Studies in Singapore Education: Research, Innovation & Practice 3

Elizabeth Ruilin Koh
David Wei Loong Hung *Editors*

Scaling up ICT-based Innovations in Schools

The Singapore Experience

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Foreword

One commonly accepted position is that the ultimate purpose of education research/innovation is to instigate change in the learning and teaching practices, so that student learning can improve. The success of a funded education research/innovation project is therefore linked to, at least in the mind of most policymakers, the quantifiable impact or the extent of improvement in student learning that the project/innovation can bring about. In order to maximise the improvement in the learning of the participants, an innovation must therefore be targeted and fit for purpose.

If we extend this to the systems level, then an extremely successful research/innovation project must be not only effective in improving student learning among participating students in the participating schools, but must also contribute directly to the improvement of the learning of other students in the other schools within the school system. The demand for impact therefore lead to many research programmes requiring the Principal Investigators of funded projects to explicitly planned for the scaling up and sustainability of their innovations in many diverse contexts beyond the study sites.

This requirement can pose substantial challenges to the Principal Investigator as there is a tension to design an innovation that is not only specific but also general, i.e. can optimise both local impact (in the participating schools) and global impact in many other schools. As learners differ by prior experience, socioeconomic status, race, interest, etc., and the contexts they are in, it is unlikely that a learning innovation that is implemented rigidly with absolute fidelity can be relevant and effective to diverse groups of learners across diverse settings. Successful scaling of an innovation therefore requires the clear identification of its 'active ingredients' which needs to be scaled with fidelity and also of the other discretionary components which can vary according to the changing contexts.

Besides focusing on the underlying technologies and mechanisms that constitute the innovation itself, it is also important to understand the external barriers against and facilitators supporting the scaling of specific innovations and of a group of innovations, such as ICT innovations. Theories and frameworks can then be distilled to guide future scaling effort so that the enabling conditions can be fostered and the impediments removed.

This collected volume on Singapore edulab presents the larger purpose and context of setting up the research programme, and the specific product, process and people involved in a curated sample of funded eduLab projects. It shares rich experience and draws insights about the design of ICT innovations and broader considerations for scaling, including organisational culture and leadership. These are useful for all policymakers, practitioners and researchers who can use them to guide their efforts in designing effective and scalable ICT innovations and in planning for their implementation and scaling. The SCAEL model that is proposed by the volume provides a good starting point to investigate how the contextual issues related to the scaling of innovations can be framed and analysed. It also opens up a fertile ground to further interrogate issues related to scaling which are ontological in nature, such as what is the purpose of scaling, and who should decide what the purpose of scaling is.

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Preface

Technology is essential in our everyday world. We reach for devices multiple times per day. Our workplace is one where laptops and desktops, projector screens and smartphones dominate. Yet our classrooms remain largely unchanged with whiteboards and workbooks. However, this has changed in incremental ways in Singapore with the Ministry of Education (MOE) implementing tools such as the Student Learning Space (SLS) and with our Office of Education Research at the National Institute of Education seeding various pedagogical innovations in classrooms across schools over the past decade. This would not have been possible without the eduLab funding provided by the Ministry of Education and we are very thankful for their support. The eduLab initiative aims to grow and nurture ICT-based learning innovations that have the potential to be adopted and adapted by multiple schools in a widespread manner across the system.[1]

In more recent times, the technological landscape within classrooms and schools, and systems, affecting teachers, students and school leaders, has evolved with the rapid rollout of home-based learning in Singapore. All schools were shut due to the COVID-19 viral outbreak in Singapore. This coronavirus is a severe acute respiratory disease which is very infectious, with massive flu outbreaks occurring around the world. This pandemic has resulted in shutting of workplaces, schools, malls and all activity spaces where people congregate. Due to the disruption, students and teachers are adopting technological means of learning more so than ever. Students are utilising video calls, SLS and submitting homework in multimodal ways through Google classrooms. We are harnessing ICT tools for learning because of pressing circumstances.

However dire the situation may be, the silver lining to be gleaned from this situation is the presentation of an unique opportunity for greater adoption of ICT-mediated innovations in the classroom, and is an extremely promising step to pave the way for the introduction of ICT innovations in classrooms. Moreover, schools in Singapore

[1] NIE (2017). Edulab Funding Programme. Retrieved from: https://www.nie.edu.sg/research/apply-for-grants/edulab-funding-programmex.

are no strangers to ICT innovations as many of these have already been explored and implemented at various levels of scaling in the Singapore education system due to earlier work from the edulab initative and other endeavours. This book offers recommendations and a model of 'SCAEL'ing that proposes a method of spreading and sustaining innovations as an iterative and organic process involving the development of people capacity and resourcing as the main drivers in sustaining change.

One of the thrusts of our strategic vision in Singapore is to deepen the pedagogical use of ICT to transform student learning. This is achieved by building the capacity of teachers, key personnel and school leaders, through partnership at schools and MOE HQ.[2] Organised by the Singapore context in the micro-, meso- and macro-layers, this book focuses on the *how* of innovation sustainability due to Leadership from the Middle efforts, the *why* of the difficulty of education change such as due to cultural-historical reasons, and the *what* of the various technology-based pedagogical innovations explicated in this book. In this book, we discuss ICT innovations and showcase specific ICT-based innovations, the close tripartite relationship between policy, schools and researchers, how that translates to implementation of innovations in schools and the ways they have spread through the education system. Close partnership with MOE is key for fostering research-practice nexus concerns as a system.

In addition, we highlight the different diffusion models of innovations through the system in this volume. The ecology of the school system in Singapore and their interactions between each layer of the subsystem (micro, macro, and micro) has been studied in this book in tandem with the ICT-based innovations implementation. We surmise that the entire ecology, i.e. levels, people, process, product and outcome of the system, is co-dependent on the sum of its parts to function. Each function is integral to the whole system in order for the ecology to operate. We found that teachers' professionalisation was a continually evolving process, with upwards, downwards and sidewards percolation through systemic leadership, mitigating power distance and apprenticing leadership through structures like communities of practices.

Singapore has long been likened to an ideal 'testbed' for innovation with a model system for the incubation and implementation of novel ideas. With our size, efficiency, close tripartite policy-practice-research relationship, rapid and agile developments can be implemented with relative speed and fidelity in our schools. Thus, we wish to thank all who have made this book possible—the chapter authors who are the researchers on ICT-mediated innovations, the school leaders, teachers and students participating in these efforts, MOE officers and other stakeholders who have played a role in one way or another. We hope to continue spreading and sustaining successful ICT-based innovations. We also harbour aspirations of providing insights into the implementation, sustainability and spread of techno-pedagogical interventions so

[2] Education Technology Division (2020). Education Technology. Retrieved from: https://www.moe.gov.sg/about/org-structure/etd.

that researchers, students and policymakers from the international and local communities can be informed about our perspectives. May lessons from the Singapore experience inspire our readers to explore, implement and scale such evidence-based ICT practices and innovations within their schools, districts and systems.

Elizabeth Ruilin Koh
David Wei Loong Hung

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Part I
Introduction—The Singapore Context

Chapter 1
ICT-Based Learning Innovations for the Twenty-First Century in Singapore: Scaling Change Through Apprenticing and Ecological Leadership

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Abstract ICT-based learning innovations have augmented learning in many ways; however, scaling innovations are complex. Scaling in education is not a linear replication of products but an iterative process with an emphasis on the capacity of people. To provide further insights, a case study of the spread of a learning initiative in Singapore is elaborated on. The resultant findings build on a translational and scaling framework, developed by researchers at the Office of Education Research (OER), NIE. The framework, Scaling Change through Apprenticing and Ecological Leadership (SCAEL), is a context-sensitive model demonstrating the approaches that learning innovations can diffuse and spread through the multiple leadership roles of stakeholders in the ecological system.

1.1 Introduction

With waves of technological advances, education researchers all around the world have harnessed the affordances of ICT to develop ICT-based learning innovations to augment and refine learning in many ways. Similarly, in Singapore, many ICT-based learning innovations have been developed over the years to buttress students' learning in various subjects in formal learning and informal learning. The development of ICT-based learning innovations in Singapore has been aided by several initiatives including the government-led ICT masterplans for education as well as national funding for education research. The Singapore education system is one that is inextricably tied to the history of the founding of our independent nation. From days of industrialization, when economic survival prompted Singapore to model the educational norms of industrialized nations, the education system has, since the very

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beginning, focused on developing human capital. In other words, the support for such learning innovations is driven by the nation's emphasis on education, stemming from the founding years of Singapore.

In recent years, education researchers at the National Institute of Education (NIE), Singapore, have spearheaded a large number of these ICT-based learning innovations. Many of these innovations have enabled teaching to be more inquiry-based, classrooms to be more explorative, and students to play and dream more. Many of these innovations were supported by research grant funding that specified the use of ICTs and the potential scaling of these innovations, namely, the eduLab funding program.

Scaling is complex and in this chapter, we posit that the basic premise of "scaling" in education is not a linear replication of products but an iterative process with an emphasis on the capacity of people which can be built upon through lived experiences at every locality where the enactment(s) is at hand. Every school is a local entity in the innovation "scaling" process, and serves as communities for learning for both the students and the teachers, both within each school and across schools. Thus, the ecosystem for learning consists of intra- and inter-communities. Within the school, the intra-communities consists of Professional Learning Teams (PLTs) and in inter-communities, they consist of school-to-school networks (STSN) such as Network Learning Communities (NLCs) and Professional Learning Communities (PLCs). The interactions between intra- and inter-communities consists of brokering, facilitating and sharing capacities, lived experiences, interactions, and enactments.

Singapore's education system is marked by centralized decentralization, where schools (and accordingly, teacher leaders) are empowered to make autonomous decisions regarding curriculum innovations, practices and their spread, and sustainment. Moreover, there is need to go beyond "teachers" to that of "schools" as networks which can support each other. In such a context, what are the enablers of scaling ICT-based learning innovations?

To provide some insights, a case study of a learning initiative in Singapore is introduced and described. The resultant findings build on a translational and scaling framework, developed by researchers at the Office of Education Research (OER), NIE. The framework, Scaling Change through Apprenticing and Ecological Leadership (SCAEL), is a context-sensitive model demonstrating the approaches that learning innovations can diffuse and spread through the multiple leadership roles of stakeholders in the ecological system.

This chapter begins by introducing eduLab, the funding program for many of the ICT-based learning innovations. It will then briefly review concepts involved in the scaling of learning innovations in the ecological system. Schools consist of school leaders, and we will elaborate on the dialectics between teacher leaders and school leaders, positing a concept referred to as leadership from the middle. Next, the background of the case study, methodology, and findings will be elaborated on. To conclude, we will discuss the findings and present the SCAEL framework.

1.2 Supporting ICT-Based Learning Innovations for the Twenty-First Century in Singapore: EduLab Funding Programme

In order to boost the development of educational innovations aligned with the aims of the fourth Masterplan for ICT in Education (Education Technology Division, 2015), Singapore's research grant agency, the National Research Foundation, started a funding program called eduLab. This fund encouraged educational practitioners and researchers to develop ICT-based educational innovations that are intended to spread and scale amongst schools (MOE, 2019). Teachers, researchers, and other Ministry of Education officers can participate in the program to develop ICT innovations for learning that can potentially be adopted or adapted by different schools across the system (Education Technology Division, 2017).

One of the criteria for the funding program is that it needs to feature a technology-based innovation which is guided by teaching and learning pedagogical practice in Singapore classrooms. Another integral feature is that the innovation must have a deliberate intention to scale and be sustained as part of its goals (Education Technology Division, 2017). At the onset, the proposals submitted for the eduLab grants must have at least two partner schools which would be willing to participate in the innovation implementation and scaling. Teachers and schools are expected to play a key role in the development and design of the innovation project. This would raise the ownership and chances of sustainability of the innovation project beyond the funding period of the project. This will also add to the capacity building of the teachers and the school in managing innovation projects.

1.3 Scaling Learning Innovations: Leadership from the Middle in the Ecological System

Scaling learning innovations is a complex endeavor, no less ICT-based school innovations. It requires the efforts of many different stakeholders notably the crucial role of middle leadership (Fullan, 2015; Harris & Muijs, 2004; Toh et al., 2014). Leadership from the Middle (LftM) can be briefly defined as "a deliberate strategy that increases the capacity and internal coherence of the middle as it becomes a more effective partner upward to the state and downward to its schools and communities, in pursuit of greater system performance…" Fullan (2015, p. 24). Leadership from the Middle (LftM) was conceived by Fullan (2015) in the context of school improvement and emphasizes the important middle layer in school systems that allows for a community spread of school improvement initiatives. In a whole system, the middle provides an avenue for a middle out community growth model, which can spread up and down (Fullan, 2015). For instance, in the context of a school district, schools (and hence, school leaders) are this middle layer between district leaders and students.

Similarly, Harris and Muijs (2004) elaborate that the middle layer, teacher leadership, involves fundamental shifts in the purposes and practices of the school with regarding beliefs, structures, trust, rewards within or on behalf of the school, and is closely related to re-culturing. Teacher leadership in school improvement requires the building of trust and development of rapport among stakeholders, diagnosing organizational conditions, dealing with change processes, managing work processes, and building skills and confidence in other stakeholders (Harris & Muijs, 2004). Echoing this is Poekert (2012) who identified that teacher leadership is a "job-embedded professional development" (p. 185) that is integral to ongoing school improvement, such as spreading ICT-based learning innovations. In sum, LftM is about cultivating teacher leaders through networked learning communities, developing teachers' adaptive expertise, and developing innovation championing by teacher leaders.

Building on the LftM growth model, Toh et al. (2014) delineates two parallel and simultaneous avenues of community growth in the spread of learning innovations—apprenticing leadership and ecological leadership. Apprenticing leadership refers to the horizontal aspect of teacher leadership which encourages peer-to-peer professional learning and support. This is akin to coaching relationships where dialogic peer coaches build the capacity of teachers as collaborative inquirers in a responsive capacity situated within their shared teaching contexts (Charteris & Smardon, 2014). On the other hand, ecological leadership is the vertical aspect of teacher leadership which emphasizes the alignment of multiple levels or subsystems of professional learning and support in the system ecology. Besides being ecologically aware at the meso and macro contexts of educational practice (Bottery, 2004), ecological leaders "exhibit initiative to coalesce or juxtapose apparently discordant orientations within and across different subsystems of the ecology" (p. 836) allowing them to succeed in the diffusion and scaling of learning innovations (Toh et al., 2014). These efforts forge alignments and convergences in the different layers and mitigate system paradoxes as well as local and cross-school tensions (Toh et al., 2014). Through apprenticing and ecological leadership, teacher-leaders provide crucial horizontal and vertical alignments for professional learning and support to enable the spread and scale of learning innovations. They are key levers within the network and enable the building of capacity at individual, school, and system levels for learning innovation diffusion.

This LftM can be seen across the ecological system—system/policy, cluster, and school subsystems. These three subsystems are also known as Macro, Meso, and Micro layers, with a capital "m," respectively, and collectively as 3 M layers. Broadly, at each of 3 M layers, the stakeholders experience different tensions. For example, at the Micro layer (of schools), there is a performance versus process-inquiry tension that can be mitigated by leadership that supports teachers who experiment with new inquiry practices through the possible implementation dip (Fullan, 2001). Teachers are able to experience epistemic shifts for sustainable change at the classroom levels through open classrooms. At the Meso layer (of clusters), there is an experimental versus sustainability tension where partnerships form "connections" across schools, e.g., the cluster model is able to optimize and enable carryover effects (Koh & Hung, 2018), in particular, apprenticing leadership for epistemic learning at the cluster and ecological leadership for percolating upwards to inform innovation efficacies and outcomes. At the Macro layer (of system), the policy versus practice tension means that positioning teacher leaders (innovation champions) at appropriate levels of the system are needed to enable the diffusion process. An epistemic carryover happens when they see shifts, and they see teachers working at not just school level but at the cluster level (Koh & Hung, 2018).

1.4 Case Study Background

The phenomenon of this case study is the Cluster Deep Learning Initiative (CDLI) that began in 2015. The Ministry of Education's Educational Technology Division (MOE ETD) was rolling out the ICT Master Plan 4 (MP4) for 2015 and beyond with the theme of "Deepening Learning, Sharpening Practices: Preparing students who will be Future-Ready & Responsible Digital Learners." It had the espoused goal of enabling quality learning in the hands of every learner empowered with technology. In line with enacting MP4 at the cluster level (schools in Singapore are organized in clusters), one particular cluster's superintendent (Mr CS) and his cluster steering committee (known as Deep Learning Committee) initiated School-Based Leadership Teams to gather vice-principals, Head of Departments (HODs) of ICT, and HODs of subject disciplines from the cluster schools to create awareness about deepening learning and sharpening practices. They began looking at the school-readiness metric(s) in adopting ICT (of schools) to share good practices among the schools with the envisioned goal of levelling up everybody in the cluster (schools, teachers, students).

This CDLI concurred with a 3-year eduLab project on "Making the Invisible Visible in Science" (MIVIS) seeded by NIE researchers in two of the schools in the CDLI cluster, TT Primary School and ZZ Primary School from 2015 to 2017. These two schools began their collaboration in redesigning lessons in Primary 3 Science Plants and Fungi to make the invisible visible in Science in alignment with the "5E" Inquiry model with subject-matter expertise support from NIE researchers to facilitate the discussion sessions among the teachers. The success of the MIVIS project was evident at three levels within the school subsystem (Micro level)—students, teachers, and school. Students developed better observation and thinking skills and deepened their conceptual understanding in the Science topic on Plants and Fungi through more inquiry. Students are equipped with portable ICT devices to interact with digitally captured artifacts within and beyond classrooms, e.g., in the eco-garden within the school premises. Teachers developed their competencies as designers of inquiry and reflective practitioners. Schools (in the cluster) deepened inquiry practices for Science and spread inquiry principles to other subjects such as Mathematics alongside the "I CAN" Math program that was rolled out by MOE in the schools.

At TT Primary School, the inquiry practices spread from two classes of Primary 3 Science to the whole level approach at Primary 3 and Primary 4 Science with deepening in Science inquiry pedagogy in the past 3 years. At ZZ Primary School, the inquiry practices spread to a whole school approach with a technological stance leveraging on ICT affordances such as NearPod and redesign of the Science curriculum and scheme of work with interdisciplinary subject integration for a holistic approach in formative assessment and performance indicator of students' inquiry learning in selected Science topics. For example, through a Science and Art department collaboration on the topic of "Light and Shadows to produce a puppet show performance by students for assessing outcomes of students" learning with practical application of scientific concepts of light source, size, and shape of shadows and art concepts of puppet making and shadow play.

1.5 Methodology

The case study methodology was adopted to derive rich insights on the multiple level phenomenon. Data was collected in the form of interviews, observations of meetings and lesson enactments, and artifacts of interactions. Interviews were conducted with the cluster superintendent, school leaders, key personnel such as the head of department (HOD) and school staff developer (SSD), lead teacher (LT), and teachers who participated in the CDLI journey. Observations were documented during core cluster steering committee meetings, post-Strategic Planning Instructional Design (SPID) network learning community meeting, Primary Science School-Based Project Team (SBPT) school-to-school network meetings, professional learning communities/teams (PLCs/PLTs), lesson enactments, and online google sharing platform for school-based project teams (Primary English, Primary Science, and Secondary Geography).

The observations of NLCs, PLCs, and PLTs at respective schools were carried out over a 6 months period. NIE researchers played the role of a participant-observer where they observed as well as shared insights and perspectives as a critical friend walking alongside participants. Researchers also reviewed and analyzed participants' artifacts such as students' work following lesson enactments.

In addition, three monthly NLC sessions for Science SBPT were observed with the sessions facilitated by the vice-principal of CC Primary School, Mr JP in the first session, followed by Lead Teacher, Mr CBY in the next two sessions. Weekly PLC/PLT sessions were observed at TT Primary School for six sessions and CC Primary School for five sessions. NIE researchers observed lesson enactments of two teachers at CC Primary School and two teachers at TT Primary School. The teachers adapted the lesson design on Primary 4 Science IBL Light to contextualize to the needs of their respective schools and students' profiles that ranged from low, mixed to high ability learners in the four classes of Primary 4 Science students.

Data collected such as field notes and transcripts were analyzed through open coding and thematic analysis among various researchers. With the analysis, we appropriated the themes and re-analyzed the data. We also confirmed with the interviewees whether our interpretations were as espoused.

1.6 Findings

In addressing the question of enablers for the scaling of ICT-based learning innovations, we describe the role of the various stakeholders in the ecological system from the case study.

1.7 Role of Cluster Superintendent at the Macro Layer (System/Policy)

At the macro layer, the cluster superintendent played the critical role of a broker in balancing policy to practice, engagement of school leaders at cluster level, scaffolding socio-technological structures, facilitating cluster board management meetings, and bringing everybody together in the cluster to learn together with opt-in basis to cluster project initiatives. The cluster superintendent invited schools on-board based on their readiness to build partnerships at school-to-school network level leveraging on cluster structural supports. He likened the deep learning journey to a "train stopping at stations." In the 3 years, he worked with his Deep Learning Committee (DLC) towards an envisioned goal of levelling up every school in the cluster, every school to be in step. With the shared belief of training a core group of people to drive the evidence-based practices for mind-set shifts, the cluster project initiatives that began with School-Based Leadership Teams (SBLTs) comprising of key personnel (KPs of the school) for creating awareness in schools evolved into SBPTs with embodied engagement of teachers alongside their HODs for deeper gathering of critical mass as agents of change in the classrooms. In the process, we see the vital role of leadership from the middle for sense-making to balance policy implementation to practice in the classrooms. Cluster structures formed nascently by the cluster superintendent helped to prime cluster readiness for adaptive changes in practices at schools and classrooms level.

1.8 Role of School Leaders and School-Based Leadership Teams (SBLTs) at the Meso Layer (Cluster)

In enacting the CDLI, various school leaders joined the DLC, systematically planned with the cluster superintendent, and coordinated with teachers in their schools and across schools. The DLC started with the joining of the vice-principal of *CC Primary School*, Mr. JP, who oversees the HODs ICT in the cluster in 2015. The DLC started looking at the schools' school-readiness metric for ICT adoption for the respective school to invite schools to share good practices in the cluster in three domains of leadership, teacher use, and students use in the entire domain for adopting and sharing of learnings from implementations in their schools. In 2016, principal of TT Primary School, Mdm CPP joined the DLC as chairman of DLC. In 2017, principal of BB Secondary School, Mr. MZ joined and replaced Mdm CPP as chairman, who still remained in the DLC. Subsequently in 2018, vice-principal of SM Secondary School, Ms. LL and the new principal of TT Primary School, Mr. WJW joined the DLC, replacing the former principal, Mdm CPP who moved on as principal of another school in another cluster.

The DLC systemically planned for a 3-year plan to scale the cluster project upwards for scaling up the schools. In the first year (2016), they looked at Phase 0 where everybody starts from the same ground with SPID training and some innovations taking place in certain schools. In the second year (2017), they looked at how they can get the schools to share the learning. In the third year (2018), they looked at how schools can scale up the other schools in the area of teaching and learning.

As an intentional structure for the cluster to train a core group of people, every school formed SBLTs comprising of key personnel such as the vice-principals, school staff developer (SSD), HOD ICT, and HOD IP. The SBLTs were the driving teams to build the culture for the schools in sharing best practices and contextualizing their learning for school ownership of adapted practices. They began with creating awareness of best practices to bring back learning for adaptive changes in respective schools.

The growth in size of the DLC from two to four school leaders (CC Primary, TT Primary, BB Secondary, SM Secondary) saw distributed leadership in sharing administrative and logistical arrangements for designing and facilitating the school-to-school network structures to promote learning together in the cluster. The DLC decentralized their resources with two members working on the SBPTs, where Mr. JP (Vice Principal of CC School) oversaw the Science SBPT as a Science-trained (secondary school Physics-trained) teacher, while Ms. LL (Vice Principal of SM Secondary School) oversaw the Secondary Geography and Primary English team as a Geography-trained teacher. With their prior Educational Technology Division (ETD) background, Mr. JP and Ms. LL understood the Master Plan 4 better for coherent sense-making of educational policies with ground implementation of practices. They worked on helping teachers to overcome the challenges in looking at the kind of lessons and discussions in the collaboration through the SBLTs.

As can be seen, the DLC grew over the years with more school leaders joining in the systemic planning. They had half-yearly cluster board meetings on key agendas to look at professional development of school leaders, teachers as designers in SBPTs, needs of project team, and SBLTs organized around program-basis. DLC organized talks to engage school leaders and SBLTs and gathered information from the school leaders about happenings on the ground by teachers. With a decentralized system approach, DLC members sat in at the monthly NLC meetings and asked teachers to give them feedback and identify needs of the schools that ought to be addressed. Through these activities, they proactively addressed tensions of school and teacher adoption of the learning innovations, and helped to spread the CDLI agenda.

1.9 Role of School-Based Project Teams (SBPTs) at the Micro Layer (School)

At the Micro layer, school-based project teams were formed based on the concept of school readiness to come on-board the deep learning journey likened to a mini INLC (ICT Network Learning Community) based on individual school's assessment of readiness and need for resources from the cluster central supply of expertise to be shared among the schools for economies of scale. The cluster collaboration through SBPTs helped schools to see the benefits of collaboration (for Science SBPT) where quality of lessons improved with valuable mutual critique of evidence-based practice using student artifacts that showed better explanation by students in Science lessons involved in 5E inquiry-based learning model. The hands-on approach by teachers in the design-enact-review iterative cycle translated to some tangible lesson design where teachers experience deeper learning themselves with ownership of design and enactment of lessons using their adaptive expertise.

1.10 Overall Findings

The CDLI was observed to be successful in resituating practices from school to school with the use of technology and deep learning aligned to MP4 using the Student Learning Space (SLS) lesson design guide template used collaboratively in SBPT for lesson design sharing. In the school-to-school network by design, apprenticing nuances grew from schools handholding schools in coming up with similar kind of lessons. Apprenticing was notable in the partnership of TT Primary and CC Primary School where relational trust was built on shared beliefs and goals over the past 3 years for de-privatizing practice to open up classrooms for mutual lesson observation and critique, sharing of lesson packages, open feedback loop. The imperative of forming critical mass for deeper gathering to go deeper in content, pedagogy, inquiry-based practices aligned to MP4, twenty-first century competencies skills, Singapore Teaching Practice, SLS Pedagogical Scaffold, and tap on economies of scale for sharing of expertise human resources (such as those from the Ministry and NIE) from central supply worked well.

Schools were supported in a centralized–decentralized approach via the core driving teams to give school ownership of deepening practices contextualized to school's needs. This is strongly evident in the current success of SBPTs in 2018, where there is more teacher agency; open sharing of resources and collective wisdom at Micro layer with involvement of teachers who are the agents of change in the classrooms. Teachers are engaged in the whole design process and develop ownership to enact lesson design adaptively in the classrooms alongside their Key Personnel (KPs) who are the LftM that mediate communication and decisions across the 3 M layers. With a systemic thinking behind distributing leadership, the strategic move away from SBLTs for creating awareness through the school KPs to SBPTs involving teachers to go deeper in their Technology, Pedagogy, and Content Knowledge. Teachers are empowered with ownership of lesson design in terms of subject-domain, topic, adaptations for student profiles and learning needs, and mind-set for change through embodied experience of design-enact-review cycles for professional dialogues and feedback loops for deeper learning.

With the intentional design of school-to-school network structures of a centralized–decentralized approach, the DLC provided a central supply of expertise resources to facilitate NLCs for SBPTs with a subject-based approach. DLC engaged human resource expertise from within the school networks as well as from external agencies like AST and NIE, forming valuable partnerships based on shared beliefs and vision. The Lead Teacher within the cluster facilitated the Science SBPT sessions alongside NIE researchers who gave insights as a critical friend to the design-enact-review cycle on the topic of "Light" for Primary 4 Science, while Master Teachers from AST facilitated English and Geography SBPTs with a subject-expertise mentoring approach on deepening content and pedagogy for teaching and learning. These cluster structures were successful in leveraging on existing structures, e.g., INLC subject chapter structure, NIE support in MIVIS eduLab project through bringing in a critical friend as facilitator for NLC sessions, providing dedicated support to walk the journey and talk about student artifacts and learning. A feedback loop mechanism was situated in the process of facilitation where valuable third party critical feedback aided teachers in deeper reflection of their lesson design and enactments.

To sustain the central supply of resources to be shared by the school network, the DLC has been growing a team of Lead Teachers (LTs) in the cluster (from 3 to 10) to support schools in growing the capacity of teachers. The role of LTs is increasingly important in facilitating learning communities (school-to-school network sessions, PLCs).

Our findings show that the structural affordances of protected time, coordination, and open sharing scaffolded within the school-to-school network design worked well. Protected time was established purposefully in setting aside time and space for schools collaboration in SBPT Science. This was evident of the administrative and logistical efforts made by the leaders in the Meso layer in making the schedule available by adjusting the timetable of respective schools to arrange for a common time to meet for discussion.

This works in tandem with the structural affordance of coordination at Macro and Meso layers by school leaders and KPs (HOD Science) to address issues, give focus, and maximize meeting time. We found that what worked well was the importance of working together at HOD-to-HOD level where the leaders at the Micro layer in the different schools gathered to discuss issues of teaching and learning, planned with a focus on gathering evidence of students' learning, and checked with the whole team. The process of coordination at the HOD-to-HOD level is valuable, but more needs to be done at the school leader-to-school leader level to coordinate and address the issues, for possible focus, etc., to maximize meeting time.

The structural affordance of a safe space within the school-to-school network learning community (NLC) also fostered an openness in sharing about what worked and what did not work by the teachers. This was evident in both the school-to-school network learning community (SBPT Science meetings) sessions and individual school professional learning teams. We documented the willingness to share success and failures across schools through the open discussions at the network learning community sessions. Teachers exhibited willingness to ask for help as well as to share perspectives. Teachers had the opportunity to openly share about difficulties encountered in lesson design and enactment while being open to other teams of teachers giving other perspectives. With open sharing of what worked and what did not work, teachers found the sessions to be good just in time with the more regular protected time given to meet. With the openness afforded, teachers learnt to see different perspectives of students' learning by leveraging on building each other's expertise, showing signs of apprenticeship learning through peer-to-peer mentoring. Through the co-designing of lesson plans in the school-based project teams, teachers gained collective wisdom while developing better lessons and making working lighter for all. In the lesson design-enactment-review process, teachers adapted and contextualized the lesson plans to the respective profile of their students while adhering to the underlying guiding principle of the lesson plan. They were able to leverage on the expertise of each individual while adapting lesson design with each iteration shared with the whole idea of working towards collaboration using SLS pedagogical canon and SLS platform for sharing their lesson plans (Table 1.1).

1.11 Discussion

As can be seen from the findings, the Meso layer, the middle subsystem played a key role in the enculturation of teachers for the deep learning innovation. The process of teacher apprenticing occurs in terms of the thinking approach and building of core capacity for adaptive expertise in order to re-contextualize and re-appropriate innovations according to their school's context. The school's leadership involved all levels of a school and collectively built an open culture of communication and collaboration. This collective culture building encompassed shared decision making in the

Table 1.1 Briefly summarizes the enablers of the 3 M layers

3 M layers	Enablers
Micro	• Conditions of protected time to co-design lessons and take risks for lesson topics • SBPT community for bouncing of ideas, embodied experience of lesson co-design, and engagement in iterative cycles • Professional dialogues in the design-enact-reflect cycle to build design competencies, collective sense-making carryovers • Open-sharing culture, opening up classrooms
Meso	• Growing teacher leaders in small groups (community building and capacity building) • Conditions cultivated for spread of best practices across schools, across subject-disciplinarily, and involvement of expert-other to scaffold the process • Culture envisioning, enculturation of practices, starting with values, and beliefs • Modeling, and unpacking frameworks with teachers for co-designing, enactment, and review cycles
Macro	• Enabling structures and organizational routines (i.e., school cluster structure, subject-departmental operationalized, blocking time for SBPTs and PLTs to meet) • Community of a cluster of schools, collaborating without competing (collective motive of collaboration instead of competition) • Iterative cycles of “design, critique, reflect, enact, reiterate” • Open culture

co-design of lessons. Through lesson observations and scaffolding from teachers in the original schools of the intervention (TT and ZZ Schools), the teachers in the diffusion schools were able to learn from such a context to re-appropriate the lesson co-design ideas into their own department’s vision and plans. Teachers who appropriated the innovation did not merely replicate the innovation in the classroom, but instead built adaptive expertise in their professional development. This is evident of the “becoming” process in embracing inquiry-based learning epistemology (Hung et al., 2015) with mind-set changes towards gaining ownership of the innovation.

