectionist and integrationist view" of reform and the "spontaneous reorganisation emerging from the interaction of elements" (Morrison, 2002, p7) explicated by complexity thinking.

Pondering upon how apt complexity theory is in terms of framing this study related to the sustainability of student-centred use of technology, I am of the view that it is a very powerful lens in leading us through the thicket of complexity by explaining the inter-connectedness of factors confronting the changes and continuity of innovations in a complex adaptive system like a school. However, I am also left with questions which cannot be answered within the paradigmatic use of complexity theory. Both Terrence and Carl were perceived as visionaries and had subscribed to the use of 1:1 technology. However, they had promoted the notion using different leadership styles. Terrence reinforced shared accountability whereas Carl

emphasized efficiency to get bottom-up innovations going. Would the focus on efficiency in the infancy stage of technology usage be necessary to ensure early success and strong foothold in this niche area? Would Terrence's democratic style be more apt during the sustainability and consolidation phases where catching the imagination of a bigger pool of willing champions is perhaps more important? Also, Carl did not foreground formal documentation and evaluation of learning gains whereas Terrence placed high emphasis on both. Would downplaying formal documentation and evaluation, both of which are resource intensive, be conducive in encouraging the uptake of innovations in the early phases?

In addition, are we able to pinpoint what kind of specific conditions are needed to enhance the use of technology at each of the four phases of evolutionary process depicted in Chapter 4? Complexity theory did not proffer much inspiration in answering such questions since it is not prescriptive in nature, nor does it subscribe to the possibility of linearity where actions and processes can be predicted, dissected and coordinated along a pre-determined trajectory. However, FPS' success seems to attest to Lemke and Sabelli's (2008) proposition that early successes and widespread commitment are critical determinants of sustainability too.

Another limitation is that the analysis of massive ecological factors has proven to be challenging and the line between careful interpretations of what is meaningful and naive reduction of information-rich analysis can be unclear at times. This was

partially addressed by reinforcing the trustworthiness of the research such as triangulating different data sources and situating the findings in literature to identify salient points. As with most single case studies, seeking direct replication or generalisation of the findings to other contexts is likely to be futile, but this is overcome by providing verisimilitude of the case school so that analytical generalisation is possible. As complexity emphasises holistic depiction, it is aligned with the notion of providing thick description.

With regard to data collection, whilst I made a conscious effort to observe consistency in the data collection process, circumstances did not always permit this. For example, although one to one interviews with all targeted interviewees was preferred; compromises had to be made due to conflicting schedules, staff movement and respect for interviewees' wish. I was thus compelled to leverage on serendipitous and opportunistic occasions to conduct interviews during seminar breaks, along the corridor or at the canteen. A considerable amount of time was spent on selecting interviewees but regrettably not all invitations for interviews were accepted. There were cases where one to two key leaders left the school and it became difficult for me to arrange interviews with them. To overcome these limitations, I either triangulated the data with other interviewees or relied on alternative data sources such as video clips and document analysis to understand their viewpoints.

As for future research, since this study is based on just one case school which focused on the use of 1:1 computing, researchers who wish to explore the robustness of complexity theory in understanding change process and sustainability of technology-related innovations can look at more meta-longitudinal studies and to look broader beyond the setting of 1:1 computing to distil the salient essence of sustaining technology-related reforms. It would also be useful if future research can explore the inter-relationships between sustainability of projects and the stakeholders' perceived impact of such sustainable use of technology on teaching and learning.

Other promising lines of research which I would have pursued if resources had permitted include: 1) finding out whether FPS' critical success factors would be transferrable to the new school which Carl had been posted to. According to Carl, he had also promoted the use of 1:1 computing in his new primary school, albeit using a different model by utilizing free Web 2.0 technologies since the school did not enjoy generous funding to procure various 1:1 mobile devices like FPS. Given the fact that Carl was previously from FPS and had been attuned to the ethos of technology-enriched school, the results would illuminate whether FPS' relative success can be cascaded to other aspiring schools with limited funding but strong technology leadership; 2) I would also like to continue to investigate whether FPS' success in one of the projects can be scaled to four other sister schools with no strong technology background through the championship of their teacher activists

who have been attending a series of professional development courses conducted by FPS for this purpose. Opportunities to examine the challenges of sustainability and scaling beyond the context of FPS abound, which may perhaps provide insights to Dede's (2006) thought-provoking question on how ICT innovations can possibly be sustained in various inhospitable conditions.

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