Greater sustainability of the innovation can occur as the teachers in the other schools appropriate innovation designs into their own schemes of work. By appropriating the innovation, teachers were able to meet both the curriculum objectives and change the way they teach, balancing the paradoxical tensions of policy and practice. Teacher leaders, who orchestrated common goals setting as well as the socio-technological infrastructure, i.e., PLCs, NLCs, supported these teachers undergoing the peer apprenticing process.

In addition, school leaders played a vital “middle-out” bridging role at the Meso layer in encouraging the teachers to take the change of process journey in good stead at the Micro layer while brokering with the cluster superintendent at the Macro layer for coherence and support of innovation enactment. An ecological leader facilitates both downwards and upwards percolation from Macro (policy) to Meso and Micro levels (aka the dip in results as learning opportunity), aligning policy to practice with facilitation and communication across the 3 M layers, especially at the Meso layer demonstrating LftM. He/she is able to mitigate the tension between performative pedagogies and inquiry-based pedagogies and epistemology in teacher mind-sets and school culture, hence aligning school practices that facilitated the teachers' work that is an example of ecological leadership in action percolating downwards. Toh et al. (2014) identified the critical alignment and coherence role that the school and teacher LftM mediate upwards and downwards for ecological consistency. This role is vital to communicate evidences of good work at department and classroom levels, making it visible for school management awareness.

The management of upward and downward percolation amidst horizontal percolation (through apprenticing leadership) is often contingent for school leaders to build trust and culture through distributed leadership that extends from school leaders to teacher leaders (Koh & Hung, 2018). For innovation diffusion to occur in a system embracing change, both upward and downward percolation has to be practiced in a fashion that mitigates power distance. Alignment efforts between the ecological layers constantly need to be carried out by middle leadership who are cognizant of the diffusion efforts on the ground and able to co-inform system leaders of said changes to mitigate the tensions between the ecological layers.

In other work, we have theorized a fractal conceptualization, where the 3 M layers are further categorized into three "m" (non-capitalized) layers (Hung et al., 2015). For each 3 M layer, the middle is conceived to play a vital role in anchoring the percolation of changes upwards and downwards. This case study briefly highlights that key personnel such as school leaders and HODs who support and coordinated with teachers enacting and adapting innovations in their classrooms as well as with other schools, were key players at the middle of each 3 M layer, mediating communication and decisions across layers.

Nevertheless, this discussion focuses on the main 3 M layers of LftM and has highlighted how the middle level of the whole system are the highest points of leverage, through which we can sustain change. Teachers, in the Meso layer, can develop their canonical pedagogies from apprenticing themselves in the context of their own schools and clusters, but at the same time, this local apprenticeship allows for the development of a wider repertoire of locally developed and shared pedagogies. Additionally, these teachers are also system brokers who can mediate different parts of the system. The ability to help along the upward and downward percolation of ideas and innovations is an instance of ecological leadership, and it calls upon teacher-leaders to transcend their immediate stratum of influence.

Through this ecological system, the findings have also identified certain groups of people, concrete strategies, ways of thinking, and common sharing that percolate upwards and downwards across the various layers. For instance, at the Micro layer, the SBPT formed a community of teachers for sharing ideas and lesson enactment. They had the enabling structure of protected time to co-design lessons and an open culture, engaging in iterative cycles over time. In essence, they are four aspects that are labeled [C]ommunities, school [C]ultures, infrastructural [C]onditions, and the [C]arryovers from the previous iterations, respectively. These are termed the 4 "Cs" which will be illustrated in the following framework, Scaling Change through Apprenticing and Ecological Leadership (SCAEL).

1.12 Scaling Change Through Apprenticing and Ecological Leadership (SCAEL) Framework

The SCAEL framework proposed shows how system changes must happen organically with respect to local conditions, and this has to be an iterative process where the growth in people capacity is accompanied by multiple resources and carryovers that support the innovative change (Hung et al., 2018). As emphasized in an earlier work (Hung et al., 2018) and this chapter, in order to be ecologically valid, the scaling must account for and deal with the "4C's": teacher [C]ommunities, school [C]ultures, infrastructural [C]onditions, and the [C]arryovers from the previous iterations.

The first C, community, refers to the people involved in the innovation, the collective capacity of people required to sustain change. Conditions are the structures, ways of organization and or infrastructure that enables change. Third, culture emphasizes the norms, beliefs, and perceptions, of the community that encourage sustained change. Carryovers relate to the iterative developmental process of which the sharing of the innovation development and process (e.g., design, critique, reflect, enact, reiterate process) is crucial to sustain the innovation.

Since this iterative process represents iterations in the local ecology, it is at the same time contextualized, probably overlapping and hence probably non-linear. Hence, comprehensive and sustainable scaling is not a simple process of multiplication, of cutting and pasting technologies or innovations appropriated elsewhere—or indeed even if the change is indigenous in origin. Every context differs. Individual classrooms, departments, and schools within a cluster or system represent a localized context. To implement the SCAEL framework is to localize every change in every locality bearing in mind the 3 M levels that enable sustainability.

While the framework may not be linear, for pictorial representation, we illustrate SCAEL in Fig. 1.1 via a 2 by 2 time and change axis for easier understanding. In

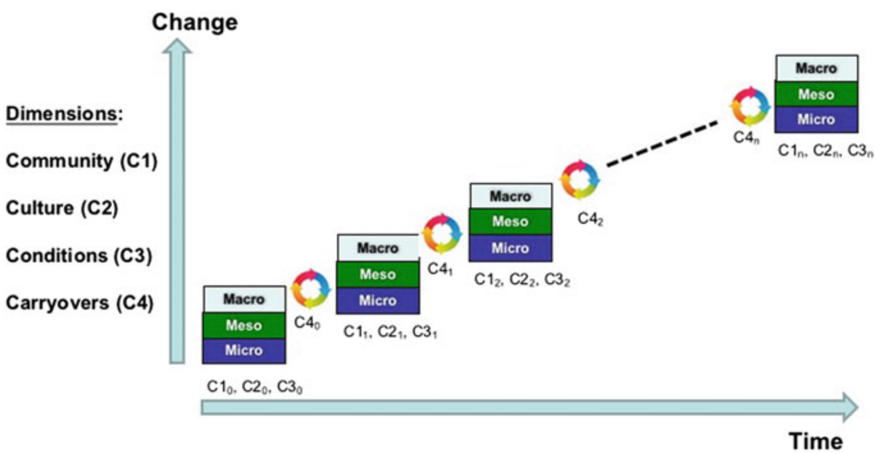

Fig. 1.1 The SCAEL framework

the chapters following, the principles underpinning SCAEL as a process would be described and discussed in detail.

1.13 Conclusion

This chapter has delved into a case study of the CDLI, a learning initiative that scaled across a school cluster, influencing a total of ten schools. Through highlighting apprenticing and ecological leadership of the 3 M layers, a resultant set of enablers categorized into four "C" dimensions have been identified. This builds on a nascent SCAEL framework and helps promote the importance of the contextualized approach of scaling.

The initial ICT-based innovation funded by eduLab, MIVIS, was an integral part of the CDLI. While there were tensions and further gaps to address at various system layers, the innovation's initiation and enabling factors helped create ripples of change for other schools in the cluster.

We are cognizant that the findings of the case study may be limited. While we endeavored to have as many sessions of field observations, interviews, and focus group discussions carried out as practically possible, it may still be short of comprehensive data triangulation. We seek to overcome this with future survey instrumentation to validate resources and toolkits developed for use in school-to-school networks for growing the professional capacity of teacher leaders.

Furthermore, this case study echoes previous work and findings (e.g., Toh et al., 2014) on aspects of LftM in the ecological system.

More importantly, this chapter introduces a frame for which innovations spread in Singapore schools. This rest of this book is organized according to the following 3 M layers—Micro, Meso, and Macro, with chapters that illustrate the contextual nuances of each innovation and respective enabling dimensions of scaling.

Traditional linear scaling is indeed not the best approach to depict innovation diffusion. Rather, a more contextualized approach of that of communities or the growing of local communities supported by a larger ecology of LftM is posited. We hope that through reading the rest of this book, the recognition and importance of such contextualization is brought to the fore.

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Chapter 2
Leadership from the Middle (LftM) in Singapore: Distributing Leadership Upwards, Downwards, and Sidewards for Innovation Sustainability in Schools

David Wei Loong Hung and Monica May-Ching Lim

Abstract This chapter describes a middle-out community growth innovation phenomenon that leverages teacher leadership upwards and downwards from observing inquiry-based learning in schools. Based on the evidence of school change in the Singapore context, inquiry-based learning interventions act as the key drivers for change within a systemic perspective. The case examples illustrated involve technology for twenty-first-century learning, and the evidence for change requires the confluence of leadership, teacher learning, and student outcomes to sustain and scale efforts. The leadership from the middle at every level of the system is needed to evolve and propel charge. The tenets and key hypotheses of capability building, community growth, and carryovers of cultural and technological supports are described. In summary, leadership from the middle is thus about micro-level apprenticing/mentoring, meso-layer alignment of ecological fluencies, and macro-level systemic thinking that all cohere in tandem sidewards, upwards, and downwards percolation of expertise, practices, and epistemic beliefs.

2.1 Background

The Singapore education system has been progressively emphasizing student-centricity in classrooms (Ng, 2008) and sound pedagogy over teacher-centricity in the last decade. But this shift goes to the core of instructional practices that have been ingrained in the educational system since the 1960s. While pockets of change can occur, sustaining student-centricity—often catalyzed by pedagogical innovations—requires significant leadership entailments both at the school and teacher levels. This chapter illustrates teacher and school leadership in believing that student-centricity is beneficial to the students—especially from less advantaged family backgrounds—and how structures and processes are set up for teacher mentoring and apprenticeship for the appropriation of skills necessary for sustaining change. This teacher (and

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school) leadership as connoted in this paper is characterized by "leadership from the middle." But teacher leadership cannot be divorced from the larger context of the school and its ethos—the "culture of care" for the student. Because change is difficult in the context of twenty-first-century learning, with schools already well-poised to deliver academic results and PISA scores, moral courage and purpose are needed by the leaders.

In this chapter, we discuss how it is critical for leadership to be distributed not just downwards from senior management to give agenticness to those who enact the innovations, but upwards and also sidewards. Traditional conceptions of distributed leadership suggest a decentralized model (Tan & Ng, 2007), however, we argue from the Singapore case that a more nuanced understanding of the cultural context is needed. In addition, the paper also argues for school leaders developing a strong moral purpose in their school's instructional decision-making, in particular on issues of equity in spite of the challenging demands (perceived or otherwise) imposed on them for achieving academic results. However, moral purpose alone cannot sustain change in instructional and school practice(s) unless there is leadership that is able to implement the necessary mandates for sustainability with moral purpose. These practical implementational leadership stances include being able to think systemically (i.e., systems thinking) yet being grounded. This paper argues for the complementary perspectives of grounded and systemic leadership, yet motivated by a moral purpose which is needed of sustaining student-centricity in classrooms, and for transforming schools in new norms relevant for the twenty-first century and for preparing learners holistically, including being cognizant of character and citizenship development. The recent COVID-19 pandemic speaks on the importance of being civic-minded and socially responsible.

The Office of Education Research (OER, National Institute of Education) has been seeding various pedagogical innovations in classrooms across schools in Singapore over the last decade. These innovations involve fostering disciplinary ways of seeing meanings. Common among the innovations is the use of language-oriented scaffolds in enabling critical thinking. For example, for science disciplinary ways of seeing meanings, scaffolds include: "My hypothesis is …"; "The evidence to support my theory includes …"; "I need more information on …." These are language scaffoldings to prompt students to think along with certain perspectives. We recognized that not only in the discipline of science were these scaffolds adopted but in mathematics and also in language, including character and citizenship education. In mathematics, we have: "What or which problem solving stage are you in now?"; "Do you understand the problem?"; "What exactly are you doing?"; "Why are you doing that?" When it comes to specific heuristics, the teacher would prompt the student with scaffolds such as "Why don't you try with … (with regards to a problem specific)?"; or that the teacher would give problem-specific hints such as: "Think in terms of smaller number… what numbers will you try?" These language-oriented prompts create in students the thinking along; for example, George Polya's stages in problem-solving. Prior to such interventions, it is common place for teachers to give answers too readily to problems or to teach formulaic procedures rather than the process thinking required. Due to the need to cover the curriculum and to help students ace the examinations, procedural knowledge was probably overemphasized compared to conceptual knowledge. In citizenship and character education, language scaffolds are given to students in first-person perspectives, rather than the third person. For example, "What would you have done in such a situation?" Such a view is consistent with first-person role-playing pedagogy in game-based learning theories.

According to the Ministry of Education (MOE) policy, every teacher is a character and citizenship teacher (Ministry of Education, 2014). Instructional materials from the Ministry of Education (MOE) often manifest instructional prompts in third-person perspectives or voices, for example, "What would Jane (or John) do this instance (of a particular situation requiring moral judgements)?" Instead, in our interviews with teachers, they found situating these decision-making scaffolds and prompts in the first-person voice appears to be more effective in students being more agentic in their answers.

We have observed that teachers adopt these student-centric instructional/learning strategies for the period of the inquiry interventions, but many of them often default back to teacher-centric approaches when teaching workloads increase or when nearing the examinations. While teachers undergoing such transformative pedagogical interventions recognize the efficacies of such approaches (as expressed in interviews), sustainability is challenging. To which, teachers have to manage a host of demands such as completing the syllabus, meeting certain assessment grade standards for their students, preparing students for procedural accuracy and fluency for tests and exams, and the like. These requirements can be characterized as performance pedagogies, preparing students for the high-stakes examinations at specific junctures of a student's academic trajectory. In Singapore's education system, typical students undergo these examinations in grades 6, 10, and 12. While there are policy intents to mitigate the stress in these examinations, changing the public or parent's anxiety is far from simply an implementation issue due to years of cultural habituations. To many teachers, preparing students for the examinations well is the responsible and ethical demand as doing well in high-stakes exams is a social lever to success. Philosophically, while student-centricity in pedagogy is morally right, it could be a perceived alignment or misalignment between *performing* (to the test) and *learning*. Even if school leaders and teachers cognitively recognize the tension between the two, being able to skillfully execute learning for a typical class of 25 students takes time to develop.

We discuss how schools can sustain these interventions despite meeting the demands of performance requirements for examinations. In the interviews we conducted, we have even encountered schools who believed in such process-oriented pedagogies that they overcame apparent tensions and dichotomies between the inquiry- and performance-oriented pedagogies. While most schools do not undergo a whole-school reform toward these efforts, they engage in a staged scaling effort within the school. These scaling efforts are also not done en masse and are usually done on a per subject or discipline basis within schools. These efforts are done progressively with significant support from school leaders as schools have to manage the learning gains underpinning inquiry-based approaches that students do not perform worst off for the examinations. We discuss leadership for sustainability as requiring school leaders to distribute leadership downwards to teachers; and yet at the same time, teachers are to align what they do with their school leaders (distributing upwards). Hargreaves and Fullan's (Leadership from the middle: a system strategy, p. 24) notion of "leadership from the middle" speaks to this upwards and downwards distribution of leadership for the sustaining of inquiry-based learning in schools.

In the ensuing sections, we discuss how ecological leadership mitigates power distance created by systems that are more hierarchical than flat, and how apprenticing leadership facilitates collectivism or the corporate desire to come together for a greater cause. Power distance and collectivism are two social-cultural characteristics evident in the East-Asian psyche. Apprenticing leadership enables teachers to undergo transformative learning experiences. At the same time, ecological leadership mitigates the tensions that arise from apparent contradictions between societal expectations that are typically facilitated by performance pedagogies (which may appear similar to drill and practice, but in fact, they are much more) and twenty-first-century process-oriented pedagogies (e.g., questioning, argumentations, etc.), which may not always be perceived as necessary for the examinations. We argue that distributing leadership sidewards is manifested through apprenticing leadership, and upwards–downwards is mitigated by ecological leadership.

In the later parts of this chapter, we would delve into systemic leadership and that of moral courage for sustaining change for the betterment of students.

2.2 Literature Review

Historically, Singapore has been a centralized system; however, in recent years, initiatives have been made to decentralize the system. In a centralized–decentralized system, the Ministry of Education controls strategic direction, curriculum content, budget, resources, and facilities while decentralizing schools to have autonomy in accommodating diversity, flexibility, and innovation in curricular matters.

A system-level perspective can also be rooted in principles of:

- Centrality of instructional practice
- Capacity building
- Distributed expertise
- Mutual dependence
- Reciprocity of accountability
- Reconstruction of leadership roles and functions.

Thus far, the Western-centric literature has a dearth of studies on leadership nuanced from a whole system view. Hence, the Singapore case aims to layer the system policy perspective not just as a context but on how the implementation of change is facilitated. A system-level perspective can be rooted in principles of alignment of policy and practice all through the system (up and down the hierarchies).

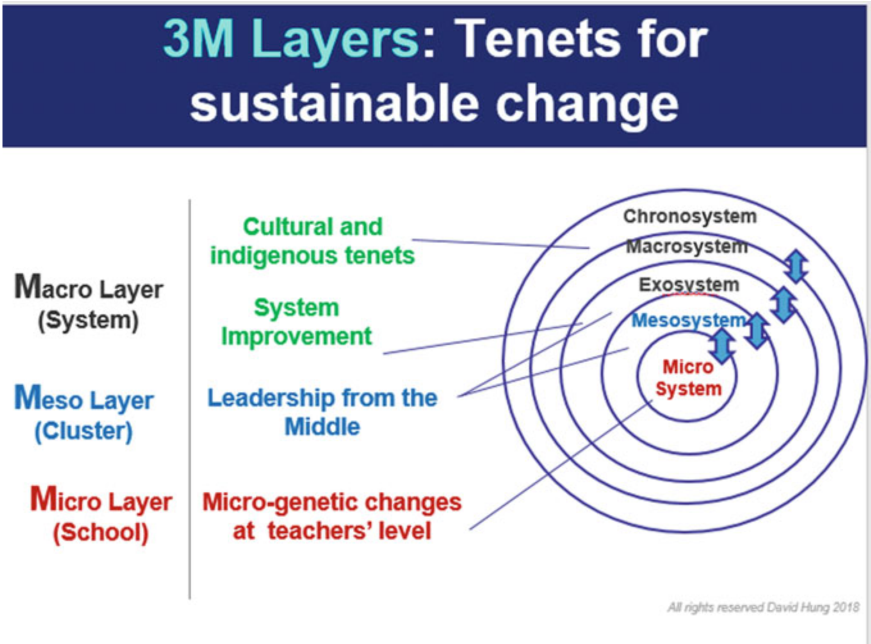

Fig. 2.1 Three levels of a system

Referring to Fig. 2.1, the 3 M layers, we see tenets of sustainable change within the macro, meso, and micro-layer which also describes the systems that exist within the layers.

In referring to cultural and indigenous tenets, indigenous tenets mainly speak in terms of native characterizations in recognition of variations in the functioning of education systems and that their historical, national, and regional policy contexts that will exert different degrees of influence on institutions' work and therefore on the role of leaders in schools (Day & Sammons, 2013). Such indigenous knowledge is known as **local knowledge** that is unique to a culture or society, and the other names for it include: "people's knowledge," "traditional wisdom," or "traditional science…" (Nakashima et al., 2000, p. 12).

Moral courage is a willingness to take a stand in defense of principles or conviction even when others do not (Miller, 2000, p. 36). A coherent policy framework to improve student outcomes is not sufficient albeit necessary (Day et al., 2009). Significant research in the United Kingdom indicates that the moral aspect of a principal's leadership ability marks out the high performers from the rest. The added impetus, i.e., the moral purpose, is provided by the vision, values, qualities, diagnostic skills, strategic acumen, management competencies, and behaviors of individual leaders (p. 194).

Fullan (2002, 2003) identifies the four levels of moral purpose in educational leadership as:

- Effecting a change in the lives of students.
- Committing to reducing the gap between high and low performers within your school or cluster.
- Contributing to reducing the gap in the larger school ecosystem.
- Transforming the working (or learning conditions) of others so that growth, commitment, engagement, and the constant sparking of leadership in others are being fostered.

On a micro-level, teachers face a constant moral dilemma as they need to strike a balance between the needs of the individual against those of the class. On a meso-level, for example, lead teachers need to make decisions on time and resource allocation to teachers and schools. On a macro-level, for example, school leaders need to make moral decisions to balance between implementation of the curricular innovations and policy to best fit their school ecology.

2.3 Systemic Leadership

Systemwide and system-pervasive leadership is democratic leadership (Crow & Slater, 1996). Systemic leadership is about the leadership at all levels of the system and involves all stakeholders in the system. For systemic leadership, each participant must be a proactive, willing exerciser of both followership, which is also about the decision to cooperate (p. 21), and systemic leadership. This leads to a diversity of opinions and viewpoints which causes disagreements, conflict, and misalignments. Systemic leadership mitigates this as leaders step in to provide direction. Leadership is often as much about balancing, following, and leading and often blending the two, i.e., the necessity of cooperation with the need to coordinate (p. 20). School leadership must pervade the school system, empowering people in each classroom, school, and community (p. 23). Building choice in the curriculum empowers students in choosing what they wish to learn (p. 26).

According to Starratt (1998), leaders want to transform the school from an organization of rules, regulations, and roles into an intentional self-governing community. In such a community, initiative and interactive spontaneity infuse bureaucratic procedures with human and professional values (p. 130).

2.4 Leadership From the Middle (LftM): A Middle-Out Community Growth Model

In our studies of implementing educational innovations in the Singapore school system, we can observe instances of leadership from the middle of which case studies are described below. Figure 2.2 illustrates instances of LftM in our local school system.

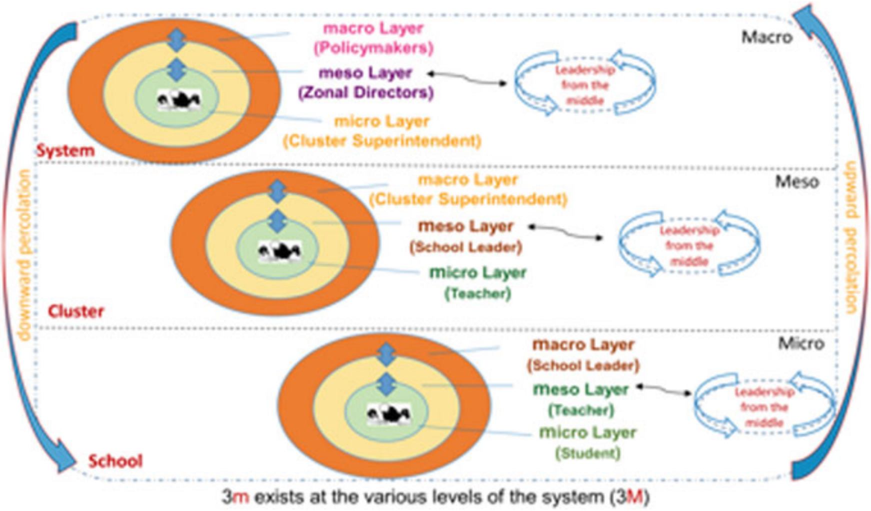

Fig. 2.2 Levels of the Singapore school system with leadership from the middle at every middle of the system

"Leadership from the Middle can be briefly defined as: *a deliberate strategy that* ***increases the capacity and internal coherence of the middle in as it becomes a more effective partner upward to the state and downward to its schools and communities,*** *in pursuit of greater system performance.* …" (Fullan, 2015, p. 24) "… it implicates the whole system starting from the **middle out, up and down**. In addition to our system-use of the concept, LftM can and should be used at other levels. Schools, for example are the middle if you use a within-district focus. Teachers, students and families are the middle when you think of intra-school and community work" (Fullan, 2015, p. 26).

2.4.1 *Hypothesis 1*

We thus hypothesize that LftM is mostly conceived from Western-centric literature with little considerations of issues such as power distance. Power distance is defined as "the extent to which the less powerful members of institutions and organisations within a country expect and accept that power is distributed unequally" (Hofstede, 1980). Singapore's traditional Confucian background and the syncretic East–West cultural values present a seemingly paradoxical system of hierarchy and collectivism from a Western-centric lens (e.g., Rowley & Ulrich, 2012). These values are largely represented by views such as respect for elders (hierarchical), collective good

(Walker & Dimmock, 2002), acceptance and expectation of unequal power distribution (Hofstede, 1997), and high(er) power distance when compared to Western societies. East-Asian leaders orientate toward harmony, collectivism, social hierarchy, and relationship-based trust (Craven & Hallinger, 2002). "…the social legacies of Confucianism can turn citizens toward communitarian democracy under which individual members collaborate instead of competing against each other" (Sing, 2013, p. 563).

While the cultural nuancing is critical, the general principles of leadership for sustained innovations in schools are consistent. Large-scale, sustained improvement in student outcomes requires a sustained effort to change school and classroom practices, not just structures such as governance and accountability. The heart of improvement lies in changing teaching and learning practices in thousands and thousands of classrooms, and this requires focused and sustained effort by all parts of the education system and its partners (Levin & Fullan, 2009, pp. 189–190).

2.4.1.1 School Improvement Tenets

School improvement tenets guide the course of change when innovations are introduced. Schools are capable of improving themselves ***when there is a coherent relationship with the broader educational context with a system-wide change strategy*** (Levin, 2012). Within the Singapore education context, our schools are guided by the school cluster at the meso-layer and the Ministry of Education at the macro-level. "Guiding coalition" (Levin, 2012, p. 18) is the idea that *key leaders at different levels, politicians, administrators, teacher educators, teachers, all understand and articulate the change strategy in very similar ways so that leadership at all levels is mutually reinforcing. Success depends on changes in the actions and beliefs of teachers* (OECD, 2009). Promoting and participating in teacher learning and development has a significant effect size of 0.84 (Robinson et al., 2009). *Factors and conditions of the (indigenous) context* are important in system improvement and related theories of action/implementation (Fullan, 2009, 2015; Hung et al., 2015), including *system infrastructure to support system-wide improvements* and the ability of an education ministry to lead and support the work (Levin, 2012) are all important tenets.

Teachers are at the center of the change process. As such "leadership from the middle … [is] *a deliberate strategy that* ***increases the capacity and internal coherence of the middle as it becomes a more effective partner upward to the state and downward to its schools and communities****, in pursuit of greater system performance.* …" (Fullan, 2015, p. 24). The teacher is the middle in many of the leadership enactments in schools. Schools are in the middle when it comes to being a partner upwards to the district or school cluster. In other words, the need to be ecologically consistent upwards and downwards is the critical role of the leader in the middle.

2.4.2 Hypothesis 2

To summarize the aforementioned constructs, we claim that varied researched approaches, each preceded by different "adjectives" such as the list below, do not sufficiently account for East-Asian cultural tenets, and are too broadly construed to attend to the gaps created in change and transformations:

- Change leadership (e.g., Wagner et al., 2006),
- Connective leadership (e.g., Lipman-Blumen, 1988; Walker, 2011)
- Constructivist leadership (e.g., Lambert et al., 1995)
- Curriculum leadership (e.g., Glatthorn et al., 2005)
- Distributed leadership (e.g., Harris & Spillane, 2008)
- Ecological leadership (e.g., Brymer et al. 2010; Toh et al. 2014)
- Educational leadership (e.g., Dimmock & Walker, 2005; Leithwood & Jantzi, 1999)
- Instructional leadership (e.g., Hallinger & Heck, 1999; Hallinger & Kantamara, 2000)
- Sustainable leadership (e.g., Hargreaves & Fink, 2004)
- System leadership (e.g., Caldwell, 2011)
- Teacher leadership (e.g., York-Barr & Duke, 2004)
- Transformational leadership (e.g., Bass, 1997; Howell & Avolio, 1993; Day & Sammons, 2013).

We theorize that the above leadership constructs have a dearth of understandings in terms of how LftM can be appropriated for upwards (in a hierarchical system) leadership. We hypothesize that LftM in the context of East-Asian cultures requires more "upwards" (trust-building and ecologicing) leadership, and sidewards (in terms of apprenticing) compared with Western systems.

2.4.3 Hypothesis 3

Much of Western literature on leadership inadequately connote the complexities of innovation change and "scaling". In other words, no single model of leadership satisfactorily captures school and teacher leader enactments, rather leadership trajectories are evolutionary in nature within the context of change.

What would probably help or work better is a leadership whose unit of analysis is not an individual nor is it non-person related. LftM has characteristics such as distributed, systemic, centralized, and decentralized, yet requires personal attributes such as moral courage and the skills to enact the change.

2.4.4 Teacher Leadership

Teacher leadership should play a very important role in brokering between teachers and school leaders especially if the change in substance is an instructional one for the betterment of students' learning. While we hypothesize that LftM is a construct-concept, the person of the teacher as "standing in the gap" as leaders from the middle at every middle of the system plays an important role.

What is teacher leadership? Simply put, it is an evolving definition "Today, leadership roles have begun to emerge and **promise real opportunities** for teachers to **impact educational change**—without necessarily leaving the classroom" (Boyd-Dimock & McGree, 1995). Harris & Mujis (2002) included **four dimensions** in their definition of teacher leadership, namely **brokering**, which is managing how teachers translate principles of school improvement into classroom practice; **participative**, which is to ensure teachers feel part of, and own, change and improvement (fostering collaborative ways of working); **mediating**, as a source of expertise and information, the teacher leader draws on additional expertise and external assistance; and **relationships, which is** forging closeness with individual teachers, to underpin mutual learning. Teacher leadership is more about "…the authority to lead is **not exclusively located in formal positions**, but is **dispersed** throughout the organization…." Some scholars conceive the nature of teacher leadership as an **influence-lateral, upwards or downwards** regardless of whether it is formal or informal leadership. Learning in context leads to cultural change (Elmore, 2004) explains that as teachers embrace innovations in their pedagogical practices within the classroom and school and even the cluster/system context, this results in an incremental cultural shift. Day and Sammons (2013, p. 2) state that school leaders "play an important role in establishing the conditions, structures, cultures and climate for professional learning and development in their schools" (p. 2). To reiterate, we believe that in Singapore's context, we need more teacher leaders to engage in upwards regulation and this requires the teachers to have moral courage, wisdom, and social capital in the midst of the realities of power distance.

In our earlier studies (Hung et al., 2013), we also observed another important distinctive characteristic that requires teachers who undergo the change-sustainability problem. Teachers have to have an epistemic change if they were to sustain inquire student-centred practices. Hung (1999) found that the apprenticeship learning process progressed from a state of tolerance to acceptance and finally cumulating in signs of epistemic change. Epistemic change occurs for teachers when they undergo an initial phase of "tolerating" the assigned role of undergoing discussions within professional learning communities engaged in inquiry pedagogy, then coming to grips with the tensions underpinning change and the struggle to "let go" of their epistemic stance(s), and this phase is followed by experiences and satisfaction when they see for themselves the fruits of their learning (Hung et al. 2018).

2.5 Methodology

This qualitative case study involved ethnographic observations and focus group discussions, with the interview participants comprising cluster superintendents, principals, vice-principals, key personnel (KP-HODs), lead teachers (LTs), and teachers. LTs have the specific assignment to work across a cluster of schools in order to apprentice teachers in the student-centred inquiry pedagogies. This study documents efforts made by LTs in particular as they engaged as teacher leaders from the middle, and we particularly highlight the efforts in distributing leadership upwards.

The lead teacher scheme is part of a specialized teaching track in the Singapore school system which enables teachers (and not just school leaders) to reach the pinnacle of their careers being good at the craft of teaching. The pinnacle of this track is being a principal master teacher.

Each of the interviews was coded and categorized into themes. From Spillane (2006), ***learning in context changes the context itself,*** our case study also found that both improvement processes and outcomes dialectically co-inform and co-evolve and we also found an intertwining relationship between leadership, curriculum and pedagogy, and teacher professionalism.

2.5.1 Cluster of Schools

These observations were documented during networked learning communities (NLCs) (i.e., teachers collaborate across the cluster of schools) and professional learning communities (PLCs) (i.e., teachers collaborate within schools and within-subject disciplines) over a six-month period. In the reported interviews we use professional learning communities and professional learning teams (PLTs) interchangeably as this is how our study's participants meet. NIE researchers played the roles of a critical friend sharing insights and observer providing input on a science inquiry-based learning topic for the design, review and student artifact analysis in 2018. We observed monthly NLC sessions and weekly PLC sessions.

The data collection involved a series of interviews conducted with the cluster superintendent, school leaders, key personnel such as the heads of departments (HODs) and school staff developers (SSD), lead teachers (LT), and teachers who participated in the cluster deep learning journey. Sample interview questions can be found in Appendix 1.

2.5.1.1 Findings

The findings of our case study can be summarized in three broad areas, namely at the micro, meso, and macro layers of the system (see Figs. 2.1 and 2.2), and they apply to the lead teachers and teachers, school leaders, and cluster steering committee (for spearheading the intended goals), respectively.

2.5.2 School-Level Micro-Layer (Teachers)

Some of our findings from observations at this level include observing apprenticing leadership in action, both in formal and informal settings and also within the school-to-school networks. In scaffolding individual epistemic change of the teachers, we documented teacher's learning trajectories, for example, on how LTs and Heads of Departments (HoDs) did the apprenticing work: "We have to explain to them [the teachers] why we are doing and then we have to tell them how we can benefit, that kind of communication. And then we have got to do it with them. It's just walking the talk" (HoD A).

Platforms such as PLCs or PLTs create space and openness for conversations and an open-sharing culture that fosters apprenticing processes such as learning from each other, questioning each other, observing each other's lessons, and gradually creating a culture of trust among the teachers. Teachers participate in PLCs and PLTs by dialoguing and bouncing off ideas in these spaces. Due to in situ professional development and peer apprenticing in such time periods, they engage in the enculturation of beliefs by teachers resuting in their epistemic change trajectory which enable them to implement innovations in classrooms to improve students' learning experiences.

Strategies for the creation of protected time lead to open discussion, share on-the-go, walking the talk. We found that teacher outcomes and learning needs are catered to by the design skills of teacher capacity to adapt, redesign curriculum or pedagogies, differentiate instructions, facilitation skills in the classroom and the PLCs, PLTs, epistemic shifts, and in analyzing student artifacts. In short, we found that teacher leaders, in their endeavour to cultivate change both for themselves and for their students, were at the heart of the change process.

Not only are LTs involved in helping and supporting teachers teach and learn better in the journey of relooking at student-centred learning and they are also focused on what can be done to bring that about in the classrooms and how that could look like. In other words, not only do they apprentice their cooperating teachers in the PLCs, they scaffold them and give them assurances in actual classroom enactments. Such enactments are the sidewards distribution of leadership.

The lead teachers are also observed to help in facilitating different perspectives when instructional dialogues occur. In an interview with a lead teacher [A]: "Because generally, practices breed practices, assessment drive practices. … Being very conscious that our teachers have developed very strong instructional strategies to bring about certain outcome in terms of teaching all these years. … see different perspectives and engage them to see what is the mindset that they are looking at and compare to what it is" (Lead Teacher A).

In the same interview with the lead teacher [A], he shares that shifting mindsets is part and parcel of his work with teachers. "I can actually shuffle the topics or shuffle the things so that with this limited time, how I can maximize my ability to help teachers learn, pupils learn." The lead teacher makes teachers realize certain things and to see that "we need to recognize that as we become facilitators, we really need to facilitate the growth and not facilitate the answer." Facilitating the growth of teachers means changing the behaviour of teachers so that they stop expecting answers and being told what to do to think about the solutions to the problems. The lead teacher also discussed templating versus designing, with his stance being that templating, while efficient in cascading down to many teachers, ends up in "locking down" teachers, while on the contrary, the nature of design means contextualized needs, which means teachers need to analyze their students' needs. Challenges faced by the lead teacher involved time to work with teachers and buy-in of curriculum innovations where teachers will learn and be enculturated in the design competencies to see meaningful changes in their classrooms.

Thus, "walking the talk" for teachers involves evolving teacher design skills, epistemic change, protected time, open culture for sharing, and these processes are facilitated by LftM principles of sidewards percolations or distributions as aforementioned. The work of lead teachers and the work of heads of departments are overlapping especially when it comes to instructional enactments. While HoDs are on the school leadership track and lead teachers are on the teaching track, the level through which they function whether within or across schools is similar. In our observations, it may be quite prudent for HoDs to switch tracks to be lead teachers as being in the school leadership track exposed them to management perspectives which are necessary for upwards and downwards percolations of leadership when learning becomes the epitome of what schools do. In a nutshell, learning cannot be neatly divorced from management and vice versa. Deliberate and intentional cross-pollination between the different tracks in the Singapore education system is crucial. LftM is a 360° distribution of learning management leadership to be successful and relevant to the people around at the very middle of the system where they are situated.

2.5.3 School-Level Meso-Layer (HODs and LTs)

An open culture in schools as facilitated by school leaders results in and comes about due to trust-building, more professional dialogue, bouncing off ideas and forming collective wisdom and fresh perspectives when teachers of different schools come together and brokering upwards with the management. Apprenticeship in schools means walking the journey together, handholding and talking things through, and working with teachers to figure things out bit by bit. These apprenticing leadership enactments are not just on instructional oriented activities but as discussed earlier overlapping into management, and the power distance cultures and phenomena.

Teacher leaders, lead teachers, and HoDs often have to "stand in the gap" (Lead Teacher, B), where they communicate upwards and downwards. This horizontal percolation is mediated by teacher leader-in-the-middle mediating upwards and downwards for ecological consistency, which communicates and makes evident the examples of good work at department and classroom levels to spread awareness.

From our study, when teacher leaders are able to spread inquiry practices inter- and intra-cluster-wise, they grow professionalism in their fraternity. Working with school leaders they engage in culture envisioning and sense-making with teachers, and in the process enable teachers to come to a realization of the need for change. Teacher outcomes and learning needs are met when ecological leadership is in place. Growing people professionally is realized when quality interactions are maximized through structures such as PLCs and PLTs that cater to teachers' need for professional dialoguing.

In summary, standing in the gap for teacher leaders in their apprenticing and ecological leadership work means good facilitation of enactments, growing expertise of teachers, sense-making of policy and practice, and enabling trust and open culture. A lead teacher, in his apprenticing work, describes it as "having somebody to walk the journey with them, helps them to see it faster, engage them to discuss through their concerns. And it is important that the person who does this also have the experiences of what they are actually looking at and helping them to see both sides…" (Lead Teacher, C).

The lead teacher [C], in describing trust in apprenticing and ecologicing, "When we came into school, when I came into school, one of the big difference is first, *gaining the trust of the teachers*, that we are here as part of the team. We forge a new vision of the school and the forging of this vision, the acceptance of this vision and direction needs buy-in and needs convincing to say that we are taking a bold step and *working with school leaders*, the enculturation becomes key. After the enculturation, the need to also look at possibilities of how this can be happening instead of telling them what they have to do and *working with them to figure out bit by bit how this comes about with certain frames put inside, giving them space to work within their own, becomes also very important because then that is how we build trust with the teachers."*

The lead teacher [C] further shares that it is a matter of beliefs and going into deep learning. "*But for the change to be enduring, the first engagement and the basic foundation in the engagement has to happen in beliefs. And that takes time. …* Because they need the talking through and unpacking in the review session process about what makes sense to catch on and the facilitation of this, *providing the frame for them to rethink* it in a different perspective becomes important. We assume that teachers know how to reflect. They do reflect in a certain way but perhaps not in the kind of…*because if we want people to think deep and work deep, to make sense of things, rather than replicate and produce things. We have to actually show them how to do it and that is an essential thing."* The lead teacher's [C] opinion on beliefs, deepening of learning and context were as follows: "The right thing is if we have the right beliefs and the right tenets of practices, scaling is possible. If the beliefs and practices and tenets of what is teaching and learning doesn't change, bringing the lesson packages and resources to another school is just blind replication. A robot could do better than the teacher in that aspect. So what we are working with the teachers now is that we are teachers, not robots. We are not looking to replicate. We are looking to understand certain things, and find certain way of doing things relevant to you and your child. And because of that, the contextual engagement, being able to be there, apprenticeship for involvement for contextual discussion becomes key. I think at the initial part, yes. And as we go further to push the boundaries of what could deep learning, active learning or teaching and learning in certain pedagogical transformation look like. That portion will have to be very intensive until a steady state of understanding is reached and a critical mass of people have been grown."

The lead teacher [C] on growing teachers professionally, said that "So the need to grow teachers and be leaders per se, … teacher leaders, pedagogical curriculum leaders takes time and need to be given space. And the investment of time and the willingness of schools and cluster to put aside the resources to engage this and giving the allowance for things that don't work out, is important. While we work out, we know that there are teachers who are ready to take up, there are teachers who [are] not [ready]."

The realities of teachers and their challenging tasks of executing instruction to students and yet at the same time engaged in professional learning cannot be underestimated in the Singapore school context. Teachers are also involved in administrative functions, including that of co-curricular activities such as uniform groups, sports, and others. For teachers to juggle all the demands and yet engage in a journey of change, in particular epistemic change, is fraught with tensions and purposeful moral courage. Lead teachers bring teachers along a journey of "growing together" about issues on curriculum, teaching and learning, and as a collective to make professional decisions within and across schools—"how that process eventually pans out, how far we can go and how do we eventually help to move toward the same direction, actually vary. We end up with different departments going at different pace. Even within the department, different groups of teachers going at totally different pace" (Lead Teacher, C).

Autonomy in teachers' professionalism was also a central theme that surfaced from our interviews—"We have to give them [the teachers] the ability and the authority to make that decision." Because with decision-making, responsibility also comes in, "I need to be accountable to my actions. I need to be clear in my thinking" according to the teachers we interviewed.

Lead teachers also relate to us how they perform the crucial functions of ecologicing across and within schools. They consistently relate the importance of working with the school leaders in setting directions, with HoDs in their department's mission and plans, and supporting teachers in designing lessons and deconstructing them, and subsequently reconstructing them, and aiding these teachers in communicating upwards.

2.5.4 School-Level Macro-Layer (School Leaders)

From our interview with school principals, fostering an open culture for teacher learning and innovation/experimentation is important for change. School leaders recognize that for teachers to be designers of learning and instruction, professional competency is key and determining how well the students learn formatively and summatively are important. Strategies employed include enabling structures and organizational routines, protected time for NLCs and PLCs, including school and cluster level teams to strategize and implement the change process. According to

Principal [A], "It's cluster for schools not schools for cluster." In other words, this school principal understood that the cluster superintendent's interest in the school was to support the school's own mission and in aiding the school in achieving the MOE's policy goals in twenty-first-century learning (aka student-centred learning) and not the former model where schools have to achieve cluster goals in a top-down fashion. Clusters and schools work collaboratively in achieving common goals facilitated by school leaders in the middle of the two. While systemic in his perspective, this principal [A] understood that "deep learning is about giving good feedback to students, *go back to what learning ought to be about, what sort of culture will need to be in the school*. Not too obsessed about using this or that frame." This grounded perspective speaks to the grounded-systemic dialectics we mentioned at the beginning of the chapter. Principal [A] noted that:

> "Now there is a new team of teachers coming on board. I think there is a tendency to say, we want to replicate, go back and enact it the same way. But then we start to realise that, oh, ***the resources are different*** … The resource person is not there anymore like the past. Then how do we deal with it? … Of course, the struggle will be different. But I think once we distil, "What was the key learning out of it?" Because at the beginning, why was it difficult to start off? I think that terrain, nobody has ventured before. So we needed a very critical friend to guide us through it (the terrain), to give us certain... Even at that point in time, they did not feel very assured until they ventured, navigated the terrain. *But once they have done so, this group of teachers, I think their mindsets have opened up."* The principal's observations on teacher learning were as follows "Really need to know the ground in order to enact. Synthesis of what matters, do we need ground enough, students learning enough to keep in view to navigate, eventually to find the equilibrium. The teacher involvement is not homogenous, as teachers progress to next level, there is still learning. There is also need to invest time to learn again. There is a lot of discomfort on the ground." The principal's observations regarding system-icing policy translation to practice were "With the existing policy, one of the priorities is to develop the capacity that is still in the school, it cannot be singularly controlled by a school leader alone. The manner in which to grow capacity is *something other than curriculum leadership but also broader as management and leadership is about*."

The principal's observations from systemicing by identifying principles, were "we are not short of resources but what doesn't help is too many things on our plate as people get confused as to how *to unify common principles.* What helped was the emergence of the STP [Singapore Teaching Practice—a model from the MOE]. STP helped us rationalize the different dimensions of learning. But internalising it at the school level, we go after the curriculum philosophy as well. The school has been in the deep learning journey. *With these 2 words, deep learning, we are also trying to rationalize what it means to us, as far as we are concerned, it is about the integrity of T&L processes, but essentially it is pinning down what are the key processes the school is concentrating on."*

2.5.5 Cluster-Level Micro-Layer

At the cluster level, the space for collaboration, the willingness to put aside resources and time for the change process to happen is important. One LT [C] commented: "The past two years plus, the time that is given to the school and the collaborating schools … School leaders putting aside time for us to meet, 2 h every week previously to look at lessons to redesign, to be willing to open the school and things to each other, is critical. The support and belief from leadership, school leadership, cluster leadership to say that, this is the direction, keep telling them that this is the direction, encouraging that this is the direction, telling them that we want you to try, it is okay if it does not work out, is important."

Building capacity for adaptive expertise to be shared across the cluster was a systemic decision taken by the Cluster Superintendent and the school principals. The operational details that enabled a cultural shift, most significant of which, involve opening up the classrooms and deprivatizing teaching and learning in classrooms.

One HoD [C] observed—"it takes 3 years on average to be willing to open up that space." Opening up of classrooms encourages a diversity of ideas as facilitated by the LTs. Spreading the beliefs for epistemic change involves spearheading innovation in groups. Differentiated instruction and looking at the data by teachers ensure they gain valuable fresh perspectives, meaning that teachers are analyzing whether pupils are responding accordingly to desired outcomes as brought about by instructional strategies such as critical thinking and questioning by the teachers.

LT [A] explained that " … spreading beliefs at multiple levels should be performed in a coherent fashion with an ecological perspective … **Now, what we are trying to do now is how to get this to work towards ecological level where within the school zone, across clusters, we can actually drive a certain direction by first identifying the people with the common belief.** … if we are not going to move into an ecological perspective, apprenticeship can only get us so far. The question that I am also grappling with now is this. I actually told my P (principal), I said, my question is yes, in the next lap as we grow this ecological leadership, the school leaders actually see that there are certain things they want me to do and the role that they want me to go into, which I am comfortable because I have been working at different levels. But the question I also ask myself is although I can do all these things, would it be that my contribution level and utility that we will gain, which means staying in this school, is coming to a point where while I can still contribute, the gain is not as much as previously. Because the school is reaching a certain state of maturity and when the school reaches a certain state of maturity and readiness, **I think we may need to reach a stage where once the ecology is set up, we need to let go and let them find their own way.** Then what I am doing here may be more beneficial to go into another school who is starting off."

In subject-based leadership teams (SBLTs) where the cluster of schools form NLCs, the teachers often are in the position of "standing in the gap" which involves influencing teachers' beliefs and moral courage to question the higher-ups, in the apparent influx of policies that come down from the top and which affect their work assignments, and in turn, their abilities to perform the intended goals in classrooms. Standing in the gap is thus the courage to disagree or to counter-propose decisions made from a higher body, yet reconciling demands on both ends.

On the other hand, "standing in the gap" also involves downward percolations in helping teachers to "see." School leaders share the "beliefs" and that if teachers are willing to go in that direction of change, e.g., in assessments, and the collective (SBLT) belief is that as a group, "if they are united, they will hit a sweet spot" (LT, C]. Through our interviews, we gathered that "standing in the gap" includes four tenets which are as follows: enabling spreading of beliefs (opportunities), fostering partnerships, encouraging sustainability (succession planning), and open cultures (percolating upwards).

The Vice-Principal's [A] observations as a member of the SBLT is in orchestrating partnerships and collaborations between schools where "**the schools saw the benefits and advantage of collaboration.** … We saw the benefit of collaboration. We find that *the quality of the lessons has improved*. So from there, the school leaders actually wanted to move together again. **Because through the critique, through the kind of form of learning, through the form of lesson plans that we have. …we are able to look at lessons involved in the 5E model, a lot of students' artefacts that they are able to explain better**."

The VP/SBLT's [B] observations on school readiness were about the schools moving on board when they are ready. He shared that "we don't have that kind of numerical plan, targets. We just want to move when the schools are ready. Because actually the cluster superintendent shared with us the concept about the MRT train. So with the analogy, or metaphor when the train comes to your door, are you (school coming on board) ready to step up the train? Once you are ready, you can alight, you can do other projects." The VP/SBLT's observations on teacher readiness were "we get the schools to share their lessons with us. So from the sharing, we roughly know where they are. So that's why 'is the school ready?' Coming back to the school readiness again. *If the school is ready and we engage them, definitely we can spread the kind of good practices.* If the school is not ready yet, definitely if the school leader feel that the school is not ready, but we can take a baby step or we do it differently. Definitely, it's about the growth of the teachers. Because it takes a while for teachers to see the benefit."

The SBLT's observations on systemic-ing structural affordances were that "It's the timetabling team that have to work on this. For example, are we going to free up 2 h for the teachers to meet? At first, the teachers will feel that this is not my teaching period, why am I here? However as time passes, they find that they actually benefit. Although we give them 1 h, actually they meet for more than 1 h because they find that it benefits them. So we are actually not short-changing the teachers because it's for their professional growth." The SBLT's continued observations were that they would share their plans with the VPs first how they could develop the teachers together. "Sharing of plans is something like not just the meeting time, what we are going to do at the meetings, who are the people and what are we going to change. So for the SBPT for the Geography and English, we work the other way. *We started to map out the dates, the meeting time, which usually is in the afternoon.* We will also send all the information to the school leaders to free up these teachers' time. For example, the last meeting was last week, so they can meet in the afternoon. So we already point out the dates. There are altogether about six meetings, so the date and time were all fixed. So at the beginning of the year, we do the planning. We can't tell them last minute we are going to meet at this hour."

2.5.6 Cluster-Level Meso-Layer (Cluster-Level Steering Committee)

School leaders should have the view of "cluster for schools, not schools for cluster" and support capacity building of teachers with no prescribed one-size-fits-all model. Local school readiness and ownership should be assessing themselves their own readiness and the decisions should be made by the school. Cluster for schools by the cluster-level steering committee means enabling adaptation by schools, planning for school readiness and adoption, strategizing for the supply of expertise, adapting the language genre for open cultures and innovations, and integrating processes and programs. These are the planning done by the cluster steering committee. One of the committee member shared: "So far, the school leaders that we have been working with, they share the same thinking with us (think of developing teachers) … we let the VP to be the culture builder in the way that we want to develop that kind of deep learning for the school. And we have to assess the readiness of the school as well. Assess means by the VP and the school leaders, definitely we take a look at that. Why did [YYY] Primary only come onboard for Science? Is that because other subjects are not important? It's not that. Because we are already engaged in another platform. For example, **Math, we already have the 'I CAN' (programme). For the English, we have the STELLAR chapters**. So we see how we can move it. And also the resources that you have, if you only have two teachers for Science, are you able to spare these two teachers all the while? It all depends on the school's needs and school basis itself. So how strong is your team in your school? How are you going to develop it? So we let the school leaders decide and of course, we have this one-off that kind of sharing, learning journey for them to create more awareness."

The cluster committee's view on resourcing or the supply of expertise were: "So first, you are able to see what the … schools are doing and [we] give more critical feedback or some constructive ways of doing things. That's why for the other two subject groups that we have, which is the secondary school Geography and primary school English, *we are able to secure support from AST [the Academy of Singapore Teachers]."* This committee had to engage in systemic thinking in its planning for the cluster and to adapt to individual school needs. By focusing on learning, coordinating with the clusters on how expertise can be shared, carried over, or spilled over creates the new organizational norms/structures and sets the tone for open cultures in the change process. For example: "What we did was we had 2 sharings. The first sharing was to get those schools to share in 3 domains: leadership, teacher use and students use in the entire domain. Subsequently, we get the schools to adopt some of the practices in their schools and second half of the year, sometime in November, we get them to come back and share about what they have done after learning, what they implemented in their schools. And we also get ETD [educational technology division of the MOE] to facilitate the whole session. We get ETD involvement in a way to talk to HOD ICT. If they need any help, actually ETD will go to the school to guide them. Some of them adopted the practices like the other schools have shared."

2.6 Discussion–Leadership from the Middle (LftM) Expanded

From the case studies and interviews, we can surmise that leadership from the middle thus is about micro-level apprenticing/mentoring, meso-layer alignment of ecological fluencies, and macro-level systemic thinking that all cohere in tandem sidewards, upwards, and downwards percolation of expertise, practices, and epistemic beliefs. The lead teacher's role consists of teacher learning, enacting inquiry practices that sustain, going deep, opening up, and facilitating different perspectives: *Ecologicing* with a view to finding structural supports, e.g., time-tabling time; *Systemicing* and sense-making of policies and identifying enabling leverages (principles); *Apprenticing* toward adaptabilities to fit into schools' needs and readiness.

LTs (or equivalents, e.g., innovation champions) are at the *middle* of Ps (VPs, KPs) and teachers, and thus apprenticing leadership and ecologicing leadership are needed. Ps (or equivalents) are at the *middle* of school and cluster with ecologicing leadership needed in particular, and systemic thinking needed at the policy resourcing levels. SBLTs (or equivalents) are at the *middle* of SBPTs and cluster/schools with the systemic thinking needed for assessing school/department readiness and how resource sharing is planned and facilitated and the ecologicing for alignments between policy and practice. Teacher leaders are from the middle out at every level (Table 2.1).

The supply of expertise leading to dynamic alignments and coherences, both horizontally and vertically, involves the micro, meso, and macro-layer, respectively. The nuances and experiences to become a lead teacher lead up to attempting to face up to challenges faced in innovation diffusion. On-the-job (OJT) training develops a skillset relevant to do well as a teacher with skills training increasing capacity and competency.

Ecological leadership exhibits the characteristics of forging alignments and convergences in the different ecological layers, mitigating systemic paradoxes as well as local and cross-school tensions … (Toh et al. 2014, p. 845). To iterate the earlier point made, while there is upward percolation, the degree of downward percolation and horizontal percolation (through apprenticing leadership) appears to be significantly more evident. This is not uncommon in a system historically and culturally

Table 2.1 Summarizes the entire levels, people, process, product, and outcome of the system. From the table, we surmise that the entire ecology is co-dependent on the sum of its parts to function, i.e., each function is integral to the whole system in order for the ecology to operate

Levels of system	People (LftM)	Process	Product	Outcomes
Micro	Student	*Learn-ing* for both performance and 21st CC (according to the 4 lives framework)	Artefacts produced by students	Values, Skills, Knowledge, including 21st CC with metacognition (4 lives framework)
	Teacher	PLCs - *apprentice-ing*	Lesson plans and nimble Apps	TPCK
	HoD	*Ecologic-ing* between teachers and principals	SPID, STP	Alignment
Macro	School Leader	Networking of schools with cluster for change management (*ecologic-ing* between schools and clusters and MOE) *Systemic-ing* for change management	Change management tools	Change in school socio-technical infrastructure
	Cluster Sup	Networking with MOE, Zones (*ecologic-ing*)	Change management tools	School to school networks
Exo/Meso	Lead Teacher	NLCs – *apprentice-ing* and *ecologic-ing* between teachers and exo parties	SPID, STP, and change management/leadership	Supply of teachers with design competencies
	ETO	NLCs – *apprentice-ing* and *ecologic-ing*	Pedagogical innovations e.g., Java Sim	Curation of innovations
	NIE Researcher	NLCs and PLCs – *apprentice-ing* and *ecologic-ing* with evidence base data	Pedagogical innovations e.g., WiRead, Mycloud, PF, etc.	Systematic evidence base
Chrono	ICT implementation & ICT innovations	*Systemic-ing* centralized-Decentralized (systems thinking) balances	Hybrid – SLS & Appstore	School cultures for transformative practices (including hybridity)

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accustomed to higher forms of power distance. However, for a system that undergoes changes in the context of diffusion, upward percolation is imperative. And there must be continuous bidirectional upward and downward percolation as connoted by Toh et al.'s notion of ecological leadership. In the context of change, as elements in the system are co-evolving, and especially when teachers are undergoing significant changes in enactment, it is important that middle management and school leaders are cognizant of what is happening. As it is often the case for upper levels to downward percolate, there needs to be upward percolation to co-inform each other and for alignments to constantly be meted out. Because upward percolation is usually more difficult to enact in East-Asian cultures, school leaders need to remain grounded, and teacher leaders need to develop trust with their school leaders.

Culture building through upward, downward, and sideward percolation is a form of distributing leadership that has to be practised. As with the observations made in this study, every teacher leader including the school leaders (*as the middle*) needs to percolate upwards, for example, school leaders to their superintendents and even policymakers at the MOE to formulate policies. Because of the close and tight ecology of the Singapore education system, it is often possible for school leaders to be represented in committees at the MOE. However, there is a need for school leaders to transcend higher power distance and communicate upwards. It is not just school leadership but all levels (from teachers to the MOE) that need to be in place (in alignment).

Apprenticing Leadership and Systemic Leadership Elaborated.

The PLC can be used as a structure to support apprenticeship. Below is a typical excerpt that is representative of apprenticing work among teachers:

Mentor: Most people when they do PLCs will do operational issues. Definitely, we will have that too. But we will make sure that every PLC we have some *discussion of pedagogical issues. … This is very important because as a teacher, our pedagogy is our foundation to what we are doing. …*

Mentee: I definitely did learn a lot, because I came from PGDE, there was only 1 year. In this 1 year, *there were not many questions like [mentor] has posed, thought-provoking questions. And it actually did open up my way of seeing things, my perspective in the classrooms.*

Schools that have a sustainable trajectory are evidenced by school leaders who exhibit three characteristics: moral purpose, being systematic yet grounded, and are situated within a broader cultural-historical perspective of the school and MOE policy (see Fig. 2.3).

A case in point is illustrated in the interview with a Principal:

> What should be the binding force for my teachers is how to transform the lives of our students. It's engrained in our school mission. We pride ourselves on a strong ***culture of care*** for the students. Knowing that students don't have a good head start, but we are student-centric, we want to drive the students forward.

Importantly, principals who particularly work with students from disadvantaged families may be motivated to care for these students, and helping them to level up to those more advantaged is a moral purpose. Moral purpose is a broader philosophical underpinning motive to appropriate inquiry-based learning for these schools.

Fig. 2.3 Keeping to moral purpose yet systemically grounded

Moreover, principals in the interviews usually attest to the fact that they have to be systemic in their thinking—to use systems thinking in approaching their school's agenda. Yet at the same time, the successful characteristic for innovation sustainability is the ability to be grounded. Principals and their key personnel (KPs) are to be grounded, knowing the pulse of what is happening to their teachers, the curriculum, and giving agency to the ones who enact the curriculum. To be systemically grounded is consistent with the ecological leadership where alignments throughout the school are achieved.

To consolidate our observations:

Apprenticing Leadership—*sidewards.*

Initial "involuntary" assignment (high power distance) does have a place here, but good facilitation is needed to achieve collectivism toward teacher learning and change. Being privileged to be called as an alternative interpretation to the initial "involuntary" assignment of high power distance.

Ecological Leadership—*upwards and downwards.*

School leaders' intentionally reach out to teachers to bridge "power distance" between levels—*two directional percolations*. Upward percolation by teacher leaders is particularly necessary to situate *"what works"* (with evidence to support) as a means of achieving alignments for the benefit of students overcoming multiple misalignments which may arise through the system.

Systemicing leadership (see big picture).

Grounded-systemic leadership at the macro layer is essential as systemic structural affordances for centralized–decentralised organizational routines of distributed leadership through leadership in the middle is necessary for orchestration at the macro layer.

Moral courage leadership (see student-centricity holistically).

Sekerka and Bagozzi (2007: 135) defined moral courage as "the ability to use inner principles to do what is good for others, regardless of threat to self, as a matter of practice." Kidder defined moral courage as "a commitment to moral principles, an awareness of the danger involved in supporting those principles, and a willing endurance of that danger" (Kidder, 2005: 7).

Moving a school is hard enough, what more a system. Moving a system toward the change desired, yet at the same time keeping to the successful indicators without an implementation dip, is no mean feat. It requires a delicate balance of the forces at play throughout the system. While we can appropriate tenets of change from systems distant from the context at hand, this study reminds us once again of the sensitivity to the indigenous context of any particular system. Apprenticing leadership co-evolves with ecological leadership in a distributed fashion and the agenda for diffusion facilitates opportunities for teacher leaders to be positioned and to be exercised toward such leadership roles.

Throughout the chapter, we have intentionally avoided a traits-based view to leadership, nor attributing leadership to one particular leader per se, and our observations are that school leaders bring their particular leadership orientations to the school. Framed from a cultural-historical lens, and dependent on the needs of the school at a particular timeframe of a school, a school leader and the leadership team fill in the gaps left behind from the previous leadership. Good leadership recognizes the strengths and weaknesses of the leadership held at a particular era and brings in a new leadership team to achieve the goals of the school for the sustainability of innovations to be achieved over time, even a decade.

2.7 Conclusion

According to Elmore (2004, p. 11), cultures do not change by mandatory means, instead they change by the specific displacement of existing structures and processes. In our research, while we acknowledge Elmore's "displacement" principle, we recognize the displacement to be evolutionary. Our work is consistent with Splliane's (2006) notion that change changes the very context itself. The three layers of enactment were co-evolutionary as the diffusion occurred. Leadership trajectories are constantly in the making as *context is evolving*. Within the indigenous nature of leadership, in Singapore's context, intentionally making formal positions of teacher leaders might enable these champions to be better positioned to diffuse their beliefs. These formal appointments, for example, appointing lead teachers to work across schools as a norm is enabling these champions to influence within the lateral networks created and cultivated through the NLC structure and process. We recognized that in order to sustain change in teachers, fostering school- and cluster-wide innovation-learning cultures is essential.

Despite the co-evolutionary nature of the innovation change context, we characterize relatively stable constructs, namely power distance issues and collectivism. Collectivism was indeed observed when unwilling teachers who underwent the peer apprenticeship learning process transited from tolerance to acceptance and subsequent to joy in acceptance. Through the process, we claim that apprenticing leadership facilitates collectivism. Ecological leadership mitigates high power distance.

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Chapter 3
Cultural-Historical Gatekeeping: Why Educational Change is Difficult Despite the Influence of Technology in Singapore Schools

A. A. Johannis, Shamala Raveendaran, Chloe Yi-Xiang Tan, and David Wei Loong Hung

Abstract The Singapore education system has attempted to integrate educational technologies since 1997, yet the trajectory of implementing this vision has been fraught with many challenges. These challenges were initially thought to be infrastructural in nature, but even with hardware in place, many remaining issues abound that were socio-cultural in nature and largely concerned with dominant instructional practices prevailing in schools. We classify these challenges as cultural-historical factors where the genesis and evolution of societal expectations and economic imperatives since nation-building started in the 1960s, underpin our theories for why change is difficult for an education system. In this chapter, we present case studies of local schools undergoing change and theorize systemic leverages, supported by evidence, that enable (or otherwise) such a process. Macro, meso, and micro points of leverage from an ecological perspective are discussed as a corrective for misalignments at the various levels of the system in order to cultivate sustainable pedagogies with technology for twenty-first-century learning. Cultural-historical gatekeepers need to be made visible in order for stakeholders in the system to be cognizant of them and their capacities. We present system-brokers who mediate and enable change in the system as a whole to enact change from the middle.

System change is slow. Even in a modern, well-funded education system like Singapore's that leads the world in many performance metrics, the mere infusion of new technology in a planned system change does not guarantee successful or swift negotiation past its cultural-historical gatekeepers. In our experience, system change is often slow or unsuccessful because of the lack of buy-in and alignment from cultural-historical gatekeepers, whose positions and attitudes have been deeply entrenched

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over time and become difficult obstacles to overcome. In Singapore, these cultural-historical gatekeepers are not only represented by personnel in the Ministry of Education (MOE), but also by the parents of students, whose demands and expectations are well heeded by the ministry.

In this chapter, we will first present a historical overview of the education system in order to set the historical backdrop of our education culture. This will show how, as we grew from historical phase to historical phase, Singapore society has built up its cultural expectations regarding examinations and success in life and how these attitudes have become part of our contemporary cultural DNA and identity as Singaporeans.

Then, through the presentation of case studies, we will show real-life examples of cultural-historical gatekeepers acting in relation to the implementation of changes in the school system. This will help initiate and substantiate our discussion on how we might correct system misalignments through ecological leadership strategies. By starting with teachers, who are at the heart of system change, we will discuss how changing classroom culture and influencing the beliefs and expectations of parents can be achieved in an ecologically valid way. This kind of system brokering by teachers should go a long way in overcoming gatekeeper intransigence and encouraging cultural shifts towards healthier and more future-ready attitudes on education.

3.1 History of the System

Singapore's education system has been, since independence, closely tied to national economic imperatives. In fact, Singapore's social mores themselves have been, to a significant extent, shaped by its economic development. By tracing the Singapore education system through its major historical eras, we intend to show the origin and development of cultural-historical factors that were once crucial to its success but now have come to form the obstacles to change.

3.1.1 Survival-Driven Phase: 1959–1978

While Singapore had been a successful international seaport during British rule, it had neither a well-rounded economy nor an educated populace. In the late 1950s, 70% of its GDP was from entrepôt activities and when the British military finally left in 1967, its bases and installations had accounted for 14% of GDP (Dixon, 1991). So, as illustrated in Fig. 3.1, from the achievement of self-governance in 1959 (and especially after national independence in 1965), Singapore entered a 'survival-driven' phase to promote economic growth and industrial jobs creation in order to avoid political collapse (Ho & Koh, 2017).

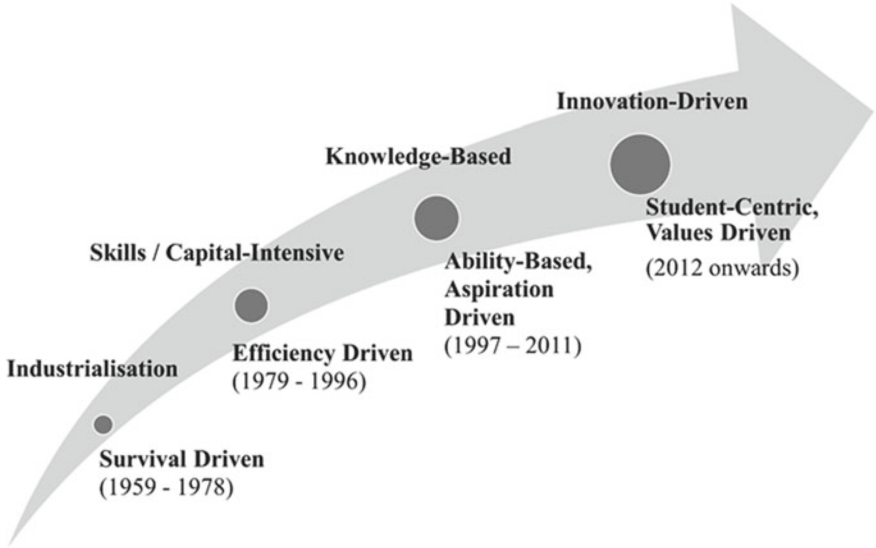

Fig. 3.1 Education policy phases aligned to Singapore's economic development (Ho & Koh, 2017). Copyright 2017 by World Scientific. Reprinted with permission

It was against this economic backdrop that the education system was revamped (from the colonial one). The focus was on expanding basic education as fast as possible to create a (minimally) skilled workforce for new industries. By 1965, 83 new schools had been built and universal primary education was achieved (Goh & Gopinathan, 2008). The variegated education landscape of various ethnic-based schools and various religious mission schools were united under one secular public school system based on English language instruction.

While the economy and the education system will go on to bigger and better things, the survival-driven phase would induce long-lasting effects in our cultural DNA. First, it would establish assisting economic development as the main goal of public education. Second, it would help imbue a sense of national duty and national pride towards the fulfilment of national economic imperatives.

3.1.2 Efficiency-Driven Phase: 1979–1996

The above swift reaction to a dire situation that threatened our survival as a nation meant that quality of education was not yet taken as important. In 1978, the Report on the Ministry of Education 1978 (also known as the Goh Report named after the then Deputy Prime Minister Goh Keng Swee) highlighted high dropout rates and low standards as the most pressing problems in the education system (HistorySG, 2016).

Downstream, Singapore was facing a severe shortage of highly skilled workers in engineering and other technical expertise.

During this phase, the government's economic strategy was to shift from a relatively low-wage, labour-intensive economy to a higher-wage, capital- and skill-intensive economy. The education system was changed from a universal quantity-based system into a quality-based one with multiple streams. Streaming also helped to reduce the high dropout rate by helping all students reach their own individual potential at their own pace. By 1986, only 6% of students were leaving school with fewer than 10 years of education (OECD, 2011). This phase of the education system also saw the introduction of the now-familiar Vice-Principal (VP) and Head of Department (HOD) positions in local schools, increasing the bureaucratic and hierarchical aspect of the system.

This phase also saw improved education standards across the board. By 1997, Singapore topped both mathematics and science in the Third International Maths and Science Study (TIMSS) (The Economist, 1997). The competitive ethos helped push Singapore to the heights of international level academic performance. Unfortunately, this success helped create the hierarchical and hyper-competitive ethos of the Singaporean system that continues to this very day (Lee, 1991). The hierarchy among school staff also led to an increase in power distance and deference across the ranks. The competitive ethos has also pushed more and more teachers to teach to the test since international benchmarking is biased towards test-taking skills (Sharpe & Gopinathan, 2002).

3.1.3 *Ability-Based, Aspiration-Driven Phase: 1997–2011*

In line with Singapore's long-term economic progression up the value chain, by the 1990s it was clear that Singapore had to adapt to the global shift towards the knowledge economy. The economic imperative was no longer about gaining higher skills but spurring innovation, creativity and knowledge creation. In fact, this was more a paradigm shift than a progression, as Singapore began to de-industrialise and focused on knowledge-based industries such as life sciences, research and technology, finance, higher education and other services.

In order to articulate the need to adapt the local workforce to these trends in the world economy, then Prime Minister Goh Chok Tong unveiled the Thinking Schools, Learning Nation (TSLN) set of education policies in 1997 (Ministry of Education, 1998). It was during this phase that the Ministry of Education (MOE) of Singapore initiated what are today known as 'centralised-decentralisation' reforms where MOE's role was to set broad guidelines and directions for the education system and it is each school's role to set up its own detailed policy implementations and pedagogical practices.

The year 1997 also saw the introduction of school clusters that comprise 11–13 individual schools and 4 geographical zones with 7–8 clusters each. The cluster was meant as an intermediate level of authority that would offer professional developmental help to school leaders including, HODs, Vice-principals and Principals and offer a platform to share resources and management and pedagogical practices.

In 1999, in order to recognise the leadership role and potential of teachers and to provide them further differentiated career progression pathways, MOE introduced the teacher track alongside the pre-existing leadership and specialist tracks. In the teacher track, an education officer may rise to Senior Teacher, Lead Teacher, Master Teacher and Principal Master Teacher. The three tracks, however, generally run parallel despite the fact that personnel are allowed to switch tracks (Ministry of Education, n.d. -a). An education officer on the teaching track may still switch over to the leadership track to work his or her way up to become a Principal or even to the Director-General of Education. He or she may also switch to the specialist track and ultimately rise up to Chief Specialist. However, relatively few education officers elect to switch tracks.

These structural changes bring their own challenges to the potentiality of system changes. The greater school autonomy meant that power and influence are somewhat diffused and this mitigates power distance to some extent. Yet, the introduction of varied career tracks has increased the perceived distance between colleagues on different tracks even though technically speaking, individuals can change tracks during their long careers. Few education officers ever take up the option to switch tracks. Nevertheless, the introduction of school clusters has allowed for greater inter-school cooperation in sharing of physical resources as well as intellectual and creative capital.

3.1.4 Student-Centric, Values-Driven Phase: 2012 to Onwards

Singapore's education policy continues to be shaped by economic imperatives up to the present day, but economic visions of the future are very different from recent history. The forthcoming Fourth Industrial Revolution and its domination by information technology, big data analytics, artificial intelligence and robotics will make physical labour and even knowledge-based jobs obsolete (Schwab, 2017). In the future, economic value will be created by innovation and the kind of soft and people skills that machines cannot replicate.

Consequently, MOE has chosen to pursue this goal more holistically by providing more informal and self-directed learning, in and out of the classroom. In 2014, MOE introduced the Learning for Life Programme (LLP), which involves non-academic activities such as sports, arts and outdoor activities that are designed to help students develop their character and values, and the Applied Learning Programme (ALP), which take lessons from academic subjects and applies them to practical activities such as using math skills in running a small business.

Other recent educational policies have also served to wean Singapore away from the result-oriented and credential-based obsessions from which it suffers. In 2012, MOE abolished secondary school rankings and ceased the long-practised tradition of announcing the names of the top scorers in the Primary School Leaving Examination (PSLE) as well as the N- and O-level results every year. Recently in 2018, MOE announced reductions in examinations during key transition stages in primary and secondary schools in order to focus on learning and to alleviate performance pressure on the students.

Unfortunately, the successes of the past can become obstacles to the future. The decades of high achievement in academic performance has been established as normal expectations by both parents and teachers (Manzon et al., 2015). After all, both sets of people are survivors of the earlier phases of Singaporean education. In the beginning, after independence, Singapore could import and develop good curricula, but we simply did not have the people capacity to provide innovative or inquiry-based pedagogies. So local teachers delivered the curriculum the only way they knew how, through basic transmission and rote learning. The academic achievement that this happened to attain justified the means and reinforced cultural belief in those means.

Therefore, system change that is dependent on cultural change will generally take a long time. Technological innovation cannot help overcome the beliefs and attitudes of cultural-historical gatekeepers about education. School leaders and teachers find it difficult to think and comport themselves otherwise, but even if they do, parental expectations remain a large obstacle.

3.2 The eduLab Programme Background

This paper draws on data collected from innovation projects participating in the MOE's eduLab funding programme (Educational Technology Division, 2017). The case studies we present here are extracted from data collected from a multiple case study research project funded by the eduLab programme titled 'Scaling as innovation: Innovation diffusion models in Singapore' (eduLab Project, 2018).

As mentioned in other chapters in this volume, the eduLab funding programme is a nationwide initiative available to teachers, researchers and MOE officers to take advantage of for the development and implementation of educational innovations that use information and communications technology (Ministry of Education, n.d. - b). It is specifically designed for the research or development of information and communications technology (ICT) innovations that can potentially be scaled to many other schools or sites. More information about the eduLab funding programme and the context behind it may be found in Chap. 4 titled 'An activity theory approach to characterising how ICT based innovations spread in Singapore schools'.

The research question that this chapter aims to answer is what the role of socio-cultural gatekeepers is in the scaling of educational innovations. It will also hypothesise on possible models of leadership and ways of scaling that can help mitigate the obstructive interference of these gatekeepers.

The case studies below show the existence of impediments at the meso and macro levels that confront change agents for educational innovation scaling as gatekeepers. The case studies chosen for this analysis aim to explicate and narrate the roles and practices of these socio-cultural gatekeepers.

Borrowing heavily from Bronfenbrenner (1979), our theoretical framework is adapted from his ecological model of human development that posits that individual human identities and social practices are developed through individual interactions with larger sociological contexts which are categorised as the micro-, exo-, meso- and macrosystems. The 'microsystem' refers to the 'pattern of activities, social roles and interpersonal relations' in the immediate environment (Bronfenbrenner, 1994, p. 1645). The 'mesosystem' is where two or more microsystems interact such as the school environment and it helps connect the microsystem with the larger macrosystem. The 'exosystem' is tangential and is not always necessary to include, but it can play a very helpful part in bridging the macro- and mesosystems, and is where 'events occur that indirectly influence processes within the immediate setting' in which the teacher or practitioner acts (Bronfenbrenner, 1993, p. 24). The 'macrosystem' is where policies and societal norms affect the scaling of educational innovations. Figure 3.2 presents the Bronfenbrenner-inspired theoretical framework that we use as adapted by Toh et al. (2014).

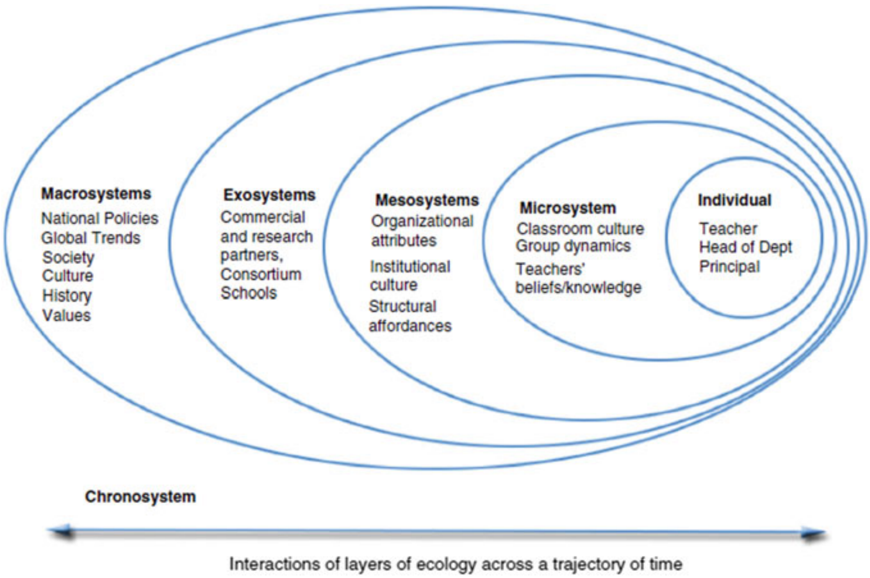

Fig. 3.2 Ecological influences underpinning the diffusion processes of school-based innovations (Toh et al., 2014). Copyright 2014 by De La Salle University, Philippines. Reprinted with permission

3.3 Methodology

This paper uses a descriptive multiple case study approach from a constructivist paradigm to engage in questions about how innovations spread in and across schools. The unit of analysis are schools that have been engaging in innovation projects. The case studies are bounded by the experiences in these schools of the teachers who are involved in implementing and spreading the innovation projects. As these case studies are descriptive, they allow us, the researchers, to explore the phenomena (Yin, 2018) of how innovations spread in schools and to understand where the sites of tension are.

We will be taking a closer look at the data from two teachers in particular, who were selected from a collection of case studies from a larger research project involving a single innovation project that was being implemented in 14 different schools. They were selected based on their being typical cases (Gerring, 2008) in the larger research project, with some variation in the execution and outcome of the same innovation project, and therefore, they serve as means to uncover the gatekeepers present in the socio-cultural context. The units of analysis in these descriptive case studies are built and narrated by collecting data from various participants working with and around the two main teacher subjects.

Interviews were conducted in a semi-structured manner with different interview protocols for different types of participants. The questions were contextualised for the different roles that they play. The data were then analysed using grounded theory with the aim of answering the research questions.

From this study, we present the experiences of two individual teachers from two different schools as case studies that demonstrate the actual and lived problems and obstacles to change which the cultural-historical gatekeepers pose on the ground in the Singapore education system and as embedded in the cultural-historical context discussed above.

The innovation project that these findings are drawn from will be denoted as Innovation X. This particular innovation project was identified in the larger research project as exhibiting a 'network' model of innovation spread (eduLab project, 2018). This network model is characterised by the presence of key actors such as community builders, ecological leaders and innovation-ready teachers (Ibid, 2018). In the network model, these roles are deemed necessary for innovation spread. The role of the community builder is to break the relationships within schools and across them. The community builder also engages in building the capacity of teachers by helping them to implement innovations in their classrooms and increasing their professional knowledge. The community builder also trains key teachers to become experts in innovation so that they can consequently impart their knowledge to other novice teachers. The innovation-ready teacher becomes part of the community of teachers who engage in innovations such as Innovation X.

These key teachers are ready to implement the innovation and also to spread the innovation to other novice teachers. The community builder and innovation-ready teachers are supported by ecological leaders who understand that innovations require support from the micro–meso–macro layers of the ecological system. They lead in identifying teacher leaders who will be integral to the implementation and spread of the innovation. They distribute responsibilities to middle managers such as Heads of the Department so that they take more active roles in spreading the innovation (Ibid, 2018).

3.4 Case Studies

For the purposes of maintaining the anonymity of our subjects, we will refer to them as ‘Teacher A’ from ‘School A’ and ‘Teacher B’ from ‘School B’. Teacher A is a senior teacher on the teaching track. Teacher A started the growth trajectory of an innovation project for her school under a network model of innovation scaling brokered by the Education Technology Officer (ETO) (Ibid, 2018). This project falls under the network model in part because it is enabled by international and local research collaborators. The network model is characterised by positive reinforcement by researchers and other stakeholders who deepen the knowledge and practice skills within the network community in question. The roles that the resource broker plays as well as that which the community builder plays are crucial in the network model. The community builder forges ties across and within schools, and amongst teachers and between them and school leaders. The community builder, resource broker and other ecological leaders are the essential stakeholders in the network model of innovation. Ecological leadership is defined as a leader who is able to facilitate both the upward percolation of pedagogies and practices and the downward percolation of school and ministry policies regarding an innovation (Toh et al., 2014). Ecological leaders engage all levels of the network.

Teacher A was initiated in Innovation X by a network community of teachers and schools. This network community was started by the ground-up efforts of a pioneering group of teachers. Teacher A first received training and instruction on the pedagogical practices and software required for the innovation. The project was implemented through a professional learning team especially set up for this specific innovation and was successfully seeded to other teachers in the innovation community. Teacher A’s sense of ownership of this innovation was exemplified by how she was willing to sacrifice her free time to observe and provide constructive feedback for improving the project. The second teacher who joined to implement the project noted, ‘[T]hey just see how their students enjoy the learning and how the children have changed in their thinking.’

Teacher A encountered certain difficulties in trying to spread the innovation within her school. She mainly faced difficulties at the meso level where the school management and school leaders were concerned with moving collectively in a different direction. The meso level was challenging in which to initiate change, as many in middle management were not keen on implementing said changes. Teacher A reported, ‘I shared and presented to the Exco (Executive committee), after that they are not very keen to take up. The HODs are not keen. So, without HOD support, you can't move into other subject areas.' Teacher A explained that support from the HODs was crucial in scaling and sustaining the innovation. The HOD acts as the gatekeeper in middle management by being the authority who allocates workloads and schedules timetables. In executing his or her duties as an HOD, an HOD can support or hinder teachers attempting to implement any new projects.

Lowering workloads and allocating more time are necessary steps for teachers who need to access student artefacts and make sense of students' writings on ICT-mediated platforms such as Innovation X. Teacher A stated that there is a '*humongous amount of official worksheets you have to do. It draws you away from time to analyse".* She feels that *"unless I analyse at 1am, 2am in the morning. You know, that's impossible*'. A teacher who has to cope with assessing both the official set of worksheets and the materials created by an innovation project is more likely to compromise on the quality of work on the innovation project compared to one who finds support from her HOD to at least temporarily lighten her load. The lightening of one teacher's workload and timetable will of course have an impact on her colleagues who will have to pick up additional work. However, these structural changes affecting the whole department are necessary for the proper implementation of any new innovation projects and it is up to the skill and professionalism of HODs as workflow gatekeepers to manage these issues. An HOD who refuses or is otherwise unable to make the necessary changes can pose an insurmountable challenge to teachers who initiate such ground-up efforts in their schools.

The above-mentioned Singaporean cultural obsession for high performance in education was also an obstacle that Teacher A faced. Singapore's credentials-based meritocratic economy means that Singapore's education system has become ultra-competitive on grades achievement. This further means that teachers have to constantly strive to achieve greater efficiencies in the usage of classroom time to help students obtain ever-higher grades. This leaves little time for the implementation of innovations or in fact, anything else that is not in the examination syllabus. The stakes are even higher in grade years when common national examinations are held, because the results of these determine which school, subject levels or education program a student may qualify for next. In grade 6, students have to take the Primary School Leaving Examination (PSLE), the results of which are fed into the highly competitive middle school admissions system. What is at stake are what academic track a student finds him or herself entering (though this streaming system has now been abolished as of 2021) and even what level of social status a student can obtain by entering the more selective and prestigious middle schools - which also consequently determines what kinds of co-curricular programs a student can access and how nationally competitive they are.

Thus, pedagogical innovations are often not carried out in the school years when students sit for the highest of high stakes examinations, in favour of concentrating on preparing students for these examinations. Teacher A was able to achieve the performance target for her grade 5 students but was forced to pause the innovation implementation the following year when they were promoted to grade 6. She recalled that this resulted in a significant dip in her students' motivation. So, even while following the widely accepted and traditional way of implementing ‘drill and practice’ pedagogy on grade 6 students, she found that her students’ grades started to slip. This dip was subsequently falsely attributed by the school management to the innovation project she was trying to implement. The school management then started to deter teachers from implementing the innovation. A general culture for high performance in schools is theoretically complementary to the implementation of alternative pedagogical innovations, however, Singaporean schools have a tendency to revert to the conservative ‘drill and practice’ pedagogies during high-stakes examination years because of the long tradition of grades-based academic excellence these pedagogies have helped achieve. This causes tension between implementing education innovations and sustaining high-grade performance because such innovation projects do not appear to translate to high exam scores, at least not in the short term.

Technological infrastructure or the lack thereof was also a major challenge that teachers face. Access to ICT infrastructure is critical for technological innovations because they make the pedagogical changes possible and efficient in a context of relatively limited classroom time. However, the quality and accessibility of ICT infrastructure differ across schools. Teacher A recollected this with frustration when she said that ‘*For me, when I first started (the project), after the term one, I almost wanted to give up. I cannot take anymore. Because I keep burning my periods. Because with the ICT infrastructure, it’s so poor, I don’t have time.*’ Thus, the success of the innovation in the school was contingent on there being sufficiently good ICT infrastructure. This is important because of the tremendous demand for classroom time given the large amount of curriculum content that teachers have to cover within the academic calendar. Although this is not a socio-historical gatekeeper, per se, it indicates that the school gatekeepers have prioritised other areas of school development in lieu of developing ICT infrastructure and is a wider testament to the priorities of the school gatekeepers with regards to implementing ICT innovations.

Innovation X involves professional learning teams in which participation is mandatory for teachers. These teams are required for the professional development of teachers in schools. Teacher B, a senior teacher who has six years of teaching experience, is part of the effort to implement and scale up innovation X in schools. The innovation project is a joint effort by professional learning teams and teachers to ‘co-construct’ lessons with students in order to better use the autonomy and agency of students themselves for their own learning. This collaborative project is aimed at enhancing the students’ motivation to learn and develop self-determination.

Teacher B was a critical element in ensuring the implementation and scaling of innovation X in School B. Teacher B started the conversation of implementing and scaling the project with his school’s middle management and mooted the idea of implementing said innovation in the same way it was done at his previous school. The HOD or middle manager who acted as the gatekeeper to instructional practice and the implementation of systemic scaling of pedagogical innovations was receptive to the idea. In an excerpt from the interview with Teacher B, he stated, ‘My HOD, from the moment I mentioned the (innovation) to her, love the idea. I already had a short presentation to the whole (humanities) department. So we decided to start with (subject) first, my HOD saw the value in it’. The HOD is the person who approves any proposed innovation to be carried out in classrooms. Teacher B reiterated that management support is key in innovation endeavours, saying that 'I think before anything first, the support from management is definitely crucial. The support from management is certainly very important. That's the first step'.

Singapore education system's success in PISA rankings had given rise to a pervasive feeling in society that the sole path to success lies in scoring well in the major high stakes examinations. This is significant because most if not all schools now view themselves as having the ultimate responsibility of delivering good grades so that their students can have the best possible chance of succeeding in our narrowly delineated meritocracy. Therefore, any pedagogical innovation project needs to assure school leaders that implementation will not cause a drop in academic results. Thus, innovations are implemented in low stakes school grade levels such as grades 7–9 in middle school. In grade 10, the year in which one of the high stakes examinations are taken, lessons are conducted using performance-oriented pedagogies. This is very similar to the case of School A, which is an elementary school.

Professional learning teams have multiple functions. Chief among the functions is to act as a resource for teachers to share their experiences in scaling up and implementing innovations. Teacher B utilised his professional learning team to organise an opportunity for fellow teachers in School B to observe the innovation in action in his classroom. This was aimed at obtaining their buy-in for the innovation. This enabled the innovation to later scale and spread. By opening up his classroom to teachers in the school to view the innovation in action, he was able to contribute to their upskilling. Apart from observations and experience-sharing, he also contributed to the capacity building of the teachers. He envisages that building this network of teachers who are enabled in the capacity to carry out innovations, will eventually help enculturate more innovation leaders from the middle.

Teachers as innovation leaders can also harness their schools' visions and missions when they are aligned with pedagogical innovations. Teacher B was able to tie the pedagogical innovation project with his school's vision and policies involved with character and citizenship education (CCE) learning outcomes. Teacher B shared, 'I must say, before that our HOD is fairly aligned to what we mentioned because we are moving more towards a… formative assessment. So, this obviously aligns very nicely with formative assessment. All this aligns very nicely with CCE learning outcomes, the idea of self-awareness and self-management, but more particularly is the alignment with knowledge building principles'. Teacher B views this alignment as an opportunity to develop their students' sense of self-awareness and self-management.

Teacher B also views the alignment with his school's vision for CCE learning outcomes as an opportunity to grow the scaling progress of this innovation project in the school. Education policies are thus important background conditions that can create conducive environments for the holistic implementation of pedagogical innovation. However, the question arises of whether school leaders would choose to be involved with innovations that do not wholly align with education policies or are against the policy dictates coming down from the system hierarchy. This raises the further question as to what kinds of additional obstacles will arise if innovations are misaligned with both school and national policies. The centralised-decentralisation phase of the Singapore education system was designed to decentralise some decision making, but cultural deference to hierarchy still influences school leaders.

Student expectations are shaped by macro-level education policies that require time to change in alignment with innovation goals. This acclimatisation to the new pedagogical innovations and instructional policies can be achieved, however, regardless of the fact that some students are 'too dependent on the textbook' and are often heard remarking, 'Teacher, this is not in the textbook'. There are also students who call into question the efficiency of innovative pedagogies in favour of the highly efficient performative pedagogies that form traditional practice. Teacher B recognises that students need to exercise patience to get accustomed to a more innovative culture. In a school where students are used to being taught with more didactic teaching methods, Teacher B had to overcome the latent inertia of the cultural-historical gatekeepers. He was able to do so by leveraging his competency in the proposed innovation. Teacher B was able to do so also because he stuck to his belief that the innovation pedagogy would eventually bear fruit.

3.5 Discussion

While we are well into the innovation-driven phase of the Singapore education system that started in 2012, it is clear from cases studies as narrated above that the diffusion of innovation change cannot be taken for granted. We saw how Teacher A was initiated in her innovation project by a professional network of teachers and schools that was started from the ground up by classroom teachers. This apprenticeship was what enabled her to gain a sense of ownership over the project and overcome any personal commitment to the status quo that she might have had. Nevertheless, Teacher A experienced strong resistance from HODs who were in the position to make decisions on changes to structural support such as workload reductions and duty allocations to teachers under their charge.

Her drive for implementation was further scuppered by the fact that she was denied permission to continue her project when her students transitioned to grade 6. Teacher A's experience is an example of a school protecting students in the year they face major high-stakes examinations from other activities or considerations that might distract focus from exam preparation (Tan, 2013; Hogan et al., 2013). This single-minded focus on performance in major high-stake examinations such as the PSLE is driven in part by parental expectations (Ong & Cheung, 1996). This coheres with other findings that Asian parents or parents of Asian extraction exhibit relatively higher levels of academic expectations compared to parents of other races (Yamamoto & Holloway, 2010).

Another obstacle for Teacher A was the lack of access to critical ICT infrastructure that is instrumental to the implementation of innovations. While Singapore is generally a rich country, ICT resources are still expensive and schools have to share certain resources. This sharing, however, is itself dependent on how well the network of school leaders at the cluster level work together (Hung et al., 2018b). Therefore, this represents another facet of the gatekeeping role of HODs and school leaders.

We also saw how Teacher B seemed to have had an easier time with his innovation implementation project. Like Teacher A, Teacher B was also involved in a professional network of teachers to help in his professional development. Not only did this help in convincing him to buy into the merits of the project, but he also used the network to apprentice other teachers into doing the same. Unlike Teacher A, however, Teacher B had the agreement and support of his relevant HOD, whose approval was needed to carry out the project implementation in classrooms.

However, School B was not immune to the demands of parents either. Like School A, the school leaders of School B also see themselves as primarily responsible for academic performance and this cashes out similarly in isolating students in the year they face a major high-stakes examination: in this case the O-level exams in Secondary 4 (grade 10) (see Tan, 2013; Hogan et al., 2013). Thus, in School B, innovations are only implemented in Secondary 1–3 (7–9th grade).

The case study of Teacher B also reveals the potential for classroom teachers to be system change agents (see Hung et al., 2018a). While Teacher B faced some pushback against his innovation implementation by his students, he is in a position to push through and help his students acclimatise to the changes despite their resistance.

Overall, these case studies are in line with the broader educational change literature that argues that system change is not a manner of simple replication of efforts across all schools. System change is not a 'cut and paste' job. While there is no shortage of theories about scaling innovations in the academic literature, we are currently short of implementation pathways that make this possible in our local context, with our particular form of cultural-historical gatekeepers. Traditional linear models of scaling fail to take into consideration local conditions that make different education systems work in their own distinctive ways. (For a comprehensive overview, see Purkey & Smith, 1983)

The possible ways around the problem of cultural-historical gatekeepers standing in the way of educational change, however, must go beyond distributed leadership models that seek to empower teachers. The claim here is that 'In a knowledge-intensive enterprise like teaching and learning, there is no way to perform these complex tasks without widely distributing the responsibility for leadership (again, guidance and direction)…' (Elmore, 2000, p. 15).

More holistic models such as Michael Fullan's (2015) Leadership from the Middle (LftM) model, in collaboration with Andrew Hargreaves, look like a better candidate because it presents a strategy to increase the internal coherence of the middle layer of the system (i.e. districts or in Singapore, clusters). This makes for more effective partnerships upwards towards the government or system level and downwards towards schools and communities. Nevertheless, the LftM model can benefit from being supplemented by ecological models such as Toh et al.'s (2014) ecological leadership model.

Toh et al. (2014) postulate that systemic and/or ecological awareness is a necessary trait for school leaders to have in order to create conditions that support sustained improvements to happen. Self-improving schools do not improve themselves ex nihilo but depend on enabling conditions in the local ecology, including other schools. Networks of schools build greater potential abilities to overcome or sidestep challenges to scaling innovative changes by being able to leverage each other's strengths when pathways to improvement are blocked within individual schools. In the Singapore education system, using this ecological leadership model also offers the mobilisation of networks of school leaders in order to have more effective partnerships with the community (parents) and help manage community expectations.

Our case studies have also shown, however, that another important misalignment in the Singaporean context is when HODs do not support the innovative initiatives brought about by classroom teachers. As cultural-historical gatekeepers (among others) in the education system, HODs can effectively stand in the way of educational change, especially if they act in defence of the pre-existing cultural-historical milieu. This is similar to findings elsewhere such as Spillane et al. (1999) and Geels and Schot's (2007) typology of socio-technical transition pathways that innovative changes can take when they percolate up from the classroom and school level and run into opposition from gatekeepers or 'regime actors' in the system. These 'regime actors' have the inclination to maintain the stability of the system by defending the status quo in rules and practices.

These experiences tell us just how important it is for HODs to act as system brokers who can mediate between different parts of the system. However, in the face of HOD resistance, teachers need to learn how to break the change themselves. The ability to help along the upward and downward percolation of ideas and innovations is an instance of what we have discussed above as ecological leadership because it calls upon leaders to transcend their immediate stratum of influence.

Yet, we also see the influence of parents in the school policies of our case study schools. The case studies confirm what the teachers are experiencing—parents are stakeholders in the system and exert influence in it. Yet, many models of education systems exclude parents. Our findings give us fresh impetus to modify such models. Even though parents are not part of the formal hierarchy within education systems, they do in fact exert a lot of influence on the day-to-day running and pedagogical policies of schools in the Singaporean context, albeit from a distance. They are also a significant constituent of our national culture and attitudes towards education. Therefore, in order to obtain parental buy-in for future innovative changes, we also need to have parental epistemic change.

Classroom teachers are perhaps the key to influencing the epistemic beliefs of parents because they have the most contact with them. This too should be counted as part of ecological leadership, because parents are part of the wider educational ecology outside of the formal structure of the education system. While the mileage for parental influence in other systems may vary, it is time that they are recognised as an indispensable part of the education system in Singapore because they constitute one of the most powerful cultural-historical gatekeepers in the local education ecology.

3.6 Conclusion

Our case studies suggest to us that when it comes to scaling innovation change, context matters and every context differs. Just because a particular innovation project is indigenous to a particular education system or involves technology, it does not mean that it can be scaled throughout the system without any specific adjustments in specific locations. Nevertheless, case studies are in themselves limited in their generalizability across the whole system. Further research can be conducted to examine the structural factors that support or counterbalance the positions of cultural-historical gatekeepers, not only in the Singaporean system but in others as well.

We need to better understand cultural-historical gatekeepers in Singaporean society specifically and in Asian societies more generally. This is because there might be characteristics of cultural-historical gatekeepers that are specifically Singaporean or those that are more common in Asian contexts. The presence of an inherited colonial administrative culture might also prove to be a culturally salient factor that divides different Asian societies in the context of educational change. Further case studies will help build the case for 'cultural-historical gatekeeping' as a relevant and salient concept in educational change literature.

Our case studies also point to the dearth of research on the role of parents in the educational change literature. While there is some research on parental attitudes and practices relevant to the development of their children, there is very little in terms of parental interaction with and impact on education systems as a whole. This might prove to be a rich vein for future research because while parents are not part of the formal structure of education systems, they are in no doubt part of the whole educational ecology. A new era of parental engagement in education seems due.

Scaling innovation change in schools is an unpredictable business that will try your patience and test your resilience even on a good day. Even a world-class education system is built on domestic particularities based on local culture and history. These cultural-historical particularities can sometimes help, but can sometimes become obstacles to change. Reformers and policy enactors must give these factors their due in order to institute substantial and important school improvements of any kind. We are sure Teacher A and Teacher B would agree.

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Chapter 4
An Activity Theory Approach to Characterising How ICT Based Innovations Spread in Singapore Schools

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Abstract Innovation diffusion is a complex process that is undertaken in various ways. The use of ICT-based educational tools have been mandated through the national policy on ICT Masterplan which is at its 4th iteration currently. In line with this, the edulab funding programme is a structure that is put in place to encourage schools to spread innovations. A multiple case study approach is employed to understand how ICT-based innovations are spread to schools through the 'spread' model. This model is observed when multiple schools implement the use of a technology in classrooms. The 'spread' model shows that the implementation of the technology appears to be due to individual teacher efforts to incorporate technology use in their classrooms. Such models of innovation spread which are centred on the implementation of technology are typically not sustained as the technology becomes outdated and replaced by other novel methods. This chapter will comment on the activity systems of the spread model for ICT-based innovative teaching and learning as well as the contradictions of the model.

4.1 Introduction

Schools and education systems are constantly on a cycle of improvement and reform. Singapore is no different to this notion of improvement. Singapore's Ministry of Education (SMOE) started its cycle of school improvement in the early 2000s when it realised that computers and information technology are rapidly becoming integral to our way of living. As part of the intention to integrate the use of information and communication technology into classrooms to prepare students to be part of a 'future ready' workforce, it announced its vision of "thinking schools, learning nation" (Ministry of Education, 2018a). As part of realising its vision, SMOE rolled out several policies that were in line with this. It developed and designed the policy on twenty-first century competencies which included skills such as communication,

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collaboration, critical and inventive thinking as well as civic literacy and global awareness (Ministry of Education, 2018b). Together with the twenty-first century competencies framework, SMOE also rolled out the ICT masterplan which will complement the framework to realise thinking schools, learning nation as its vision. At its current iteration, the ICT masterplan (ICT mp) aims to include the creation of a culture of innovation and to engage schools and practitioners in innovation efforts ("Educational technology journey", 2021). This is an explicit intention of the SMOE in its efforts to enthuse schools and practitioners to develop and scale innovations across disciplines, teachers, schools, and organisations. The macro level changes to policies that support school improvement and reform, provide an impetus to the spread of educational innovations within and across schools. The synergy between the twenty-first century competencies framework, ICT masterplans and the vision of "thinking schools, learning nation" is the macro level environment where this research study takes place in. It aims to juxtapose the micro level educational innovation scaling efforts in the midst of these policies that encourage more innovations to thrive.

Since the initiation of the first ICT masterplan in 1997, there have been updates on the Information Technology masterplans with to align policy with the desired practice in schools and within education as a whole. Singapore's Ministry of Education has been actively pursuing school improvement through these policies. The core aims of the ICT mp since its advent in 1997 is to deepen and enable teachers to design learning environments and school leaders to build innovative cultures to meet the objective of quality learning for every student that is empowered with technology (Division, 2018). Since 1997, the ICT mp has undergone several iterations to respond to changes in the school and global environment. At the current iteration on 2015, the ICT mp4 is focussed on preparing "future-ready and responsible digital learners through quality ICT-enabled learning and design" (Division, 2018).

In order to encourage more teachers to develop educational innovations aligned with the aims of ICT mp4, a research grant agency, the National Research Foundation, gave rise to a funding programme called edulab which aimed to encourage educational practitioners and researchers to develop ICT based educational innovations that are specifically meant for scaling amongst schools ("Educational technology journey", 2021). It is a key programme for teachers, researchers, and other ministry of education officers to participate in developing ICT innovations for learning that can potentially be adopted or adapted by different schools across the system (Division, 2017). One of the criteria for the funding programme is that it needs to feature a technology based innovation which is guided by teaching and learning pedagogical practice in Singapore classrooms. An integral feature of the edulab programme grants is that it must have a deliberate intention to develop the innovation for scaling and sustainability as part of its goals (Division, 2017). At the onset, the proposals submitted for the edulab grants must have at least 2 partner schools which would be willing to participate in the innovation implementation and scaling. Teachers and schools are expected to play a key role in the development and design of the innovation project. This would raise the ownership and chances of sustainability of the innovation project beyond the funding period of the project. This will also add to the capacity building of the teachers and the school in managing innovation projects.

This chapter will be focussing on the school based implementation of ICT educational innovations through this edulab funding mechanism. The school based implementation of innovations explicitly calls for the scaling and sustainability to be built into its design. These funding programme intentions while laudable brought about different instantiations of innovation diffusion and scaling as well as variations in the 'success' of the innovations. This chapter will be using the activity theory framework as an analytical tool to understand how these school based innovations spread in schools with a focus on contradictions in the activity system.

4.2 Innovation Diffusion

Rogers and Shoemaker (1971) originated the concept of diffusion of innovations, stemming from his observations on rural agricultural processes. He defined innovations as "an idea, practice, or object perceived as new by an individual" (p. 19). He adds that the novel aspect of innovations can be understood in terms of knowledge, approach or decision in adopting the innovation. Adopting or developing innovations usually signal a desire for change or reform to some extent in the organisation. When innovations are developed in the education system, it is affected by complex interactions between dominant cultures in the school, its leaders and contextual factors within its ecology (Ownston, 2003). Given this complexity, innovations can arrive in many shapes and sizes, each unique to its context and needs of the organisation. Fullan (2016) asserts that one of the biggest issues facing schools is the "fragmentation and overload" (p. 21) of innovations.

This suggests that it is not the lack of innovations that is plaguing schools but the sustained development of high quality innovations and its' subsequent diffusion. Innovation diffusion is the "process by which an innovation is communicated through certain channels over time among the members of a social system" (Rogers & Shoemaker, 1971, p. 10). The diffusion of high quality educational innovation aims to create a significant change in the ecosystem of education. The resultant change causes an increase in the experience, development of skill and expertise in the utilisation of the innovation (Dooley, 1999). Although the backdrop of the Singapore government's push for innovations and policy realignment encourages this change and reform of the system, it is argued that the greatest barrier to change is the system itself (Dooley, 1999). However, not all innovations are created equally and there are factors that enable innovations to diffuse more rapidly or otherwise.

Innovation diffusion is affected by both internal and external factors influencing its spread. They are characterized by factors known as relative advantage, compatibility, complexity, trial-ability and observability (Rogers & Shoemaker, 1971, p. 22). The diffusion of innovation theory as presented by Rogers, consists of a decision making process where an individual passes from first knowledge to decision to either adopt or reject and eventually to a confirmation of this decision (Rogers & Shoemaker, 1971,

p. 39). Relative advantage is where practitioners or schools believe that the benefits from the implementation of the innovation is greater than the current status quo. This perceived value of the innovation inspires teachers positively to adopt the innovation changing their attitudes towards the innovation (Hart & Laher, 2015; Ownston, 2003). Such innovations are likely to be adopted if the innovation is improves their current status and student outcomes in the classroom. Teachers who believe that the innovation will not improve student learning, even in the face of compelling research and anecdotal evidence, may not adopt the innovation due to their negative perception of it (Pierce & Ball, 2009). This relative advantage of innovation is complemented with innovations that are more compatible with the needs of the school and its culture. Such innovations are more likely to be adopted and successfully diffused across the school (Kunnari & Ilomäki, 2014). In a study on motivations to implement educational innovations, it was shown that more than half of the teacher population would continue with the innovation adoption if they observed curricular improvements, professional development and pedagogical improvements simultaneously (Edwards et al., 2014).

Complexity of the innovation refers to the degree to which it is deemed comprehensible and implemented in the prevailing school context (Rogers & Shoemaker, 1971). Complexity of the innovation is relative to the users of the innovation and is affected by practitioners' level of competence. Low users of technology and high users or technological natives may perceive the same innovation differently leading to its success or otherwise. This perspective is further asserted in studies on the implementation of computer technology in schools showing that the critical human factor that affects the implementation of innovations is the individual perceptions of technology (Frank et al., 2004).

Besides individual perceptions of technology, innovations can be perceived as low or high risk posing a natural barrier to its implementation. As such, innovations that can be 'trialed' in classrooms, reduces the risk factor of implementing the innovation. When innovations pose a considerable risk due to accountabilities of teachers, they will be less likely to adopt it (Hung, Jamaludin, & Toh, 2015). High stakes education system such as those in Singapore may hinder innovation adoption due to its structures on accountabilities to stakeholders in schools. As such, if the innovation can be sampled or tried out in classrooms, it makes it more transferable to other contexts. Attributes of observability show how easily the benefits of the innovation are observable to practitioners. In studies that look at innovation diffusion reinforce that the observability of the advantages after the implementation of the innovation had a significant impact (Demir, 2006).

4.2.1 Innovation Diffusion as Social Change

Innovation champions or change agents can also positively influence the diffusion of innovations. An innovation champion is one who has the necessary skills to facilitate change and shares communality with stakeholders (Dooley, 1999). They are understood to be those with the 'innate' ability to inspire and motivate others with their vision of the efficacy of the innovation and display great persistence in advancing it (Howell & Higgins, 1990). Innovation champions set themselves apart from others with the social capital that they possess enabling them to communicate effectively with others. They are able to convince others to try out the innovation by sharing the value of the innovation. It is argued that innovations are spread through the consistent communication with other potential adopters to change their perspectives of the innovation to convert them into adopting the innovation (Rogers & Shoemaker, 1971). This social pressure to innovate or adopt the innovation is effectively applied by innovation champions or change agents in schools (Frank et al., 2004). The transfer of ideas within a social system such as a school or between schools is facilitated with the voice of the innovation champions to sustain the innovation.

When transferring ideas within a social system, the culture of the system is equally important in influencing this diffusion (Kunnari & Ilomäki, 2014). Schools are a social system, as such when they implement and diffuse innovations, they become sites of social change. School cultures that encourage innovation diffusion would have attributes of openness, approving atmosphere and spaces for encounters (Kunnari & Ilomäki, 2014). Current research indicate that organisational culture and structures must evolve and change such that it matches the new ways of thinking to succeed in the diffusion of innovation (Kunnari & Ilomäki, 2014). The school environment and culture needs to be perceived positively for the development of the innovation (Webster et al., 2013). This could be through support from administrators on funding procedures, adjustment of teacher accountability indicators, peer encouragement or peer recognition. The culture of collaboration and professional learning communities influences the implementation and development of innovations by feeding on each other to produce better results (Fullan, 2000). The culture of the school also includes the contextually specific needs of the school that is addressed through the implementation of the innovation. The innovation is more likely to be sustained and spread through the school if it addresses specific issues that needs to be resolved through the innovation (Smith, 2012).

Diffusion is essentially a special type of communication concerned with the spread of messages that are new ideas (Rogers & Shoemaker, 1971, p. 39). The key in the diffusion is communication. Innovations are successfully communicated with the right type of leadership in schools. There are many types of leadership theories such as transformational, ecological, transactional, system and situational leadership. Among these models of leadership, ecological leadership is argued as exhibiting characteristics allowing innovations to flourish. One such theory argues that ecological leadership exhibits characteristics that allows for the successful diffusion of innovations. Ecological leaders display initiative to unite fragmented implementations of changes within their ecosystem leading to a more solidified stance to innovation diffusion (Toh et al., 2014, p. 836). This method of leadership tries to bring together independent parts of the system by creating support systems that allow for the realisation of the vision for the school reform through the innovations.

Innovativeness is the degree to which people are motivated to implement innovations (Rogers & Shoemaker, 1971). This can differ from person to person. It is clearly shown in the use of a S-shaped cumulative adoption curve as shown in Fig. 1. This adoption curve shows that innovators are the first to adopt new innovations and are typically high risk takers and are enticed by the novelty factor in innovations (Dearing, 2009). The early adopters include opinion leaders who tend to chart the course of the innovation diffusion by selecting moderately risky innovations that have proven its efficacy in teaching and learning. These early adopters including the opinion leaders are well regarded amongst their peers and are integral to the communication of innovations to others (Lim et al., 2010). The large majority of adopters subsequently follow because the innovations have already been set in place and has become commonplace. The small number of adopters at the tail end are resistant to changes and innovations requiring persistent persuasion from administrators or change leaders. For innovation diffusion to be effective, early adopters have to be convinced of the efficacy and benefits of the innovation as they are able to hasten the communication of innovations to others as opinion leaders. These opinion leaders within the early adopters can also serve as an impediment to the spread of certain innovations if they are perceived as non-beneficial. Opinion leaders whilst they can be a boon to its spread, can be a bane to educational reform and diffusion if they resist those changes. As such, distribution of social capital becomes unevenly distributed within a system leading to some teachers being at a disadvantage when it comes to the diffusion of other innovations.

A meta-analysis of over 200 parameters on innovation diffusion models showed that innovations that are perceived to be lower risk are also adopted more quickly especially if they were trialed at other organisations or communities (Sultan, Farley, & Lehmann, 1990). High-risk innovations or interventions carry threats as they might result in lower educational achievement levels in the advent of the innovation. In high stake environments such as Singapore, this can pose a very real issue when teachers are held accountable to parents and other stake holders lowering their openness to innovations (Hung et al., 2015). How does this tension between the results oriented environment of education systems affect the innovativeness of practitioners? It is argued that the desire to innovate may be hindered by competing responsibilities and duties that practitioners deal with on a daily basis (Edwards et al., 2014).

Beyond results, a key part of innovations is the use of technology within the classroom. It is believed that pedagogy is the driver but technology is the vehicle for educational innovations. As such, the presence of resources (Pierce & Ball, 2009) such as Internet connectivity, gadgets, personal computers and mobile devices can affect the diffusion of innovation. The presence of such tools and resources may be a non-issue for some schools, however is the distribution of funds to purchase these tools evenly distributed such that 'hardware' is not a limiting factor for the implementation and diffusion of innovation. In education systems such as Singapore, autonomous schools which have delivered value-added ness to their students through their educational programs receive additional funding per student (Wy-Cin, 2009). The additional funding when provided to schools which have exceeded their expectations may go on to produce better programs and innovations as tools as resources are more readily available to them.

The notion of scale has become more contentious as school improvement advocates move away from the ‘how many’ to the ‘how’ innovations are spread across schools and organisations (Coburn, 2003). However, the measurement of how many schools have implemented the innovation is an ‘attractive’ way of measuring the scalability which has greater allure to bureaucrats and administrators who are concerned about performance indicators. It is therefore easier to measure the performance of an innovation through such means instead of diving deep into the process of innovation and the activity systems of innovation. This chapter aims to contextualise the spread of innovations beyond just the reporting of numerical indicator of how many schools implemented the innovation.

4.2.2 Theoretical Framework

Activity theory is a multi-layered framework for describing human activity and provides a sociocultural perspective where individuals carry out activities as part of a social space (Engeström, 1999; Leont’ev, 1974; Murphy & Rodriguez-Manzanares, 2008; Nardi, 1996). As innovations and school improvement take place in the social setting of the school and its’ norms, activity theory is an appropriate lens to understand and study how innovations spread within and across schools. The activity theory framework began with the conceptualisation by Vygotsky (1978) who described human activity from the basis of the triad of subject, object and tools. He explicated that meaning making occurs through the active interactions with artefacts and tools found in an individual’s environment. This basic triad focuses predominantly on the role of the tools and artefacts, however Leont’ev (1974) and Engeström (1987) extended this triad to bring in the influences to the activity at the community level. They believed that the context and collective nature of human activity supports the activity system as it is mediated by tools and artefacts. Activity systems are described by the following terminology and definitions:

Subject: Individual or participant who is involved first hand in the activity

Object: Target of the activity

Instruments/Mediating tools: Mediating artefacts that help the subject achieve its object or target of the activity

Community: Other individuals besides the subject who are involved in the collective achievement of the object

Rules: Norms and conventions that limit actions or activities

Division of labour: Refers to the division of tasks among the community and “vertical division of power and status”

Outcome: the goal of the activity.

I concur with Gedera (2016) who implies that these categories in the activity system is not immediately transferrable to the education setting. He refers to the adaptation of some of the categories such that they are more applicable to schools and activities based in education systems. For example, he suggests renaming the category division of labour to ‘roles’ as it more clearly indicates the scope of work that teachers or other participants in a school take part in. This can be explicated in the instance of ICT innovation implementation where teachers may play roles that are different from that of a teacher when participating in an activity where they are including ICT based lessons. He also suggests that object be renamed to ‘objective’ as it is more relatable to a classroom setting where the teacher or student moves toward meeting a lesson objective or incorporating ICT into a lesson.

4.2.3 Contradictions

An integral part of understanding the sociocultural perspective of human activity systems includes contradictions and systemic tensions. Contradictions are an inherent part of the activity system framework. It is not necessarily a ‘bad’ occurrence as contradictions give rise to opportunities for resolution which shape and change the activity system (Yamagata-Lynch & Haudenschild, 2009). Kuutti (1996, p. 34) defines contradictions as a “misfit between elements, between them, between different activities, or between different developmental phases of a single activity”. Engeström (1987) states that there are four levels of contradictions and named them primary, secondary, tertiary and quaternary. Primary contradictions are those that occur within an element of the activity system such as conflicting roles in a system. Secondary contradictions occur between elements of the activity system such as between rules and the community. Tertiary contradictions arise when there are changes in the external environment and the participants have to respond to those changes such as new educational policies that affect the current activity system. Quaternary contradictions occur between two different but connected activity systems such as the activity system of the classroom implementation of ICT innovations and school leadership activity systems. Contradictions may appear as sources of positive change and development. It prompts the community and participants to think of ways to manage and find ways to resolve the tensions in the activity system. This can drive positive change where activity systems aim to transform teaching and learning.

4.3 Research Context and Question

There are two research questions that this chapter aims to address.

1. What are the activity systems associated with the spread of technological innovations en masse in Singapore schools?
2. What are the contradictions in the activity systems when spreading technological innovations en masse in Singapore schools?

4.4 Research Methods

This book chapter is a part of the large scale research project that aimed to understand and distil innovation diffusion models using a multiple case study approach of selected innovation projects from the edulab funding programme mentioned above (Division, 2017). The case studies presented here are extracted from data collected from a study funded by the MOE's edulab project titled "Scaling as innovation: Innovation diffusion models in Singapore" (EduLab Project, 2018). There were 11 innovation projects that were selected from a range of pedagogies and types of technology (edulab final report, 2018). Data was collected progressively from the third quarter of 2015 to the first quarter of 2018. From these 11 innovation projects, 14 schools that were participating in the innovation project were identified as cases. Data was collected from these school cases through interviews with teachers, school leaders and documents. Documents such as progress reports and final reports were collected as part of the data collection process. Interviews with Ministry of education officers such as education technology officers (ETOs) were also conducted.

11 innovation projects were selected based on the maximum variation sampling (Patton, 1990) techniques through discussion with stakeholders such as the Ministry of Education, Singapore (Edulab Final report, 2018). Maximum variation is useful when capturing and describing themes that is consistent through variation in programs or participants (Patton, 1990, p. 172). In this way, by uncovering central common patterns despite the variation in cases would be of great interest in terms of understanding educational innovation scaling. Maximum variation sampling is used here as a means to describe variations in the way the innovation projects are enacted and scaled. The 11 innovation projects contain variations in the length of time that the projects have been funded which will show the projects at different stages and aspects of pedagogical practice and if the projects were school based projects or otherwise. Each innovation project had unique aspects in terms of type of pedagogical practice. For example, innovation projects were classified based on types such as in-situ learning, knowledge building, diagnostic tools, critical thinking, collaborative learning, student generated artefacts, gamification and multimodal learning. At least one innovation project from these categories were selected including a mix of innovation projects that are school-based projects and projects led by university research teams.

The case studies presented here represent schools and innovation projects that were categorised as spreading technological tools en masse which represents the spread of the technological tool as the main object (in-press, Tan, 2019) where resource development takes precedence over other requirements for the spread of the technological tool. It aims to spread the technological tool simultaneously at scale (In-press, Tan, 2019).

4.5 Data Collection

From these 14 school cases, the data from 4 schools were selected which expounds the contradictions. They were selected based on typical cases (Gerring & Cojocaru, 2016) with variation in the outcome and execution of the same innovation project as a means to uncover the gatekeepers present in the sociocultural context. These typical cases were selected through the analysis of the larger research project which identified these two cases as being typical schools which had variations in their outcomes and scaling of the innovation project.

Interviews were conducted in a semi structured manner with different interview protocols for different types of participants. The questions were contextualised for their roles that they play. Some examples of interview protocol questions are shown below:

Teacher

1. What kinds of formal and informal supports (such as resources, time, training, and communities) from within and beyond school were provided to help you develop capacity to integrate this innovation into your lessons?
2. Can you share with us how you feel about your collaborative experiences with partners such as experimental teachers from other schools, learning designers and commercial vendors (if applicable)?

School leaders

1. How do such scaling efforts affect your views about the use of technology in classrooms (if any)? Your role as a leader (such as, the scope and nature of leadership)?
2. How do you harness resources to help department and experimental teachers mitigate the challenges that they faced when implementing the curriculum innovations?

4.6 Findings

Innovation F

This chapter focuses on the spread of technological tools as the main object together with teaching resources that align with the technological tool (In-press, Tan, 2019). The main strategy for such innovations would be to implement the technological innovation for an entire class or groups of classes at one time as well as teachers to execute the technological innovation simultaneously. These types of technological innovation were observed in the case studies that were studied as part of the edulab research funding project.

Innovation F is one such example where the technological tools took centre stage. This innovation aimed to develop an application that would help students navigate the learning of science nomenclature and rules through self-discovery and gamification. The activity system that was gleaned for the intended activity of Innovation F shows that the main outcome for the innovation was to design and develop the application as well as to garner better student's learning outcomes for Science. In addition, the innovation also aimed to build the capacity of the teachers in innovative pedagogical practices. The community and people who were involved in this innovation included learning designers from the Ministry of Education, Singapore and teachers. They worked together to co-develop the lesson design as well as the resource packages that was used together with the application. In addition, they engaged the services of a software developer who made the application design a reality. As they rolled out the application for use in classrooms, teachers and students reported the benefits of using the application for the teaching of scientific nomenclature. They continued to share the application with other schools and teachers through workshops and professional development sessions with other teachers. They made improvements on the design of the application with the inclusion of a data analytics platform. All the teachers and classes in a particular level have implemented the innovation.

The innovation is implemented differently across the various classrooms where at times the innovation design principles is brought into question when the innovation is used in a non-discovery learning approach. The innovation is deemed to be interesting and engaging for the students as it has elements of gamification in the application. Slipping into using the application for rote learning purposes is an inherent tension due to the high performative nature of the education system (Deng & Gopinathan, 2016) where teachers and students are expected to perform at the highest level. Such notions impede the discovery learning process which the intended outcome of the innovation F. This is echoed in the focus group discussion with teachers who mention that "students….they are focused on, like, you know, high score, because that's the only thing that they can see". This emphasis on scores is evident as a tension between the norms of the classroom and the outcome.

Assessment modes are another source of tension where teachers concede that there are aspects of the innovation which are teacher centred. There is a need to refer to a more blended pedagogy where aspects of teacher and student centred pedagogy is implemented. This is evident in teacher interviews where they explain that "Sometimes we need some verbal instructions, explanations, rather than we just read it from the screen. So I think there's the balance". The tensions that arose from this innovation activity system is within the outcome of the innovation where teachers tend to use the innovation in markedly different ways based on the capacity and 'innovativeness' of the practitioner. For example, some teachers used the innovation as a teacher centred tool instead of the intent of the innovation which was to introduce more student centred pedagogical practices. The innovation lacked the targeted professional development where teachers who tended to revert to more comfortable practices could have benefitted from. The mediating tool here was being used as replacement of more traditional practices albeit in a more engaging interface.

Activity system of Innovation F

Subject: Teacher

Object/outcome: designing the game and mobile application with a dynamic feedback system or content management system

Instruments/Mediating tools: mobile application; teaching pedagogical approaches

Community: professional learning communities; edulab research project community

Rules: curriculum; performative learning culture

Division of labour: MOE learning designers; teachers who execute the lesson.

Innovation C

Innovation C was mooted by a Ministry of Education educational technology officer (ETO) who took the lead in sourcing for partner schools. The innovation aimed to introduce a central pedagogical framework that is mediated by a technological tool in classrooms. The main teaching and learning problem that this innovation was trying to resolve was to assist teachers to respond to the changes to the curriculum that was introduced in recent years. The ETO who was leading the innovation project found that there was some anxiety related to the curriculum changes when he attended professional development workshops for teachers. The view among teachers was that these twenty-first century competencies were not easily taught and required more integration with information and communication technologies based on our interviews with the ETO. He then set forth to collaborate with a subject head of department through his personal social network connections built through multiple interactions at professional development workshops. This collaboration was extended to the school where they formed a purposeful professional learning community consisting of like-minded teachers. They went through the process of co-developing the lesson plans and the pedagogical framework. However, as the ETO was seen as the expert and knowledgeable other, the main guidance of the development of the framework was led by the ETO. The teachers had lesser input on the development of the framework and were able to execute the lessons. The ETOs also conducted lesson observations of the innovation in action and this was typically followed up by debrief and comments on the lessons. The teachers noted towards the end of the innovation cycle which lasted 6–8 weeks that the students were resistant at the initial stages as they felt that the innovation included aspects that were not tested as part of their formal curriculum. Teachers likewise noted that even though the twenty-first century competencies were taught based on the innovation, that the mode of teaching included aspects outside the curriculum and therefore were not able to see the continued connection to the curriculum. This gave rise to quaternary tensions where the intention to scale innovations from the perspective of the ministry of education is evident, but in the classroom, students and teachers face a tension from getting buy in especially if the innovation is not closely aligned with the curriculum and has an instrumental effect on the grades and performance of the student.

Activity system of Innovation C

Subject: Teacher

Object/Outcome: Pedagogical framework

Mediating tools: Technological tool; Lesson packages

Rules: Curriculum

Community: MOE Edulab HQ, school

Division of labour: Teachers executing the lesson; ETD officers providing the expert knowledge and information; use of the pedagogical framework.

Primary contradictions in rules include the anxiety that comes with changes to the curriculum.

Secondary tensions between the rules and the object/outcome: Curriculum does not specify the teaching of this mode of viewing. Students prefer to stick to the curriculum in line with performative culture.

Quaternary tensions include the tension to scale the innovation from the ministry of education perspective however the curriculum poses a challenge in getting buy in from teachers and students to continue with the innovation.

These two innovations which were centred on the spread of innovative tools with the purpose of spreading the tool without well-developed communities and roles for the individuals that were involved in the innovation. Teachers tended to retain their roles as executors of lessons and did not participate extensively in the development of lesson plans that used more innovative pedagogies. The collaborations between the ETO and the teacher was predominantly seen in an instrumental perspective as the transfer of information and resources from the expert other to the teacher. This transfer of information and resources did not extend the partnership further. Between the two innovation projects, Innovation F was more enduring as it was enabled through the tight alignment to the current curriculum being taught in schools. However, the use of the technological tool lost its fidelity as the teachers who used the tool saw it merely as a tool for their own teacher centred pedagogies. In the other instance, the innovation did not spread beyond two classrooms in one school. This can be attributed to the transactional partnership between the community and roles of the ETO as well as the non-alignment of the innovation to the curriculum.

Although these two innovations focused on the spread of the technological tool and were trying to increase the numbers of students and classrooms that utilise this technological tool with less emphasis on the development of the roles and changes in the meso and macro layer of the school, they still had benefits and value to this form of innovation diffusion. One such benefit that is to increase the comfort and capacity of the teachers involved in the innovation project. Teachers often cited that they are now more comfortable with using technology in the classroom. This comfort and ease of use of technology in the classroom may have long term effects on their future development as practitioners. As this research study did not trace longitudinally the development of the teachers involved in the innovation project, this could be potentially another extension of the research project.

4.6.1 Contradictions Between and Within Value Systems of Teachers and Policy Intentions

There are contradictions within activity systems as explained above in terms of three levels: primary, secondary, tertiary and quaternary levels. One such contradiction is when the value systems of teachers are not aligned with the innovation. This can manifest in several layers. The work on educational innovations is not a formal requirement of the Singapore teacher although they are encouraged to do so in professional learning communities. The variability of the professional learning communities and their objectives are different across schools and within schools (Hairon et al., 2013). The schools have sufficient autonomy to decide how they intend to operationalise the professional learning communities and their goals for the year. The workload of the teachers remain the same when teachers undergo the intensive innovation design and development process. The high workload when engaging in the innovation project coupled with the existing workload of teachers in Singapore schools appears as an obstacle to innovation projects and innovativeness. This is compounded to rationalisations such as the high performance of the students at international benchmarking assessments (“Singapore tops latest OECD PISA global education survey,” 2016) which signal that the current pedagogical method is ‘working’ even though it may not be part of an educational innovation. This tension in the subject which is the teacher is articulated during our interview sessions where the teacher explains that, “So one thing I realised is it needs teacher buy-in, and I think it’s difficult to get the teacher to buy in when, you know, it isn’t broken. Why fix it? I think it’s a very strong… It’s quite pervasive throughout the school… I mean, throughout the education industry” [Innovation M]. When the educators view the education system has serving its purpose and that there is no immediate need for school improvement and reform, then innovation projects tend to be seen as an ‘add on’ to their current work and identity as a teacher.

Educational policies such as the ICT mp4 encourage schools to innovate however high workload of teachers as well as the performative nature of classrooms can contradict these educational policy intentions. As such, the infrastructure such as roles, norms, communities in the activity system of innovation projects provide insight into what are the processes required for the scaling and sustainability of innovation projects. This is further amplified when teachers consider innovativeness as an innate trait that is dependent on individuals. For instance, during our interviews we find that teachers believe that innovation projects are "dependent on teacher empowerment…Self motivated teachers will find time to become experts. Some teachers are entrepreneurial in nature. The competency of the teachers is a factor" [Innovation M]. The innovation project lead from his interactions with the teachers involved in the innovation suggests that the impetus for change lies within the teacher and is implicit in saying that it is their 'nature'. This can hamper the development of changes in school structures that aid the development of the innovative culture of teachers as opposed to viewing it from the perspective of the 'nature' of some teachers. These conceptions of teachers involved in the innovation program and the selection of teachers who are actively involved may serve as an impediment as they are seen to be 'different' and that epistemology about teaching is 'fixed'. In such instances, what type of professional development would unravel the fixed mind-set about the type of teachers needed to enact the innovation. Or can it be developed through innovations such as this in schools?

4.6.2 Contradictions Within Roles of Teachers and the Rules of Accountability of Teachers

As teachers are expected to ensure that the grades and accountability to parents and students to maintain a high enough standard of grades, there is tension when implementing innovative practices as they often cause implementation dips. When researchers partner with schools, their main accountability is still with the school as their performance are decided by their main work as a teacher regardless of innovation practices. The main accountability of teachers is to the schools, students and the parents (Ng, 2013). The stakeholders of the education system are students and parents. As such, in a performative system, parents expect that the classroom pedagogy is aligned with the assessments and high stakes examination climate in order to achieve higher grades (Ng, 2010). For example, one of the respondent points to this tension that ""It's not just how important the school sees it. It's how important MOE or the government sees it, and if you want all these values" (Innovation M). As such the contradiction between the roles of the teacher is in conflict in this situation, where the teacher is expected to ensure that students perform at their peak given the constraints of their work as a teacher. This is also echoed in other interviews where the teacher references the high academic expectations of the school. "The academic stakes is the difference—when the stakes are high, the school is conservative in terms of trying out the intervention. If the academic stakes are not that high—they will try out very fast" [Innovation M]. However, innovations as the name suggests, can cause an implementation dip when students are trying to get accustomed to the innovation while trying to ensure that their performance in tests and assessments is kept high. As such, these implementation dips can affect the accountability structures of teachers (Lee & Tan, 2010). Teachers may be assessed negatively in performance reviews if it happens. This is echoed in our interviews with teachers who feel that "For school, one thing is the school allows you to try out new things. Certain schools are quite restrictive, quite conservative. But thankfully, my school is quite open to new ideas and new matters in teaching, which is very good." Often teachers are dependent on the schools' approach to innovation projects. As such, supporting school cultures that allow them to try new innovation projects would be more aligned with innovations.

4.6.3 Contradictions Between Roles and Norms (Rules) of Activity Systems

Contradictions between the roles and norms of the activity systems of innovation projects in schools manifest as power distance (Hallinger, 2010) and social capital differences create tensions between rules and the roles of teachers in schools. There is greater autonomy for middle managers such as heads of departments to suggest innovations and enjoy greater traction or spread when it comes to spreading innovations. Our respondents point towards the difference when he described that having the formal authority can make a difference when planning or negotiating with the school management for additional time or changes to existing structures for innovation projects. For example, one of our respondents cite that, "For young teachers, they find it quite discouraging but for HOD like me, I can provide alternative. We can negotiate. We have the rank and experience to negotiate." [Innovation V]. This power distance and hierarchical nature of schools pose as contradiction as innovators are hampered by their formal rank and privileges due to the social network of the innovators. This is also exemplified in the top-down nature of innovation projects as school leadership support is seen as crucial for the spread of innovations. The school culture and norms set by school leaders will be integral for the setting of local culture. This is also demonstrated when innovators or school staff who are involved in innovation projects who are not of high 'rank' they tend not to spread beyond a small scope as they lack the buy in from the school management and they are unable to articulate how the innovation strategically aligns with school needs. System level conduits or brokers are useful to mitigate these issues as such educational technological officers (ETO) can bring the gap between teachers and school management committee who can aid in the spread of innovations through adjustments to the norms of the school.

4.7 Closing Remarks

Contradictions in the activity systems of innovation projects can be mitigated through progressive forms of leadership such as ecological leadership (Toh et al., 2014) and apprenticeship (Hung et al., 2015). The theorisation of the roles required for innovation spread and tension resolution informs school reform advocates to design better equipped systems to meet the challenges ahead. It urges systems and policymakers to rethink the traditional roles and relationships in systems for school improvement. Innovation diffusion goes through various iterations as they are reconceptualised to different environments and communities. The tight but loose framework "combines an obsessive adherence to central design principles (the tight part) with accommodations to the needs, resources, constraints and particularities that occur in any school or district (the loose part), but only where these do not conflict with the theory of action of the intervention" (Wylie, 2008, p. 35). This struggle with innovation diffusion shows that innovations are not mimicked and reproduced independent of the context or situation. They go through various iterations and are adapted for adoption depending on the discipline, situation or environment. Instead of trying to tightly adhere to the specific design processes of the innovation, diffusion would be aided if they are recreated based on the context (Lim et al., 2010). Adaptations to the innovations are necessary to the diffusion process as the innovation cannot be applied in its entirety in another context, however it is necessary that it does not take away the essence of the inn.

As school improvement advocates move away from the numerical scaling of innovation projects, a recommendation would be to trace and document the innovation capacity building of teachers. The innovation capacity of teachers is to be taken as developmental and not as an innate trait which can be supported through the deliberate changes in the school structures that support innovation projects. While the properties of different innovations can expedite the implementation of innovations, the sociocultural activity system builds a case for changes in the macro and meso levels for sustainable innovation diffusion.

Research shows that organisational norms and values has to be in line with the innovative ways of working and that collaboration must be intentionally set up to succeed in the diffusion of innovation (Kunnari & Ilomäki, 2016). Even though the innovations spread due to the use of the technological tools, teacher learning need to be reframed for the innovation use to be sustainable (Vermunt & Endedijk, 2011). Teachers are the gateway to the diffusion of educational innovations in the classroom as they decide how and when they are implemented. From our study, the contradictions between their roles and values with systemic structures of accountability, policy and norms can determine their decision in the implementation of such innovations. It is precisely because of these contradictions that tensions arise and will induce the needed change to the system that would allow for greater progression of school innovations. For more innovative culture—the tensions can bring about change.

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Part II
Micro Layer Ecology—School-Based Innovations

Chapter 5
Making at Scale: A Development Strategy for Expanding Access to Progressive Educational Goals

Michael Tan

Abstract The maker movement has attracted much recent attention as a cultural and material technology promising to revolutionise learning in a variety of contexts. Although the marquee aspects of the movement appear to be the increased ease of access to advanced manufacturing technologies such as the 3D printer, the educational significance of such a movement may not be located in the things, but rather, the people. Specifically, the educative promise of makerspaces lies in the cultural organisation of people to use the things to achieve educational goals distinct from the traditional. Based on this principle, an investigation into the possible diverse goals for learning needs to accompany strategies for persuading teachers to consider these goals as important. In this chapter, I report on the challenges of framing a curriculum innovation in the form of a 'Trojan Horse' gift of 3D printers to school. Through two comparative case studies, I will elaborate on the relative importance of changing things and changing goals, and whether it is possible to change goals by changing things.

5.1 Introduction

At the core of this chapter is the question of what it may mean to scale up an educational intervention. While it may appear fairly straightforward, the assertion I wish to make here is that any intervention that is educationally worthwhile carries with it an inherent contradiction that can cause the prospect of scaling to become hopelessly futile. This contradiction is experienced daily by teachers who have to respond to the demands of administrative accountability on the one hand, and the ideals of education on the other. As for teachers, this same contradiction scales up to all levels, in a fractal-like self-similar manner. As much as we would like to emulate the industrial revolution achievement of scaling up craft making into

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mass produced manufacturing, the difference between *manufacturing things*, versus *educating people* must give us at least a moment's pause to consider the admissibility of the project. This is not to say that the sentiment is ill placed: the industrial revolution has provided vastly expanded access to a much improved levels of comfort. It is only natural to suppose that an educationally effective interaction in one context ought to be spread to another. Yet, the flip side of the industrialisation process is the intensification and scaling up of our species' destructiveness to the environment, and the perversion and deliberate 'hacking' of natural human desires to create a demand for things that we do not need and which are not good for us. It would be wise to consider if a similar approach may produce a similar result for education, and if we are willing to tolerate the offensive byproducts of such a process.

This chapter will discuss making; as a process of creation that seemingly creates something from nothing. The rise of tinkering and making, within what has been termed the makerspace, has been a recent academic and more widespread fashion. Spurred on by popular magazines such as Make, and relentless efforts by all involved up to and including the 44th President of the United States (White House, 2014), the idea of making has spread far and wide. International discourse on making has also been subsumed under the umbrella of Science, Technology, Engineering and Mathematics (STEM), perceived by many as a future oriented set of disciplines that will be necessary for the younger generations' success. Such an approach carries with it many hidden assumptions, least questioned of which is the notion that one may be able to predict the future. Even if such prognosticating could be rendered sufficiently accurate, the nature of creation and the nature of the STEM disciplines will conspire with the nature of educative experiences to create a complex of considerations that should make a sceptic of any evangelist. The plan for this chapter thus is as follows: in the first part, I review the nature of making, followed by an argument borrowed from Biesta (2016) concerning the weakness and accompanying risk of education. In the second part, I will illustrate how my colleagues and I managed to develop and deploy an intervention project centred around enlarging access to material innovation, and what compromises we had to accept in order to retain the educative value proposition of the project.

5.2 What is Making?

It may be slightly trite to make a statement such as making defines the human species; yet as tool users and modifiers of the natural environment, we are certainly unique in the extent to which we make things. As Sterelny (2003) surmises, the very act of making co-evolved with our expanding cognitive abilities; making is not the 'mindless' activity that suffers from the low esteem issues that we in contemporary times have appeared to have assigned to people who 'work with their hands'. This dichotomy between minds—and hands—appears to be a relatively recent invention that arose from the industrial revolution as we started to realise mass production techniques that privileged what Crawford (2009) termed as separation of thinking from doing. The effectiveness of this approach of industrialisation and industrial rationalisation is so well regarded that to a large part, we hardly question its application in the 'production' of 'human resources', euphemisms that obscure the lack of humanity in these forms of thinking. It must be recalled that the the Fordist era time-and-motion studies sought to optimise production lines with ever cheaper labour: if complicated craft work could be decomposed into its smallest stepwise elements, it will then become possible to fill the factories with "men [sic] who are of smaller caliber and attainments, and who are therefore cheaper than those required under the old system." (Taylor, 1915, in Crawford, 2009) We hardly question school procedures to: (i) age-grade students into groups based on 'seat-time' in the classroom; (ii) decompose knowledge into discrete elements that constitute the minimal amount considered assimilable, while neglecting the interconnectedness, contextual dependency and complexity of knowledge in use in practical contexts; and (iii) produce standardised products via regular quality control procedures and expect that such standardisation is an ideal outcome of schooling.

From this perspective then, it might become obvious that the school has long stopped being a centre for education, but of cognitive training or production of a standardised set of 'learning outcomes', worked upon by replaceable units of 'small caliber and attainments'. To be fair, this is not necessarily the case in all systems and in all schools; significant variations exist, teachers do care and do try their very best in acknowledgement of the humanity of the interaction. Nonetheless, the basic premise of the industrial logic pervades schooling—how else could one explain the desire for education research to find novel educative means, and to 'scale up' educational interventions, often using metaphors based in (most recently) medical practice. While I will engage with a deeper critique of school systems' abuse of the industrial metaphor, it may be useful to consider alternatives and historical precedents to manufacturing, in order to situate and describe the maker movement, and to also offer alternatives to the industrialisation—manufacturing metaphor for school.

I want to talk here about making, not in contemporary terms associated with now widely popularised makerspaces seen as fulfilling the objectives of STEM education. These include economistically[1] driven goals such as preparing a workforce for technically demanding careers, exposing young people to new technologies or rearranging the furniture and pedagogy to 'engage' learners to persuade them to learn cognitively demanding material. In solidarity with Zuboff (2019), I argue against an uncritical acceptance of technological inevitabilism, the position that was "once glorified in the motto of the 1933 Chicago World's Fair: 'Science Finds—Industry Applies—Man Conforms'" (*ibid*., p. 21). To further this line of argument, it is important to consider that, as Zuboff argues, the deployment of contemporary surveillance technologies of social media, behavioural prediction and futures markets and mass manipulation serve at the behest of capitalist *intention.* There is nothing inherently technologically inevitable about, say, a web search provider needing to keep our search history forever and mining it for behavioural patterns. Similarly, then, there is nothing inevitable about needing our students to acquire competence in particular

[1] I use the term economistic, akin to how scientistic refers to a misperception of the goals of science.

technologies, especially if deployed uncritically without consideration of purpose and intent. This is not to take the Luddite position and deny the existence or centrality of contemporary technologies, but rather to emphasise the importance of the critical stance as a prior consideration to its deployment, especially in public schools.

To develop a positive thesis then, I seek a description of making that considers its emancipatory potential for changing the world, a form of instruction that encourages transgression from social norms, and, in general, opens up the space for a critical education worthy of its name. To that effect, it may be useful to consider making as an activity prior to its augmentation by contemporary technologies. In terms of historical precedent, and prior to industrialisation, making, design and all the associated thought processes that drove making were coextensive activities: there simply was very little distinction between thinking about making a thing, and the process of making it. Consider the making of a handaxe: Ingold (2013) summarises the debate on the status of prehistoric handaxes as a debate between the status of the handaxe as an artefact that has natural or cultural precedent. On the one hand, the regularity and balance of the handaxe inevitably conjures up thought about the designed nature of the tool. It was definitely not a random process that created these artefacts. It is almost apparent that "their makers first 'saw', in their mind's eye, the form of the completed object, and then set to work to execute it in the material" (p. 35). This, then, is the argument for the handaxe as a mark of culture, a crucial piece of evidence that distinguished our early ancestors from other animal species.

On the other hand, if one considers the pervasiveness and ubiquity of this design, spanning over a million years and across three continents, we begin to see the possibility of a different interpretation. Perhaps, just as birds make nests and beavers create dams, and they do so with such regularity and attention to detail, and without any other accoutrements of culture such as a language or needing instruction from their elders; perhaps early hominids were merely making and using handaxes merely as co-evolved objects. As Ingold (*ibid.*) describes, prehistorians were caught in a double bind: "If one the one hand, the form of the biface is tied to the body plan, then we can account for its constancy but not for the apparent intelligence of the design. If, on the other hand, we regard the biface as a product of a complex intelligence, then we can account for its design but not for the constancy of form" (p. 37).

As Ingold tells it, the solution to this paradox does not lie in more empirical evidence one way or another, but with our assumptions and especially with a particularly pernicious ontological assumption that most Western informed civilisations have adopted since the time of the Early Greeks. Dubbed hylomorphism, from the greek *hyle* (matter) and *morphe* (form), this idea posits that artefacts are the result of an abstract form impressing itself onto passive matter. For handaxes, the paradox is resolved if we do not suppose that the form of the handaxe must have existed, complete, in the minds of its makers, or that abstract representations could be used to communicate the idea and specifications of the handaxe for individuals to reproduce. The making of a handaxe requires skill, attention and intention, but not a kind of prior intention: "the intentionality of the skilled practice inheres in the action itself, in its qualities of *attentiveness* and *response*, whether or not any prior intentions are affixed to it (Ingold, 2013, p. 43, emphases added)." The artefact of the handaxe is an emergent property of the process of knapping the stone. The skill of expert knappers is not reducible to either mental capacity or bodily biomechanics alone, but of a responsive interaction between the maker and the artefact. The stone is not some inert material whose role is merely to receive and be shaped by the maker; stored within its structure is a complex sum of tensions and compressions from its geological formation; the maker's role in the making is to become attentive to the potential, and respond to it in a manner that is harmonious to the nature of the rock such that their intent may be obtained. Put another way, as Michelangelo may have been reputed to have claimed: "The sculpture is already complete within the marble block, before I start my work. It is already there, I just have to chisel away the superfluous material." Making, then, is not an imposition of a complete design in a stepwise itinerary of assembly, but a mutual itineration between the maker and their artefact, "a passage along a path in which every step grows from the one before and into the one following, on an itinerary that always overshoots its destinations" (*ibid.*, p. 45). Making is a not a process of imposing one's will onto material, but rather one of 'surrendering' to the material and the 'following where it leads' (Deleuze & Guattari, 2004, in Ingold, 2013).

This anti-hylomorphic theory of making, as it were, also finds usage in what Andrew Pickering has termed the Mangle of Practice (Pickering, 1995; Pickering & Guzik, 2008). In careful studies of the practice of scientists, not depending on scientists' own retellings of their work processes, Pickering surmises that an alternative ontological metaphor is needed for science: if we want to move away from the notion that science is a body of knowledge, we also have to move away from the representational idiom, because such an idiom makes it impossible to ask any other question than if scientific knowledge corresponds to its object. Instead, Pickering offers that we should also consider the material and temporal dimensions of scientific culture, of dealing with how people act *with* things, and how things act in response: "One can start from the idea that the world is filled not, in the first instance, with facts and observations, but with *agency*. The world, I want to say, is continually *doing things*, things that bear upon us not as observation statements upon disembodied intellects but as forces upon material beings (Pickering, 1995, p. 6, emphasis in original)." The practice of science is aided by technology; machines in general help us do the work that naked human minds and bodies are incapable of. These machines need to be interpreted, under the similar notion as Ingold proposes for materials, as possessing a non-human agency. The practice of science, again, is not reducible to a 'scientific method' of abstract hypothesis formation and subsequent imposition of these abstractions onto a passive nature. Pickering proposes what he calls a new ontological metaphor (Pickering, 2008) of the dance of agency, similar to Ingold's call for an anti-hylomorphic approach to understanding making. The practice of science appears not as an attempt to understand the secrets of Mother Nature so that we may dominate her in all subsequent interactions, but as a practice of being attentive and responding to the machines as they act in response to human agency. By machines, while Pickering gives examples of complex devices used for high energy particle physics, I propose that even a simple 'machine' as a pair of Vernier calipers used to measure objects requires the same kind of careful attention and responsiveness to material agency: how else can one achieve precise readings, especially of objects which are not perfectly perpendicular, or perfectly rigid?

To summarise then, the concept of making that I wish to propose here is not a version that seeks to advance the economic imperative of preparing students for future careers, or serves as a means of engagement to deliver captive audiences to predetermined goals of schooling. The sense of making that I am interested with here is an accurate apprehension of the complexity of the interaction of human intention and non-human agency behind making-as-creation. I am not interested in making as merely an assembly of prepared objects to obtain a limited set of goals, while shifting the focus to an abstract theoretical 'design method' that has no grounding in either the way materials may be formed, or more importantly, *de*formed with time and usage by its intended users. Even for the achievement of STEM learning goals, such an approach to making or STEM instruction can inform students a more accurate ontology of the scientific practice, and can have implications on public appreciation of STEM. If people understand that, for instance, the process of making claims about nature requires an extensive translation to-and-fro between the devices and our representations, and that this process is not lossless, greater public participation may arise. This may be especially so not because of the flexibility between phenomena and representation allows novices entry, but because this flexibility is not arbitrarily linked. Real reality produces phenomena of limited ranges of behaviour of which limited forms of representation may express. We do not simply, as Feyerabend (1975/1993) insists, make it up as we go along. For now, let us consider more closely the sense of making-as-creation, paying attention to the creative process and what it constitutes. The claim, as I will elaborate in the next section, is that creativity needs to be construed as a weakly determined emergent process, building upon the insights of the anti-hylomorphic conception of making. The eventual goal, as the astute reader might well gather, is that these perspectives will inform the developmental strategy for scaling such an intervention. To prefigure the argument, as we make, so should we educate, and perform educational research. In the next section, I shall discuss perspectives on creation so as to acquire insights on how one might 'teach' creativity.

5.3 What is Creation?

If we are interested in making-as-creation as an educational goal, it would be necessary to have an orientation towards 'teaching', or more accurately nurturing, creativity that is compatible to the theory of making outlined above. Already, a first insight into the process of creativity arises from the notion that the hylomorphic theory of artefact formation is mistaken: if we cannot make 'in the abstract', and apply these abstract designs fully formed onto matter, we similarly cannot invent 'out of thin air' a fully formed idea which we can then communicate with others. Surely this is a trivial argument: to express ourselves we need to have some form of representation; any mode we may choose to do so will have inherent 'tensions and compressions' akin to that stored within the stone, and users of representational media need to deftly make use of processes to 'liberate' the potential meanings inherently expressible to create a meaning of their own.[2] In this section, I wish to think with the work of Gert Biesta, to consider what might be an ideal orientation to the facilitation of creation, as an educator in a classroom, and in parallel, as an education researcher concerned with the coming-into-being of a new approach to education. The plan for this section is to introduce the concepts of metaphysical and existential creation as two interpretations of the act of creation. As I hope to be able to show, these forms of creation lead us to very different orientations towards its nurturance. In the tension between the quest for certainty on the one hand provided by the metaphysical form of creation, and the risk of failure on the other from the existential; it should not surprise the reader that I advocate for a more open armed embrace of this risk, over certainty. I will elaborate as follows.

In considering the nature of creativity and creation, Biesta (2016) starts with a rather unusual approach of considering the creation narratives that almost all cultures possess. He argues that while creativity has acquired a positive, uncontentious association as one of the goals that educators ought to nurture, the act of creation is far more contentious than we usually consider. At the heart of the problem is the distinction between creation as an act of metaphysics, as *creatio ex nihilo*; versus creation as an existentialist phenomena, as the outcome of a series of encounters and events. Comparing the biblical accounts of creation, as these appear to have the strongest influence on the English-speaking world, Biesta finds a distinction between Elohim and YHWH (Yahweh). The creation of Elohim is one of calling into life by a "calm, distant, celestial, hands-off creator" (p. 14). On the other hand, Yahweh creates as a "nervous […] hands-on micro-manager" (p. 14). Biesta (*ibid.*) summarises the theological argument:

> Yahweh does not so much give Adam and Eve life as he gives them a test of life. "He gives them life on a kind of conditional trial loan to see if they are going to abuse it and try to become like him, in which case he is prepared to withdraw from the deal and wipe—or wash—them out" (Caputo, 2006); this is unlike the story of Elohim where life is what Derrida (1992) would refer to as an unconditional gift. Yahweh, as Caputo puts it, "seems to have a bit of a short fuse, seems inordinately suspicious of his own creation, and is far too nervous about his offspring for a good parent" (ibid., p. 69).

The point of this theological excursion is to provide a philosophical insight into the *quality* of an ideal educational interaction, given that education can be seen essentially as the *creation* of particular kinds of individuals. In this perspective, Biesta's intent is for us to be more accepting of the messiness, dissent, noise and all manner of associated risks that need to be considered an attendant part of the process of education as creation. Much as the stone knapper creates handaxes out of the inherently risky process of striking with no means to be certain of the result, education-as-creation involves a similar degree of risk that we cannot, or in fact *should not* hope to remove. Biesta (2016) opens his book with this elegant passage:

[2] Such as I hope to be successful here.

> The risk is not that education might fail because it is not sufficiently based on scientific evidence [...] The risk is there because students are not to be seen as objects to be molded and disciplined, but as subjects of action and responsibility. Yes, we do educate because we want results and because we want our students to learn and achieve. But that does not mean that an educational technology, that is, a situation in which there is a perfect match between "input" and "output," is either possible or desirable. And the reason for this lies in the simple fact that if we take the risk out of education, there is a real chance that we take out education altogether (p. 1).

It should be clear that such a position poses problems for currently dominant perspectives on the prospects and practices in scaling up educational interventions. A strong form of this argument would render suspect many forms of education research, let alone scaling as a researchable goal. In this regard, researchers such as Selwyn (2016), Contandriopoulos (2019) have been recently notable for questioning educational technology and nursing, respectively. Much of the discourse in the public domain and in some areas of research, they claim, are effectively worthless, deserving of the technical term defined by Frankfurt (2005): *bullshit*. In common, their critique suggests that bullshit is characterised by such factors as excessive use of opaque, impenetrable, yet confidence inspiring terms that few can disagree with. A sampling includes such recurrent phrases as 'customised learning', 'virtual learning environment' or, as Contandriopoulos contends, this ostensive definition:

> The social world includes social-economic-political, transcultural knowledge development, and evaluation and implementation of rules of law and systems to co-create the meaning of critical human caring ethical action (Ray & Turkel, 2014, p. 132)

The problem with bullshit is that such discourse can be taken up by other observers and researchers, creating a feedback loop that perpetuates and further entrenches these terms as increasingly legitimate descriptions of the purposes and processes of the field. Thus, obscured, the field becomes littered with fashionable nonsense that makes navigation as precarious as actually stepping out onto a cow pasture.

Certainly, I am not well placed enough to make similar pronouncements about the status of research interested in expanding access to educational interventions found successful. What I wish to do is to minimally query the goals and processes involved in scaling, to consider what might constitute a success state, and the possibility for the extraction of an 'essence' of an intervention for portability to another context. I wish to adopt the weaker (and more accurate) interpretation of Biesta's claim, not dismissing outright the possibility or desirability of creating an 'educational technology' that possesses deterministic control over outcomes, and at the same time embracing what he termed the weakness and concomitant risk of education. The central question for this chapter, in terms of the concepts thus introduced, is to consider what an effort at scaling up an educationally weak intervention might look like. This weakness is a necessary complement to the definition of educational value discussed above: it acknowledges the fundamental autonomy and agency of the teachers whose practice we seek to disrupt for ostensibly educative purposes. This weakness is necessary given the irreducible complexity of educational contexts.

And finally, this weakness is necessary because we ought to recognise the deep practical expertise, craft knowledge and the phenomenological uniqueness of every educational interaction that teachers experience.

5.4 The Weak Educational Intervention

The main purpose of this intervention was to develop more sites where a more open-ended, making-as-creation perspective to instruction could flourish. My colleagues and I also eventually (see below) desired that such a project would have influence on the manner in which the mainstream instruction was to be carried out. In other words, it was not sufficient for the project to only affect the after-school setting. We wanted the project to confront the gritty realities of teachers having administrative and academic accountability laden on their shoulders, to show that an increase in the authenticity of innovativeness need not be accompanied by any costs to academic accountability. Thought of metaphorically as a process of flint knapping, we wanted to make use of the 'internal tensions and compressions' stored in the stone over geological time, to become sensitive to possibility as we journeyed along a path that was not determined at the outset. The goal was also to educate teachers, to increase their wisdom and efficacy at making educational decisions; for them to have enough judgement such that when situations inevitably change, they would be able to discern what constitutes improvements in their educative circumstances (Biesta, 2016).

Even in the initial conception of this project, such latent tensions presented itself fairly rapidly. An exploratory effort was conducted to prepare the research proposal, which included a visit to sites in the US to understand the maker movement; as a means to understand the recent international interest in making. Making was perceived, then, as a practical context for the introduction of STEM concepts, where students would be enthused to try out the latest technologies, so as to 'feed the pipeline' of graduates for STEM careers. When proposed, we had suggested that participating schools would build a makerspace, a purpose built space equipped with contemporary technologies associated with digital fabrication, ubiquitous computing and smart devices. Emblematic of such makerspaces would be 3D printers, Lego robotics kits, microcontroller boards and associated discrete electronics. While we had support from the funding agency, we were quickly advised not to pursue the infrastructure development route, but rather make use of the Design and Technology (D&T) program and facilities as that was the perceived best fit among school programmes that could make use of makerspaces. We found partners in the Ministry of Education: specialists in D&T curriculum planning and development, who quickly realised the value proposition of the project and suggested that 3D printers could 'plug in' readily to the computer-aided design software workflow that was already being used in schools. Such 3D printers would be the 3D analogue to laser printers printing out draft essays so that mistakes could be more obvious to the author.

These sources of potential energy needed to be harnessed: I decided that this was not to be a project concerned with the 'technical upskilling' of teachers to the demands of new technologies, but instead one which made use of the ministry-wide discourse about innovation as a curriculum goal to set teachers of D&T to think more deeply about the nature of their discipline and how they could be more instrumental in using their discipline to bring about innovativeness in their students. In congruence with the ideas about making-as-creation above, I believed that it was important that the agency and autonomy of the students be respected as they set about deciding what it was that they were intending to create. As for students, similar considerations applied for the ways in which the teachers were to interpret the intervention. The central principle to be adhered to was a closer reconsideration of the nature of design, specifically in the manner in which lessons were to be carried out. Teachers reported during initial visits that much of D&T instruction was carried out in a strongly guided manner. For the sake of assessment and accountability considerations, and with a desire for perceived efficiency, students had minimal input on the design of the artefacts. The challenge that my colleagues and I set out to attend to were the taken-for-granted notions of what constituted 'good' D&T instructional procedures.

A significant challenge to the project, which I later realised should be reinterpreted as an asset, was that none of the project team members had any experience as D&T instructors in school. Traditionally, this would have been a relatively fatal flaw: how could one propose to intervene in disciplinary pedagogy if one had not had any prior experience in it? Instead, because we were not 'experts' in D&T instruction, we set out to listen closely to the teachers as the experts in their own contexts, and provoking change by posing them a challenge that was within their discipline and which was expected of them (nurturing innovation), and noticing a central contradiction in the manner in which they typically carried it out (in teacher directed ways). Also, since we were not disciplinary 'insiders', and did not attempt to carry ourselves in that manner, we posed no threat and could ask rather pointed questions as to why instruction had to be carried out the way we observed them to be.

To summarise this section then, my colleagues and I developed an intervention programme based on the notion of making-as-creation, and Biesta's concept of the weakness and risk of education. For the students, we desired that they experience making as an act of innovation, of bringing into the world an artefact that was simultaneously respectful of the internal 'tensions and compressions' of the materials used, and which does not further entrench the hylomorphic model of making. For teachers, we wanted to confront the challenge of developing teacher judgment such that they may be reliably counted upon to continue making wise educational decisions even when the project was complete. In order to achieve that, we made assumptions about the maturity of teachers: we did not consider teachers as in deficit of some privileged form of knowledge or experience, but began the project with the supposition that these teachers were already competent in the forms of instruction that we desired. This is not a position of wishful thinking, nor an act of convenience, but a decidedly political act that treats educator and educated as equals, as a form of role modelling of the ideal relationship between teachers and their students in turn. As I will detail below, we had mixed success in this venture as was to be expected, mostly hinging on this assumption of maturity. It was not as if being mistaken about this basic assumption resulted in a lack of success, but the manner in which teachers responded to the perceived goals of schooling which ultimately determined the educative outcomes of this project.

5.5 The Cases and Their Contexts

Although we deployed this project in various extents to eight schools, I will report here on two major categories of results, represented by two pseudonymous schools: Able and Brave Secondary. These pseudonyms do not refer to individual schools, but, for anonymity reasons, refer to composite characters drawn from multiple schools and teachers participating in this project. This project ran for 3 years, and had a fairly basic design: in each of these years conceived as one iterative cycle, the project team would consult intensely at the beginning of the year with teachers as to their goals for the year. My colleagues and I would offer suggestions as to what they could do and how they could do it, but otherwise left them with minimal direct intervention as they carried out their plans. We would visit intermittently to provide feedback as to how we believed the project was progressing, and then end the year with a joint conference among participating schools as to what was achieved in the year. At points, we made visits overseas, to related conferences and school visits, for teachers to get a better sense of how schooling could be directed towards the interpretation of diverse educational goals.

I use the case study method in this chapter to report on the findings. Case study is not intended to have numerical generalisability, but instead be used as a means to report on situational complexity in order to expand on and demonstrate theoretical insights (Flyvbjerg, 2011; Stake, 2005; Yin, 2009). In this regard, case study is akin to a mathematical existence proof or a proof by contradiction. Data reported upon here include field notes, audio recorded interviews, video-recorded presentations, photographs of student work, teacher lesson plans and project briefing presentations. Data was collected over a 3-year period.

Able Secondary is a composite of schools that embraced the strong version of schooling. In these schools, which ranged from medium–high resourced to the standard level afforded by a relatively wealthy Ministry of Education, the central belief that we could not get to shift was the necessity of risk, ambiguity and improvisation in instruction. Teachers in such schools believed that it was important to have clearly planned lessons and perceived this project as mostly about technical upskilling and incorporating new technologies as part of the D&T curriculum. In contrast, Brave Secondary tended to not be academic high achieving. Instead, Brave Secondary had students from the lower end of the academic spectrum, for whom D&T was perceived as an ‘easy subject’ to sit for and get good results. Teachers in Brave Secondary tended to have an interpretation of school and education on the ‘weaker’ end of the spectrum, and while they may have started the project towards the stronger end, they emerged from the project with a greater appreciation of the weakness of education. In other words, Able Secondary represents the cases where the project achieved success in ‘plugging in’ new instructional technologies to the established and dominant conceptions of what schooling should look like. On the other hand, Brave Secondary represents the schools in which the teachers made changes to the ‘cultural technology’ of schooling, and which managed to make a shift in the goals of school to privilege a more ethical, more human approach to instruction. I discuss these in turn.

5.6 Able Secondary

Typical of schools making up the composite Able Secondary was either high academic achievement and/or attempts to show that the school was on a trajectory towards high achievement. In order to achieve this, teachers in Able Secondary had formulated a well-intentioned programme of education, for which students roles were clearly defined. Student cooperation and active participation in this programme determined academic outcomes. In order to carry out the programme of academic achievement, Able relied on the perceived effectiveness of academic achievement tracking. This resulted in classes which had students who were either high intrinsic academic ability and/or possessed strong conscientiousness on the one end, and students whose behaviours were perceived to need management by tight controls on the other. For both ends of the academic achievement spectrum, however, participation in this project was perceived to contribute to this programme of academic achievement by providing a tantalising inducement, a metaphorical sugar coating or as a necessary ‘advancement’ to the modernisation of the D&T curriculum in order to keep the discipline up to date to contemporary demands.

For higher academic achievement classes in Able, teachers used this project as a means to push more sophisticated concepts onto their students. For instance, Andrew (all names pseudonyms) decided to not only use 3D printers but also got his students to make use of microcontrollers together with basic sensors and actuators such as light-dependent resistors, switches, motors and light-emitting diodes. Andrew created a high challenge condition which was appropriate for his students, high academic achievement students who were not expected to move on to offer D&T as one of their examinable subjects for their grade ten high-stakes examinations. Because Andrew’s classes only did D&T for grades 7 and 8, he decided that this was a valuable opportunity to make use of limited curriculum time to have his students acquire practical skills in technologies that could be useful for their future. Many of Andrew’s students were taking part in competitions as school representatives in events such as robotics competitions. When they did, they eventually came back to Andrew for assistance in making and crafting components of those devices. As such, Andrew also saw value in instructing his students in common technologies that would be of use in these after school competitive ventures. More significantly and in alignment with the ‘design method’ that was being taught, students were tasked with a practical scenario which involved having them interview actual potential users of their inventions as part of a needs analysis phase of their projects. This anthropological excursion to the making process gave students a better sense of who they were making for, and prompted Andrew to report to us that his female students now expressed a greater confidence in, and interest for, engineering as a potential career choice.

In lower academic achievement classes, classroom management was perceived to be a problem as the classes with lower academic achievement tended to be accompanied by a slightly increased incidence of non-compliant behaviour. 3D printers were deployed as a means to 'reward' on-task behaviour. Boris, for instance, taught a lower achieving class, and had planned a series of lessons where students would 3D print a keychain with an integrated soft membrane switch for an LED light. He judged that a majority of his students would have difficulty working with the 3D drafting program, and that they would not have the persistence to continue exploring the programme to find solutions for their problems. As such, he chose the higher performing students in his class to reward them with a holiday programme to learn how to print artefacts. These students were then deployed during the regular lessons as de-facto teacher aides, helping their classmates when they encountered difficulty. Because 3D printers were considered novel, rare and possessing a certain technological cachet, giving these higher performing students the privilege of first access and mentorship raised their status and self-esteem. Clara, also teaching another middle- to low-achieving class, perceived the challenge as one of communicating a long convoluted set of instructions to students with less than ideal patience. As a result, Clara simplified the scope of the task for her students, and as a starter activity, got them to print variations in spoke design for the wheels that were to be attached to a motorised car.

In Able Secondary then, teachers mainly perceived the project in strong educational terms, as a challenge in communicating new concepts such as computer-aided design (CAD), the functioning principles and best practices for using the 3D printer and a stronger emphasis on the user needs analysis portion of the design process. Because teachers in Able wanted to maintain control of the process and guarantee a minimum threshold of achievement by their students, room for student autonomy and experimentation was minimal. Once again, it is not as if Able Secondary did not generate positive outcomes: the girls in Andrew's class gaining confidence as engineers, and Clara's lower achievement students gaining confidence in what was deemed as an 'exotic' technology must be celebrated as successes. However, at least from the project perspective of attempting to nurture innovative dispositions by respecting and developing student autonomy, Able did not quite do as well. Further, on developing the perspective of making as a mutual dance of agency between humans and materials, it would seem that the instructional choices of the teachers in Able may have stood in the way. In prioritising the 3D printer, Boris and Clara essentially cemented the notion that design and making were two different process. The first being the 'higher level', clean, abstract cogitation in the CAD software where 'mistakes' never happened; and the second being the messy, error-prone and inexact 3D printing where the predetermined form was 'produced' (not made). What might have exacerbated this situation was Clara's notion that it was not useful for students to wait for their prints to complete, and as such she took it upon herself to continually feed a 3D printer with student files to print, away from students' view. This machine (she only had access to one at the time) continued printing outside of students' lesson hours, divorcing the design from the making process.

Andrew's case is probably marginal in the achievement of both goals of having students perceive a different relationship of making, and respecting students' autonomy in the design process. While he managed to give his students a high degree of design decision making, the pace of instruction, especially the challenge of teaching the use and programming of microcontroller systems, meant that there was reduced time and opportunities for students to reflect upon the chaotic process of making. It was especially telling when we were in discussions for Andrew to set up a makerspace in Able: I had asked him if he could envision a space for students to work on projects of their own initiative. Andrew expressed concern that he could not imagine that his students, with their already overloaded school days and after-school tuition/enrichment activities, could find the time to do so.

5.7 Brave Secondary

Teachers in Brave Secondary tended to have students who were middle to low academically achieving. While almost all schools in Singapore have a strong orientation towards academic performance, Brave Secondary had teachers who seemed to be somewhat more open minded about the means to get towards academic excellence. As with Able, the lower achieving students also had some issues with being on task, but the teachers in Brave appeared to be have developed a better demeanour to translate students' latent interests into activity that counted towards academic achievement. Typical of this approach was Douglas, who had a particularly jocular, almost irreverent manner which suggested to the project team that he was not afraid to take risks for what he felt amounted to an educationally worthwhile activity. His students tended to be attracted to his easy-going personality, and his generosity.

Douglas was initially sceptical about participation in the project, and took his time querying the project team on the nature of the changes that we sought in his class. Only when he was convinced that the project had educational value did he decide to get completely on board. Once he did, however, the socio-cultural resources that he brought into the project made the classes that he taught in one of the role models of the project. His early objections were based on his belief that his low achieving classes did not need additional complications to further cause confusion. We handled this concern by providing training for his students in CAD software usage, while continuing to understand his concerns. As it turned out, Douglas by his own admission considered himself averse to computers, and so we supported his self-motivated shift of focus of the project to concentrate on aspects of the design process, without excessive technological interference. Among other things, this took the form of his self-initiated purchase of a large quantity of Lego bricks that he would bring to class and pour with aplomb onto student group tables, and then invite students to rapidly make objects with the random collection of bricks. Elena and Frida also conducted similar sessions with their students, with Elena challenging her students to build elastic band powered racers, and Frida's students making 'marker bots'—upturned paper cups supported on three marker pen legs, with an off-centre motor driving the motion randomly.

Teachers reported that these activities would not have been considered legitimate prior to their participation in the project. Under the old thinking about D&T, it was always considered that there was a lot of content to deliver, much of it fairly nuanced and not readily accessible to students who were often perceived to be somewhat immature. Under such assumptions about the learner, teachers had prepared extensive programmes with bite sized instruction and minimal goals. For instance, Elena expressed scepticism when we suggested that her students be asked to build elastic band racers; her typical instructional sequence would be for students to work on ideational 'shape borrowing' and sketching first as a means to determine the design plan for weeks before the students came close to touching any material or tool, true to the hylomorphic model of artefact making. Through our encouragement, teachers decided to 'flip' their instructional sequence to bring forward improvisational making first. The prevailing sequence came about from a rational consideration of material use: as teachers did not want students to 'waste' new materials on mistakes, they deemed it important to get the design of the artefact right before tools touched materials. We suggested that students be given low cost or reusable prototyping materials, with the emphasis on: (i) making mistakes as a means to learn; (ii) teachers helping students notice mistakes; and (iii) developing conceptual language based on joint experiencing of phenomena.

All the teachers in Brave Secondary reported benefit from these and other changes. Douglas was excited that more students chose to accept D&T as examinable subjects after his modifications. One of the projects he decided to work on with his grade nine students was a community action project. In collaboration with a local community service agency, his students visited needy elderly residents within walking distance of the school. As with Andrew's class, Douglas' students worked with real people in circumstances which mattered; the artefacts that they made would actually be counted upon to be used. However, unlike Andrew's case, Douglas' students were not constrained to demonstrate their competence with microcontrollers. Nonetheless, almost all the groups ended up fashioning some form of storage furniture in response to the elders' reported needs to organise the paraphernalia of life. One group decided to make an in-principle prototype of a wheelchair motorisation with a battery powered drill. Most heartening for Douglas were occasions when his formerly unmotivated students would now ask him when they could start work on their projects, or when he had to chase them out of the workshop on weekends.

Teachers from the project participated in an educational conference, where, unprompted by the project team, Frida reported key characteristics that resulted in project success such as: (i) increasing the type and quality of interactions deemed legitimate in the conduct of D&T learning; (ii) increasing student engagement by attending to student interests; (iii) designing learning tasks which support multiple outcomes and student input on possible goals; (iv) emphasising process of testing and prototyping along possibly divergent paths instead of a monotonic approach to a fixed goal, and (v) pursuing a style of facilitation where teachers are co-learners on a path towards understanding.

5.8 Discussion

To reiterate, the two main goals of this project were the implementation of an alternative pedagogy that sought to respect student initiative and provide expanded opportunities to experience making as a complex practice. As a meta-level goal, it was also important for the project team to positively model this alternative form of instruction in the implementation of the project. Key to the success of this model is the assumption of competence and maturity as a starting point, for both teachers and students. It can be tempting, especially for the learning of complicated procedures, to simplify and apply an industrial rationality of decomposition to its basic components. While such an approach of simplification may work for industrial processes dealing with the mass production of widgets, the required changes in beliefs about teaching can hardly be considered as a candidate for such a process. As I outlined in the review, the process of teaching and learning needs to be considered as a process of creation, specifically of a form that recognises the weakness and associated risk of the creation of a new kind of person capable of new forms of interactions. Here, besides the ethical obligation of treating another human with the assumption of autonomy, it is useful to note that as Labaree (2004) reminds us: education is distinct from other professions in that our client's cooperation is necessary for the success of the intervention. Engineers and doctors (for instance) can almost entirely do their work without their clients' participation; and in many circumstances, such participation is actually unwelcome (such as when doctors are trying to perform surgery). On the other hand, for educators seeking to implement a programme of learning that does not lean toward indoctrination, the active consent and participation of the educated is necessary to the interaction. In this way then, the question reduces to one of extent: what degree of active cooperation should be deemed necessary in order for an interaction to be deemed educative? How might one describe the quality of such an educative cooperation? If it may in the first instance be possible, how does one 'scale up' an educational intervention such that these essential qualities are preserved?

Through the cases of Able and Brave, three crucial properties that determined the success of the project are (in no particular order): (i) acceptance of the weakness of creation; and (ii) the assumption of maturity on the part of participants. In accepting the fundamental weakness of the process of creation, my colleagues and I did not attempt to institute mechanisms of control; instead, taking the analogy of flint knapping as a process of releasing and harnessing stored potential energy as a mechanism for change, we made use of teachers' innate desires to provide better educative opportunities for their students. This was apparent in all the participants, but took shape in several different forms. In Able Secondary, for instance, what was deemed important educationally were measurable shifts in student academic outcomes, with interest and engagement being contributory conditions. While it could be said that Boris and Clara further reinforced the hylomorphic conception, all teachers in Able still managed to engage their students in some expanded form of agency for their design outcomes. On the other hand, teachers at Brave Secondary demonstrated a great, almost pent-up desire to give to their students experiences of making that expressed the tentative and fluid nature of intending a design to arise. These results emerged through a process of creation that recognised that contextual variations were not to be treated as resistance that needed to be smoothed over, noise, or 'infidelity of implementation' but rather a natural variation appropriate for the participant in question.

The assumption of maturity is a natural consequence of the respect for the autonomy of the individuals involved in the educative process. That is to say, if we desire an interaction to be educative, it is important to begin with the assumption of participants being of equal status. Yes, the educator does bring into the interaction new information, but that does not reduce the educated to one of immaturity and subservience. In this project, teacher participants were deemed as experts who at least had latent competence or an implicit awareness of the complex nature of making. This was a safe assumption in this case because most teachers of D&T would have had extensive experience in making, either when they themselves were students, or while they facilitated making experiences for the students. In this sense, the nature of this project was not so much bringing a new idea, method of instruction, or assessment technique into a situation that was devoid of its presence, but more of a leading out from within a particular understanding; paying attention to, and giving the experience a name. In turn, this assumption of maturity was to be extended to students, the role of the teacher not so much of talking at them of conventional representations of phenomena, but once again leading out latent understandings of the process of making, or providing experiences and directing learners' attention to particular aspects of phenomena. The role of technology that we brought into the context here was not intended as a means to bring the educated down to a renewed level of humility and subservience to us who impose the new and complex. Instead, we intended the 3D printer (and other technologies) to be a sufficiently novel experience which allowed participants to 'remember' what we believed to already be there, but which might have been forgotten due to particular established practices. Again, Biesta's (2016) retelling of the comparative nature of biblical creation between Elohim and YHWH is useful here: we sought the weak, existential creation, a calling into existence; rather than the strong, metaphysical creation of something-from-nothing. In practice, this took the form of in-depth discussions with teachers to challenge their taken for granted notions of what instruction in their discipline looked like, and how the imposition of new technologies which challenged their established workflows may cause them to reconsider what was truly important to communicate to their students.

5.9 Conclusion

I began with a question as to nature of scaling of an educational intervention. This chapter is in equal parts a philosophical assertion of the impossibility of the strong form of scaling, that is, scaling where there is 'perfect fidelity' across different contexts; and a case study of how a weak scaling intervention may be developed. I believe such an alternative form of educational intervention is necessary given the character of the educational goal desired. To reiterate a significant point of this chapter, we are human beings, and the goal of educating human beings should not be thought of in mechanistic terms. Besides being a thoroughly distasteful metaphor, the question that we need to ask ourselves continually is the purpose of scaling: are we intending to scale the training of individuals, or would we prefer to scale the judicious use of skilful ability? Do we want teachers to use different methods to achieve the same tired old goals, or do we want teachers to desire different things? To use a term that is not particularly glamorous in contemporary discourse: should we not want to expand access to *wisdom*? On the one hand, we have deficit, and a permanent need for researchers to continually intervene and steer; and on the other, we have an enlarging sphere of trust, and an open-handed letting go. It is, at least for me, quite clear which way we ought to proceed.

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Chapter 6
Perception as Expression: Virtual Reality in the Classroom

Deborah Yu Ting Ong

Abstract "It is the real, and not the map, whose vestiges persist here and there in the deserts that are no longer those of the Empire, but ours: *The desert of the real itself*." (Baudrillard in Simulacra and Simulation, 1994). VR is a new medium that is helping to dissolve the boundaries between technology and imagination. The VR market is expanding at a fast rate with worldwide growth rates in 2019 of up to 69% per year (Sinclair in AR/VR spending to jump 69% in 2019-IDC, 2018). In this paper, we will examine how virtual reality with fully immersive head-mounted display systems help students to develop creative confidence and improved attitudes. The research will extend existing research on VR to examine *content creation* apps; with a focus on Google's Tilt Brush. In the first section, this paper will discuss the educational applications of VR, and the second section will include the statistical analyses of VR in the art classroom. Finally, we will conclude and evaluate whether VR is a useful tool in fostering creativity in the classroom environment. This research project makes use of a mixed methods research platform to investigate students' perceptions and learning outcomes. Quantitative data is dominant in the study where surveys and sculptural artifacts are analyzed.

6.1 Introduction

One of the earlier definitions of Virtual Reality comes from the widely known father of computer graphics, Ivan Sutherland, who wrote in 1965 that graphics would evolve to a point that it could be "a room within which the computer can control the existence of matter" (Sutherland, 1965). Sutherland later invented the first head-mounted display system in 1968 together with his team at Harvard University. It was 10 years later that the term "Virtual Reality" was coined by Jaron Lanier who interestingly describes it as "computerized clothing" and that minimally, one would wear "a pair of glasses and a glove" (Lanier, 1989). Already in 1989, by describing VR as mundane "clothing," Lanier envisions the everyday applicability of VR in the future.

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Since the first head-mounted device (HMD) in 1963, VR has been increasingly used in "clinical, behavioral, industrial, entertainment, educational" contexts, where it's application and effectiveness has been significantly studied in the last 20 years (Cipresso, Giglioli, Raya, & Riva, 2018). Looking at this development, it can be useful for students to be early adopters and natives of this technology. Cipresso et al. further provides data that, out of the 10,199 papers that were written in 2018, most were related to computer science and engineering, whereas 4.3% was related to education. Despite VR's well-studied applications, it is only in recent years that the price of head-mounted displays like *HTC Vive* dropped from several thousands of dollars to $799 (USD) today. Reaching the mass market has allowed for more educational applications, making research on VR in education timely and applicable.

6.2 Educational Applications of Virtual Reality

Virtual reality is relatively new in the education sector and its use warrants concern from both parents and teachers alike. It has been studied that "VR is likely to have powerful effects on children because it can provoke a response to virtual experiences similar to a response to *actual* experiences" (Aubrey, Robb, Bailey, & Bailensen, 2018). While it remains unclear regarding VR's possible negative effect on children for reasons such as lack of supervision, or prolonged usage; it is shown to be useful in the highly curated class environment where teachers can decide appropriate content and usage time for the students. The three properties of VR that lends it to be conducive for learning are:

6.2.1 Problem-Solving

Many experts argue that VR is effective in training and preparing users for certain situations or problems. Problem-solving games are available in apps like *Fantastic Contraption (2016)* or *Job Simulator (2016).* With teacher guidance, these and similar games are recommended for children under supervision. Despite not having a straightforward benefit to curriculum, the effect on students is immediate. They are observed to have focused attention and creative zest in solving these puzzles in order to move on to the next level. Less intense games such as *HoloLAB Champions* (Chemistry) and *Number Hunt* (Mathematics) have curriculum applications and also uses gamification to make the subject more interesting. There has been much research into gamification to address problems of engagement in the classroom context as games "attempts to harness the motivational power of games and apply it to real-word problems" (Lee & Hammer, 2011). The realism provided by VR can invoke a powerful range of emotions in students, as with video games; making this experience more memorable. In fact, a number of psychologists theorize that problem-solving is simply a type of remembering (Weisberg & Alba, 1981). This positive correlation suggest that students could perform cognitively better by gaining problem-solving skills while using VR. With VR apps being increasingly developed and curated for education, this creates even more opportunities for memorable learning.

While there is positive research on VR education, it has also been studied that, while students feel more engaged while learning using VR, "they do not necessarily learn more through VR than through video or computer games" (Aubrey et al., 2018). Despite this, a majority of VR Apps make effective engagement tools that are good to use for introduction to a concept or unit, hence leading into deeper learning.

6.2.2 Immersive Environment and Focus

Another quality of VR that lends itself well to learning is its immersive platform. In the classroom, students often have multiple sources of stimulation. This includes the subject material on the board or projector, the teacher, their learning materials and not forgetting their social network of peers seated around them. In contrast, the VR environment puts them in direct contact with the subject matter at hand. For example, in the game *The Body VR: Journey inside a Cell* (2016), players are *experiencing* the cell instead of having to imagine the cell based on scientific narrative. "One of the attractive features of VR as a learning tool is its ability to display objects and situations not normally visible to humans, and to enable humans to interact with them" (Barker, 1993); for example, by reaching out to 'touch' the atoms of a complex molecule.

The VR environment not only immerses the viewer in the subject matter but can also work to *reduce* stimuli. In certain games or apps, this is achieved by placing users in white rooms, plain backgrounds, or enclosed spaces with little distraction of the busy classroom environment or ambient noise. The VR platform has been observed to encourage a *state of flow* (Csikszentmihalyi, 1975) in students using Google's *Tilt Brush* as the inky blackness of the 3D environment provides them with real-time feedback and no other visual distraction. This quality of art creation where the student is fully involved and energized is prized and shows that VR can encourage focused mental states.

6.2.3 Proprioception and Visual Processing

VR works in education contexts through a "combination of multi-sensory visualization and interactivity" (Christou, 2010). The interactivity of this technology allows the user to move with their entire bodies by mapping, accessing, and utilizing the space around them; both physically and virtually. Natural physiological elements of visual processing have been well studied by epistemologists to determine their role in knowledge-forming. A growing body of research affirms the claim that mindful moving and critical viewing can enhance users' perceptual awareness or metacognition (Flavell, 1976). When technology is able to provide accurate and sophisticated haptic feedback; such as body sensors and eyeball tracking, the user is able to fully immerse in the virtual world and move freely depending on the virtual context. This movement in space, also called *proprioception* is the ability to perceive depth. These skills are picked up unconsciously as students analyze the strength and movement required to make each brush stroke. Here, drawing becomes more spontaneous and self-aware.

The concept of moving with awareness is not a new one, it has roots in cultures all over the world, with different names of yoga, *qigong* and various martial arts. More recently, many techniques have been developed such as the *Feldenkrais Method* (mid-twentieth century), the *Alexander Technique, Hannah Somatic Education, Ortho-bionomy,* etc. The techniques researched include both the Feldenkrais and Alexander approaches and have shown positive results despite the challenges of blind trialing most of these movement approaches which could suggest a lower evidence rating.

Nonetheless, despite the generally weak research in the area of movement therapy, there is an interesting contrast between the novelty of the technology and how it can possibly return us to a more natural way of learning with our bodies. Enough research in the health sciences, neurobiology, and even education research shows that psychomotor skills support cognition (Bloom, 1956).

To investigate this, the study uses Google's *Tilt Brush* to measure artistic expression by requiring the student to draw with his/her entire body by moving around the space. Being better able to judge distances between objects and spaces could also help students improve in their 2D space representation, or observational drawing beyond improving proprioception and developing what can be called "skillful perception" where "perception is not something that happens to us, or in us," but "It is something we do" (Alva Noë, 2005).

> Neuroscience research shows that the only way we can change the way we feel is by becoming aware of our inner experience and learning to befriend what is going on inside ourselves (Kolk & Kolk, 2015).

6.2.4 *Creative Confidence as a Marker*

Building on VR's more widely known benefits of problem-solving, immersive environments, and tracking, this research extends the scope to study if VR can increase Creative Confidence (Kelley, 2013) by using apps that allow the player to recreate their imagination or environment from scratch. "*Creative confidence is a way of experiencing the world that generates new approaches and solutions*" (Kelley, 2013). The application, Google's *Tilt Brush,* shifts the user from a passive viewer, player, or avatar into a content creator able to shape the world around him/her to a very high degree. While the finished artwork might not be a realistic portrayal of reality, it is a personalized endeavor and creative act where "Creative thinking is characterized as an ability to solve problems in not normal, unique, and various ways."

(Maedi, 2013) in *Piaget's Theory in the Development of Creative Thinking.* Here, *Tilt Brush* belongs to a smaller set of VR education apps (e.g., *Kingspray, Google Blocks, Fantastic Contraption*) that works not just as an engagement tool but as the main learning aid.

6.3 Research Methodology

Ethical clearance to conduct this research was approved by the Educational Technology Division, Ministry of Education Singapore, and permission was obtained from Woodlands Ring Secondary School to conduct the research on their premises. Individual students have also indicated acceptance of their participation in this research by a legal parent or guardian.

Three groups of Upper Secondary Art students were selected to take part (Table 6.1):

The mixed-methods research is two-pronged:

6.3.1. PsyCap Questionnaire Survey

6.3.2. Sculpture Artifact Study

6.3.1 Survey Predicting Student Attitudes

The Academic Psychological Capital Questionnaire is a questionnaire of a higher order construct that is based on the approaches of positive psychology (Seligman & Csikszentmihalyi, 2000). It is recently developed and applied in organizations to measure employees' level of well-being and overall resilience in the workplace. With permission from Mind Garden, Inc., the survey has been modified to reflect the academic environment in the art classroom (See Appendix A). The unchanged variable, PsyCap, being measured in this research refers to the psychological strengths of HERO (Hope, Optimism, Resilience and Self-Efficacy) which is hypothesized to indicate positive mental health and thereby greater resilience in individuals when faced with challenging situations.

> The arts teach children that in complex forms of problem-solving, purposes are seldom fixed, but change with circumstance and opportunity. (Elliot W. Eisner, 2002)

Table 6.1 Breakdown of secondary art students by group

	Control group	Test group	
Subjects	Secondary 4	Secondary 3 and Secondary 5	
Number	23	12	6
Total	23	18	

Embarking on an art project engenders more than the application of technical skills acquired over the course of one's art education. It often requires a high degree of trial-and-error, problem-solving, experimentation, and an onward trudge toward the resolution of an artwork; all involving the need to assess, analyze and make qualitative judgements (Feldman, 1992). Adding to these mental dispositions, attention also has to be paid to classmates and their qualitative relationships in their attempt to complete a group task; or the sharing of a mental and physical creative space and art materials. With so many tasks to do on hand, this PsyCap questionnaire will investigate how positively the students view such experiences and processes in the context of art creation.

Please refer to **Appendix A: Academic Psychological Capital Questionnaire.**

Info from Literature on PsyCap Variables: The findings were analyzed through the calculation of means and standard deviations of the summated subscale dimensions—Hope, Efficacy, Resilience, and Optimism [HERO] (Luthans et al. 2007). Hope: items 7, 8, 9, 10, 11, 12; Efficacy: items 1, 2, 3, 4, 5, 6; Resilience: items 13R, 14, 15, 16, 17, 18; and Optimism: items 19, 20R, 21, 22, 23R, 24. Items 13, 20, and 23 were reverse scored in both the categories. In this study, the individual HERO dimension scores were calculated by taking the sum of all the items within each dimension. Dimensions of PsyCap scale has an interpretation based on the construct measured. Higher scores are reflective of higher levels of the construct being measured (Luthans et al., 2007).

Academic Psychological Capital Questionnaire Pre-Intervention (n = 41).

Reliability of Scale

Cronbach Alpha score of 0.9 indicates acceptable to good reliability within each scale and overall excellent reliability. Therefore, while it is useful to consider each of the subscales *individually*, it is more accurate to measure the amount of PsyCap (Psychological Capital) as a *whole* (Table 6.2).

Pre-intervention Survey Results (Control and Test Group): (n = 41).

The calculation of means and standard deviations of the summated scores were calculated (Tables 6.3 and 6.4).

Table 6.2 Reliability of scales showing that additive HERO scores are more reliable

Scale	Hope	Efficacy/confidence	Resilience	Optimism	Overall Scale
Cronbach Alpha (Pre-test)	0.83	0.77	0.70	0.72	0.90
Cronbach Alpha (Post-test)	0.88	0.83	0.79	0.55	0.93

Table 6.3 Pre-intervention survey results showing healthy HERO mean scores with the maximum for each variable being 36 points

Variable	Mean	SD	Min	Max
Hope	22.71	4.77	12	32
Efficacy/confidence	24.56	4.67	11	32
Resilience	22.63	3.94	10	28
Optimism	22.15	4.59	9	32
Total	92.05	14.99	44	115

Table 6.4 Post-intervention survey results showing slightly lowered mean scores overall for the whole group which is inconclusive until further testing with paired t-test for both the different groups

Variable	Mean	SD	Min	Max
Hope	21.70	5.34	10	30
Efficacy/confidence	23.05	5.18	12	31
Resilience	21.83	4.72	11	30
Optimism	21.30	4.06	12	29
Total	87.88	17.56	46	118

Post-intervention Survey Results (Control and Test Group): (n = 40).

In the pre-intervention, students were averaging scores of approximately ≥ 4 in a 1–6 numbered scale for each subscale. Thus, most students are reporting generally positive attitudes to art-making. This result can be attributed to the selection of students who are already interested and passionate about the subject class, Art. Given that these are upper secondary students, they would have personally opted in to take the subject at the Cambridge O'level Examination. Thereby explaining a certain level of motivation and positive attitude apparent in this group of students. The summary of these scores show that there is not significant improvement in attitude overall, however, looking at the paired T-tests can provide a clearer picture (Tables 6.5 and 6.6).

Paired *t*-test for Control Group (N = 21).

Cohen's guidelines for effect size: 0.2 – small effect, 0.5 – moderate effect, 0.8 – large effect

Paired *t*-test for Experiment Group (N = 17).

While there appears to be no significant effect pre- and post-test for the control group, it can be seen that the already healthy scores for HERO were maintained despite having a five month difference when the two tests were run. This is an affirmative result given that most students are observed to waver in their interest in the subject from the start of the year compared to the end of the year, high-stakes, summative assessment being one of the reasons. In summary, the data shows that for the control group who did not use VR their Hope, Efficacy, and Total Variable scores dipped

Table 6.5 Showing statistical significance for variables Hope, Efficacy, and Total where pre-test scores are better than post-test scores

Variable	Time	*n*	*M*	*SD*	*df*	*t*	*p (2-tailed)****	*Effect Size*
Hope	Pre	21	24.00	4.58	20	2.394	0.027***	0.22
	Post	21	22.10	5.59				
Efficacy	Pre	21	27.00	3.36	20	2.695	0.014***	0.27
	Post	21	23.95	4.71				
Resilience	Pre	21	23.86	3.43	20	1.401	0.177	0.09
	Post	21	22.81	4.24				
Optimism	Pre	21	22.86	5.14	20	1.763	0.093	0.13
	Post	21	20.90	3.90				
Total	Pre	21	97.71	12.92	20	2.739	0.013***	0.27
	Post	21	89.76	16.71				

***Significant at $p <= 0.05$

Table 6.6 Showing no statistical significance between pre- and post-test results

Variable	Time	*n*	*M*	*SD*	*df*	*t*	*p (2-tailed)****	*Effect Size*
Hope	Pre	17	21.88	4.47	16	0.000	1.000	0.00
	Post	17	21.88	5.06				
Efficacy	Pre	17	22.82	4.47	16	0.095	0.925	0.00
	Post	17	22.71	5.35				
Resilience	Pre	17	21.88	3.39	16	0.186	0.855	0.00
	Post	17	21.71	5.35				
Optimism	Pre	17	21.82	2.72	16	– 0.783	0.445	0.04
	Post	17	22.47	3.81				
Total	Pre	17	88.41	12.23	16	– 0.102	0.920	0.00
	Post	17	88.76	17.03				

over time, whereas the experiment group maintained their healthy scores in all the variables.

6.3.2 Sculpture Artifact Study

These research findings are gathered by an independent researcher who documented and assessed the sculptural artefacts based on a unique set of assessment rubrics determined by the project objectives. The wider objective is set out to determine if the use of VR in Art Education had enabled students to develop experimental mindsets, problem-solving skills, and personal artistic style. Here, the Sculpture

Artifact Study hopes to complement survey findings by qualitatively assessing the creative and proprioceptive skills of the students through a simple modeling exercise (Figs. 6.1 and 6.2).

Fig. 6.1 Example of pre-intervention and post-intervention artefact by a student that shows a more articulated form after 6 months. One can also note the startling similarity of the figures despite the student not having access or looking at the sculpture that was done 6 months prior, hinting at the existence of a *cortical homunculus* of which this study has yet the width to explore

Fig. 6.2 Pre-artifacts collected and sorted by student name (names redacted) before handing over to the researcher

6.3.2.1 Lesson Outline

1. The students were tasked to produce a self-portrait (head bust ovule) resulting in a series of head bust made independently using clay sculpting techniques over a duration of 1 h.
2. The students were introduced to VR and Google Tilt Brush where they explored how movement and an interactive digital media can be designed to support them to learn, play and interact in a physical, sensorial, and perceptual activity planned by the teacher.
3. Students were then tasked to produce a subsequent self-portrait using clay.

6.3.2.2 Research Methods

1. The head busts were documented and assessed using the specifically crafted assessment rubrics and descriptors in Tables 6.7 and 6.8.
2. The results were then analyzed and each student artwork documented individually and side by side. See Fig. 6.1.
3. The resultant outcome in Tables 6.9 and 6.10 will determine if the VR experience had in fact aided their learning and art-making

The assessment rubrics and descriptors are based on these considerations (Table 6.8):

Table 6.7 The assessment rubrics and descriptors are based on these considerations

Rubric	Descriptor
Measure *Measurements and Facial Observation*	Where the descriptor assesses how the student has developed observational and problem-solving skills in determining the relative distances of facial features in the facial schemata
Surface *Sense of Touch and Sensor Motor Ability*	Where the descriptor assesses how the student has explored touch and sensory motor skills to explore the limitations of the material and developed an understanding of surface qualities and tactility through clay sculpting
Geometric Form *3D-Perception and shape of form*	Where the descriptor assesses how the student has developed perceptual and problem-solving skills in understanding the shaping of form through a perception of 3D shapes
Create *Artistic choice in creation*	Where the descriptor assesses how the student has developed artistic choices and in the process of creation developed a personal response to the task

Table 6.8 Assessment rubrics and descriptors

Total 20	Poor 0–1	Fair 2–3	Good 4	Excellent 5
Measurements and Facial Observation **MEASURE**	Accuracy lacking in observation, poor understanding of facial schemata	Some accuracy in observation, fair understanding of facial schemata with major errors in proportion	Relatively accurate depiction of facial schemata with some errors in proportion	Accurate depiction of facial schemata
Sense of Touch Sensor Motor Ability **SURFACE**	Surface poorly resolved, no modelling of clay	Response to material adequate and some effort seen in responding to limitations of the clay	Displays some skill in responding to the limitations of the clay	Demonstrates craftsmanship in responding to the limitations of the clay
3D-Perception and shape of form **GEOMETRIC FORM**	Unfocused and vague in shape	Some semblance of the head contour	Ovule form relatively resolved with accurate cheekbones	Understanding of ovule form well resolved
Artistic choice in creation **CREATE**	Work shows no artistic choice made and lacks any care or attention to detail	Some attempt to depict 3D form with care and artistic choice	Demonstrates some artistic choice, care and attention in depicting a 3D form	Demonstrates artistic choice in creation of a well-constructed 3D form

6.4 Summary of Findings

a The majority of students **(9 out of 12 or 75%)** improved in their overall development of experimental mindsets, problem-solving skills, and personal artistic style after participating in the learning of VR google tilt brush.

b. **58.3%** of students saw an improvement in the area of **SURFACE**, where the students explored touch and sensory motor skills to explore the limitations of the material and developed an understanding of surface qualities and tactility

c. **50%** of students saw an improvement in the area of **CREATE**, where the students developed artistic choices and in the process of creation developed a persona response to the task.

d. **33.3%** of students saw an improvement in the area of **MEASURE**, where the students developed observational and problem-solving skills in determining the relative distances of facial features in the facial schemata.

e. Lastly, **16.7%** of students saw an improvement in the area of **GEOMETRIC FORM,** where the students developed perceptual and problem-solving skills in understanding the shaping of form through a perception of 3D shape.

Comparatively, the control group of 12 students who did not undergo the VR experience exhibited the following research findings that were inconclusive (can be found in in Table 6.10 in Appendix B).

a. About an even ratio of students (7 out of 12 or 58%) improved in their overall development of experimental mindsets, problem-solving skills, and personal artistic style after participating in the learning of VR google tilt brush. Twenty-five percent of the students saw 0.0% improvement in their overall development across the four descriptors.
b. 0.0% of students saw improvement in their understanding of **SURFACEs**, indicating that the students' senses of tactility in sculpture-making was generally consistent during both sessions of art-making.
c. Only one out of two students or 8.3% of students saw an improvement in the area of **CREATE**, where the students developed artistic choices and in the process of creation developed a persona response to the task.
d. 8.3% of students saw an improvement in the area of **MEASURE**, where the students developed observational and problem-solving skills in determining the relative distances of facial features in the facial schemata.
e. Lastly, 8.3% of students saw an improvement in the area of **GEOMETRIC FORM,** where the students developed perceptual and problem-solving skills in understanding the shaping of form through a perception of 3D-shape.

Table 6.9 Results tabulation for experimental group (Woodlands Ring Sec)

	Name	**MEASURE** *Measurements and Facial Observation*		**SURFACE** *Sense of Touch Sensor Motor Ability*		**GEOMETRIC** *3D-Perception and shaping form*		**CREATE** *Artistic choice in creation*		**Results**/*20*		**Percentage**/*100*		**Variation**/*%*
1	*[redacted student name]*	*2*	*3*	*3*	*4*	*3*	*3*	*3*	*4*	*11*	*14*	***55***	***70***	**+ *0.15***
2	*[redacted student name]*	*2*	*2*	*3*	*3*	*3*	*3*	*2*	*3*	*10*	*11*	***50***	***55***	**+ *0.05***
3	*[redacted student name]*	*2*	*4*	*4*	*4*	*2*	*4*	*3*	*5*	*11*	*17*	***55***	***85***	**+ *0.30***
4	*[redacted student name]*	*2*	*2*	*2*	*3*	*2*	*2*	*2*	*2*	*8*	*9*	***40***	***45***	**+ *0.05***
5	*[redacted student name]*	*2*	*3*	*3*	*3*	*3*	*4*	*3*	*3*	*11*	*13*	***55***	***65***	**+ *0.10***
6	*Janelle Ong*	*2*	*3*	*3*	*4*	*3*	*3*	*3*	*4*	*11*	*14*	***55***	***70***	**+ *0.15***
7	*[redacted student name]*	*3*	*3*	*3*	*4*	*3*	*3*	*3*	*4*	*12*	*14*	***60***	***70***	**+ *0.10***
8	*[redacted student name]*	*4*	*4*	*4*	*5*	*4*	*4*	*4*	*5*	*16*	*18*	***80***	***90***	**+ *0.10***

(continued)

Table 6.9 (continued)

9	*[redacted student name]*	2	2	2	2	2	2	2	2	*8*	*8*	***40***	***40***	***+0.00***
10	*[redacted student name]*	2	2	2	2	*3*	*3*	*3*	*3*	*10*	*10*	***50***	***50***	***+0.00***
11	*[redacted student name]*	2	*3*	2	*3*	*3*	*3*	*3*	*3*	*10*	*12*	***50***	***60***	***+0.10***
12	*[redacted student name]*	*3*	2	*3*	*3*	*3*	2	*4*	*3*	*13*	*10*	***65***	***50***	***-0.15***

Table 6.10 Results tabulation for control group (Woodlands Ring Sec)

	Name	**MEASURE** *Measurements and Facial Observation*		**SURFACE** *Sense of Touch Sensor Motor Ability*		**GEOMETRIC** *3D-Perception and shaping form*		**CREATE** *Artistic choice in creation*		**Results**/*20*		**Percentage**/*100*		**Variation**/*%*
1	*[redacted student name]*	2	3	2	4	2	3	2	4	8	14	**40**	**70**	**+ 0.30**
2	*[redacted student name]*	2	3	2	4	3	3	2	4	9	14	**45**	**70**	**+ 0.25**
3	*[redacted student name]*	3	3	3	5	3	4	3	5	12	17	**60**	**85**	**+ 0.25**
4	*[redacted student name]*	3	4	4	4	4	3	4	4	15	15	**75**	**75**	**0.00**
5	*[redacted student name]*	2	3	3	3	2	3	5	3	12	12	**60**	**60**	**0.00**
6	*[redacted student name]*	4	3	4	4	4	4	4	3	16	14	**80**	**70**	**–0.10**
7	*[redacted student name]*	2	3	2	3	3	4	3	4	10	14	**50**	**70**	**+ 0.20**

(continued)

Table 6.10 (continued)

8	*[redacted student name]*	3	4	4	4	3	4	4	4	14	16	**70**	**80**	**–0.10**
9	*[redacted student name]*	2	3	3	3	2	3	3	4	10	13	**50**	**65**	**+ 0.15**
10	*[redacted student name]*	3	3	2	3	2	3	3	3	10	12	**50**	**60**	**+ 0.10**
12	*[redacted student name]*	3	4	3	3	4	4	4	3	14	14	**70**	**70**	**0.00**
11	*[redacted student name]*	2	2	2	4	2	2	2	3	8	11	**40**	**55**	**+ 0.15**

6.5 Conclusion and Implications

The data collected show that using VR in Google's Tilt Brush has the effect of maintaining student morale and positive attitudes to Art as a subject while adding value to the student's proprioceptive and creative approaches to art-making.

Art is a highly under-utilized resource with interdisciplinary applications in the Singapore school setting. Art appreciation offers students the chance to develop their visual, spatio-temporal, and kinesthetic skills alongside verbal and logical learning and can be summarized as two basic actions: *seeing or perceiving*. By acknowledging and engaging these skills, art curriculum design, coupled with the availability of technology, has the advantage of reflectively moving beyond set disciplines and representational skills in order to once again embrace play, experimentation, and a higher level of reflexivity.

Furthermore, there is also a need to enable artistic expression beyond traditional 2D/ 3D art in the art syllabus. Other than harnessing VR's interactive and kinetic capabilities, less traditional art representation such as installation and performance art are also promulgated due to having similar spatial–temporal qualities.

Besides aiming to develop an experimental mindset, problem-solving skills, and individualistic expression through using VR as an artistic and future-ready medium, this research will also affirm the relevance of *embodied learning* and *learning-by-making* in school.

Not least, research on VR Technology will encourage a wider-scale adoption of this medium in Singapore schools. By having its pros and cons evidenced through research and analysis, art and non-art educators can be better aware of its challenges, motivations, and benefits of introducing this medium in their schools.

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Appendix A: Academic Psychological Capital Questionnaire

Name: ______________________________________ Class:________________ Date: ______________

Academic PsyCap (A-PCQ; Luthans, Luthans, & Jensen, 2012)

Below are a series of statements that describe how you may think about yourself RIGHT NOW. We are asking you to consider each question relative to your art-making and school life aspects. Use the scale below to indicate your level of agreement or disagreement with each statement.

Strongly disagree	Disagree	Somewhat disagree	Somewhat agree	Agree	Strongly agree
1	2	3	4	5	6

Art practice refers to drawings, sketches, visual journaling as well as any visually creative endeavor.

		When I make art…
I	I feel confident identifying problems to help improve my art	
2	I feel confident in presenting my ideas in my artworks	
3	I feel confident sharing about strategies I use in my art	
4	I feel confident setting targets/goals for art	
5	I feel confident contacting people to discuss problems concerning my art	
6	I feel confident sharing my art with a group of students	
7	If 1 should find myself in a jam with my art, I can think of many ways to get out of the jam	
8	At the present time, I am energetically pursuing my artistic goals	
9	There are lots of ways around any problem concerning art-making	
10	Right now, I see myself as being pretty successful concerning my art	
11	I can think of many ways to reach my current goals in art	
12	At this time, I am meeting the goals that I have set for myself concerning my art	
13	When I have a setback in my artwork, I have trouble recovering from it, moving on	
14	I usually manage difficulties one way or another in my art practice	
15	I can be “on my own” so to speak, if I have to make art	
16	I usually take stressful things in stride with regard to my art	
17	I can get through difficult times at school because of overcoming difficulties before in art	
18	I feel 1 can handle many things at a time in my art	
19	When things are uncertain for me with regards to my art, I usually expect the best	

(continued)

(continued)

		When I make art…
20	If something can go wrong for me with my art, it will	
21	I always look on the bright side of things regarding my art	
22	I'm optimistic about what will happen to me in the future regarding my art practice	
23	With regards to art, things never work out the way I want them to	
24	I approach my art as if "every cloud has a silver lining"	

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Chapter 7
An Integrative Approach to Scientific Argumentation: Pedagogy and Technology Tenets of IASA

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Abstract IASA, which stands for "Integrative Approach to Science Argumentation," is a project that sought to augment the goals of science education by integrating scientific argumentation with conceptual learning within the lower secondary science curriculum. Bearing in mind the constraints that our science teachers might face within a content-packed syllabus, our team set out to develop a pedagogical model embedded with novel contextual tasks. These student tasks were aimed at developing argumentative skills, which encompassed data sense-making, evidence harnessing, options weighing, and reasoning and communicative skills, alongside content development. Multiple resources that constituted our IASA "toolkit" were developed over the course of the 2.5-year project to provide professional learning and support for science teachers keen in embarking on this pedagogical innovation. This chapter will outline the designs of our pedagogical model, digital platform, IASA toolkit, and professional learning model as well as explicate impact for students as an overview of the project's conceptualization and implementation.

7.1 Introduction

There have been widespread efforts in recent years to expand the goals of science learning. Science education scholars and policymakers are veering away from an exclusive emphasis on learning science concepts and science process skills (Bricker & Bell, 2008; NRC, 2013). They argue that, while these goals remain essential to science learning, there is a need to re-position young science learners as legitimate participants in the practices of science communities (Ryu & Sandoval, 2012). The recommendation is for school science to be framed not just as science-as-knowledge but as science-as-practice (NRC, 2012; Stroupe, 2014). The latter entails promoting

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authentic disciplinary practices in the classroom. One such practice of science is argumentation, which entails harnessing information and data in a principled and rational way, weighing multiple options objectively and critically, and communicating their choice in a clear and convincing manner (OECD, 2013). Student engagement in scientific argumentation prepares them beyond the classroom, towards becoming proficient problem solvers in everyday life and competent participants in broader discourses of a science-dominated, technology-driven society (Ryu & Sandoval, 2012).

7.2 Background

The current curricular mandate in Singapore schools to teach science as inquiry enjoins teachers to adopt teaching approaches that introduce leaners to the knowledge-building practices of science (Berland & Reiser, 2009; MOE, 2012). While scientific argumentation is clearly recognized in curriculum documents as essential to teaching science as inquiry (Zembal-Saul, 2009), notwithstanding its alignment with schools' current thrust to develop learners' twenty-first-century competencies (Osborne, 2010), it is not accorded in classroom practices the prominence it deserves (Sampson & Blanchard, 2012). In order to address this issue, we embarked on a project to develop and test a pedagogical model, which we called Integrative Approach to Structured Argumentation (IASA) that aims to improve Lower Secondary learners' skills in scientific argumentation. Based on this model, we designed three learning tasks that provided science learners the opportunity to craft well-reasoned scientific arguments following the Claim–Evidence–Reasoning (CER) framework (McNeill & Krajcik, 2008). Accomplishing the learning task involved having learners work through a scientifically oriented problem by interpreting authentic data, learning relevant scientific concepts, and applying these concepts to the problem in order to advance, substantiate, and argue for a claim. We also developed a web app as a technology-enhanced platform to support learners' engagement with the IASA pedagogical model.

7.3 Why Structured Argumentation?

Developing learners in scientific argumentation is a promising step towards refocusing school science from mere conceptual instruction to acculturation to scientific practices (NRC, 2012). Argumentation, as one of the core practices of science, enables scientists to build up explanations, models, and theories about the world; it is a tool for generating and confirming scientific knowledge (Duschl, 2008). Similarly, in the science classroom, when learners engage in writing tasks that demand the use of data for substantiation of claims, they have the opportunity to engage in the social practice of using evidence to build scientific knowledge (Berland & Hammer, 2012; Sampson, Grooms, & Walker, 2011). Through constructing arguments, learners could come to a better appreciation of the processes and norms through which knowledge in science is built over time (Manz, 2015).

Learners benefit from engaging in argumentation in several interrelated ways. Constructing arguments can:

- enable learners to understand science concepts (Sampson & Blanchard, 2012). Arguing to learn requires them to know and critically apply scientific ideas as they make sense of data that they have generated themselves or collected from other sources (Osborne, 2010). Learners' understanding of science concepts is enriched as they shift from merely giving definitions to invoking actual, real-life instantiations of science concepts.
- change learners' view of doing school science as merely memory work. It introduces them to the view that science is a particular *way of knowing* the world around us, providing descriptions and explanations of phenomena based on methods that are agreed upon by the community of scientists. Argumentation, as an epistemic practice, provides opportunities for learners not only to learn science content that the syllabus requires but they also learn about the social context within and through which scientists generate knowledge (Bricker & Bell, 2008; Duschl, Schweingruber, & Shouse, 2007).
- enculturate learners to select, evaluate and communicate their ideas. A good scientific argument is one that is robustly supported by a set of ideas that have been carefully selected and critically examined. The process of arguing demands that learners learn how to communicate the ideas that support their argument in a persuasive manner (Berland & Reiser, 2009).
- provide a good exercise for logical reasoning (Kuhn, 2010). Such thinking is fostered when learners are asked to articulate why a particular data set is considered evidence for the claim or how a scientific concept can be applied to a problem.

7.4 Challenges in the Teaching of Structured Argumentation

Teaching scientific argumentation (SA) remains an exception rather than the norm of science classrooms globally (Berland & McNeill, 2010). Many reasons have been suggested to explain its rarity. Being a complex practice, teaching SA requires substantial new knowledge gain and understanding from science teachers (Zembal-Saul, 2009), who are likely to have very little prior experiences in this practice either from their educational or professional training. Teachers also face practical constraints such as the need to prepare students for assessments (Li, Klahr, & Siler, 2018), limited curriculum time and accountability pressures (Alozie et al., 2010; Sampson & Blanchard, 2012).

In addition to the above challenges, science teachers in Singapore also face other challenges that may or may not apply to other educational contexts. Although science as inquiry has been advocated for more than a decade in the lower secondary science syllabus, science content, rather than scientific practices, remains the main curriculum emphasis. The study by Kim, Tan, & Talaue (2013) is insightful of the challenges that our local science teachers are likely to encounter when teaching SA. Though the study was on the perception of teachers towards inquiry-based curriculum reform, the challenges identified in it are likely to hold true for the teaching of SA. These challenges include "students' readiness and abilities," "lack of class time," "confusion on the meaning of inquiry," "assessment conflicts," "lack of time for preparation," and "heavy content in the curriculum," "lack of content knowledge," "lack of community support," and "other concerns, such as class size, noise, and giving up power to students" (ibid. p. 301). Anecdotally, our conversations with science heads of departments and teachers also suggest that teachers encounter difficulties with supporting students in addressing data-based questions, which require students to utilize and apply given data from a range of scientific representations (e.g., table, graphs, charts, diagrams) to explain scientific phenomena or conclusions. Such questions entail skill-set from students similar to SA. Challenges pertaining to addressing data-based questions are thus likely to compound the challenges that teachers face in integrating SA into their instruction.

When designing the pedagogical model for incorporating SA into the local science classrooms, these challenges are taken into consideration to generate adequate buy-in from science teachers who have to shoulder the risks of disrupting their classroom routines in embarking on this rather arduous educational innovation with us. Such considerations can also better optimize sustainability in the implementation of the pedagogical innovations when researchers eventually leave the research sites as it seeks to address the theory-practice gaps between research recommendations and classroom interventions (cf. Windschitl, 2002).

7.5 Pedagogy: IASA Design

Of the numerous challenges likely to be encountered by the local science teachers, we focused primarily on the following: (1) content-heavy curriculum, (2) time constraints, and (3) teachers' limited experiences and knowledge of SA. We believe that tackling these three challenges is a stepping stone towards resolving other challenges as teachers pursue this pedagogical innovation in the long run. We describe the tasks and pedagogical model below to illustrate how we took the three challenges into consideration when developing the IASA design.

7.5.1 IASA Tasks

We generated a total of three tasks, one each for the three science disciplines (Biology, Chemistry, and Physics), as prototypes of argumentative tasks that incorporate several desired design features. These task features include (1) invoke the need for canonical science knowledge as demanded in the syllabus for its successful completion, (2) involve two or more claims that are plausible to students, (3) contain multiple sets of data in various representation forms that serve as evidence for determining among the possible claims, (4) set in an authentic everyday context with a specific target audience for the argument generated by students. The last feature is necessary to ensure that students construct arguments purposefully (Berland & McNeill, 2010).

The first task feature is particularly pertinent in tackling Challenge (1), as it ensures that our argumentative tasks address the content objectives in the syllabus that science teachers are obliged to address in their lessons. We engaged in regular intensive discussions with our participating teachers to ensure that the tasks, while complex and challenging, can be completed within the time frame of their scheme of work (Challenge 2). In considering Challenge (3), our task design is situated at the simplest end of the instructional context dimension outlined in Berland and McNeill (2010)'s learning progression of learners of SA. That is, our tasks involve closely defined questions, implicate no more than a handful of potential answers and contain a data set that is confined to appropriate data. We believe that this approach provides a gentler runway for our teachers to take flight with the integration of SA.

The three tasks developed are on Ecology, Chemical Change and Heat. The Ecology task exhorts students to explore the effectiveness of various mosquito control measures in the fight against dengue fever with consideration of the impacts of these measures on biodiversity conservation. The task on Chemical Change examines the nature of the changes that take place when a mysterious chemical, a highly versatile household product, is used for various purposes in our daily life. Lastly, students compare between several aquarium designs in terms of their energy efficiency for the task on heat.

7.5.2 The Claim–Evidence–Reasoning (CER) Framework

We adopted the CER framework (McNeill & Krajcik, 2012) to guide the process of SA. Its three-part structure—claim, evidence, reasoning—ensures that students attend to the essential components of a scientific argument. It is important to note that the use of CER in our IASA model is *not* intended to be an answering technique for test preparation. Rather, it serves as a frame for guiding students in thinking about what they know and how they come to know. This mode of thinking engages students in working with evidence and developing reasoning skills, disciplinary practices that are crucial in generating knowledge claims in Science. Through engaging in such practices, we hope to shift students from being passive consumers to assuming the role of active contributors and critics of scientific knowledge.

7.5.3 Pedagogical Model

Due to the nature of the tasks, we are concerned that teachers may use them only at the end of a lesson sequence as a means to consolidate students' learning of the content objectives. We consider such an approach as less ideal as students would have less opportunities to practice SA alongside learning the content. It would also defeat our original objective of transforming current teaching practices with the goals of engaging students in scientific practices and developing twenty-first-century skills, such as critical thinking and reasoning. To counter such tendency, we develop a pedagogical model with the tasks as cornerstone of the lesson sequence within which the associated content objectives are relevant. The model seeks to ensure that students engage with SA alongside content learning throughout the lesson sequence.

Figure 7.1 illustrates the three-phase pedagogical model that integrates SA and content learning. We describe below the main lesson activities that accompany each phase and how these activities correspond with the 5E inquiry model (Bybee et al., 2006).

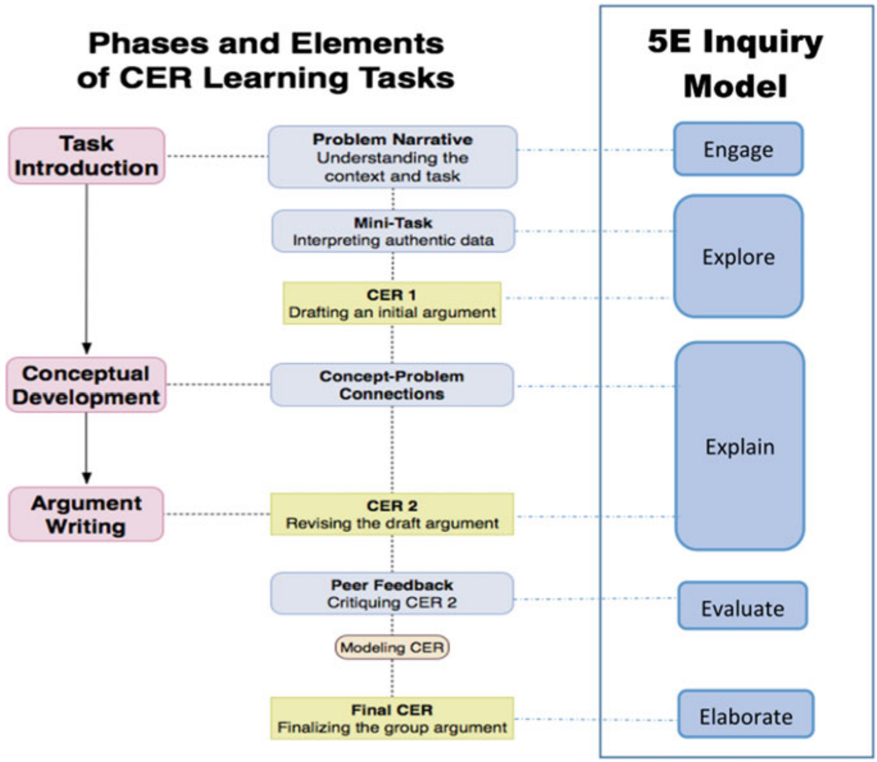

Fig. 7.1 IASA pedagogical model

Task Introduction. We propose introducing the task before any content introduction as a trigger for the topic. By providing an argument-driven context, the task prioritizes the process of SA over the accumulation of scientific facts (Driver et al., 1996). This phase comprises several activities. The first activity involves students familiarizing with and understanding the task. Being embedded in a narrative of a real-life scenario that simulate scientific investigations relevant to everyday life, the task serves to stimulate student interest in the topic and enables them to connect with their prior knowledge [5E: Engage]. The next two activities seek to build students' understanding of the phenomenon targeted in the task [5E: Explore]. Students are provided with mini-tasks to build their understanding of the context of the task and the multiple data sources. They are then asked to draft the first CER based on their initial rudimentary knowledge of the topic. Given the complexity of the task and their lack of canonical knowledge, students are unlikely to provide accurate and comprehensive argument at this stage. Nonetheless, this act of engaging students in crafting their CER1 is considered crucial in surfacing and mobilizing their prior knowledge and creating impasse that engender the impetus for students to attend to the relevant content knowledge in subsequent lessons (Kapur & Bielaczyc, 2012). Additionally, CER1 serves as a form of formative assessment, which offer teachers valuable insights into the extent of content knowledge and SA skills their students possess for the topic. The information gathered also allows the research team to provide contingent support to the teachers.

Content development. This constitutes the bulk of the lesson sequence during which teachers conduct lessons to address the content objectives [5E: Explain]. Two changes mark the difference between how teachers taught the topic previously and how they are encouraged to conduct this phase. One change involves making regular reference to the task by getting students to reflect on how the content knowledge taught can be applied to the task. To support teachers in this aspect, teaching materials containing reflection prompts were provided which teachers can adopt and adapt for their teaching purposes. These prompts draw students' attention to the connections between the content they learn to the task introduced to them in the beginning of the topic. This reflection process also encourages students to continuously review and revise their CER1 as they acquire new content knowledge and understanding of the topic that are relevant to the task. The regular referents to the task allow students to appreciate the relevance of the scientific concepts learned in solving everyday problems like those described in the tasks.

The second change involves teachers exploring opportunities within their teaching materials where CER can be applied. Teachers are encouraged to find instances of knowledge claim where evidence are available and to model how the CER structure can be applied to argue for the knowledge claim. Such modelling process illustrates to students how CER can be adopted to generate knowledge claims in science and increases their capacity to do the same for the task. In addition to the way teachers present scientific knowledge to students, changes were also made to learning activities. An example are the changes made to the practical activities for the topic on

Chemical Change. For this topic, students are typically required to conduct practical activities that involved testing the presence of carbon dioxide gas from reactions involving heating and the addition of acids. These practical activities presented opportunities to connect with the task which requires students to investigate the nature of a mysterious chemical. Instead of heating or adding acid to a known chemical, the practical worksheets were revised to allow students to test the effect of these changes on the mysterious chemical. Through the test for the presence of carbon dioxide gas, students are expected to deduce the nature of the mysterious chemical. Not only do the revised practical activities allow students to fulfil the original learning objectives, these activities now acquired an inquiry dimension that enables students to gather additional evidence that can be used for their CER construction in response to the task.

Argument refinement. With the completion of the content development phase, students return to the task to craft a new CER [CER2] based on the new understanding they acquire over the lesson sequence [5E: Explain]. To further support students in the process of SA, students' initial draft of CER2 are subjected to peer evaluation [5E: Evaluate]. Students are guided with a set of rubrics to evaluate and critique their peers' CER. The process of peer evaluation offers students opportunities to engage in the "utterance functions that are key to the argumentative process' such as "stating and defending claims," "questioning one another's claims and defense," "evaluating one another's claims and defense' and, "revising their own and other's claims." (Berland & McNeill, 2010, p. 776). With the feedback gathered, students can either improve on their individual CER or work together with a few peers to construct a group CER that synthesize the individual CERs into a coherent whole [5E: Elaborate]. Students are further guided with a set of question prompts prepared by the research team to guide them in formulating the group CER as students may need help with recognizing agreements, critiquing differing ideas, coming to a consensus and pulling ideas together, important skills for working in a team. Finally, teachers are encouraged to provide feedback to students on their CERs using the same rubrics as that used for peer evaluation.

Although group work tends to take up more time relative to individual work, group discussion serves an important role in the process of SA. Not only does group discussion enables students to consolidate the various data sources as evidence for their claim, students are also more likely to generate and appropriate persuasive discourse especially when disagreements arise, as students are compelled to generate arguments to convince opposing members to consider one's perspective. Such rehearsal of rhetoric could then be incorporated into their writing. It is worth noting that scientific knowledge is always generated by a community of scientists and participating in peer evaluation and group discussion reflect the real-life practices of scientists.

7.6 Technology: IASA Web Tool

To support the IASA pedagogical model, we developed a web-based integrated platform that affords students the ability and agency to harness scientific argumentation tasks that capture the core components of authentic science inquiry (Fig. 7.1). Recognizing that the epistemology of conventional scientific inquiry tasks (e.g., simple experiments, simple observations, and simple illustrations) may be antithetical to the epistemology of authentic science, the design of the IASA platform was underpinned by salient tenets of authentic scientific inquiry processes such as concept-problem connections, group deliberations and peer feedback. Areas of scientific content learning that were based on authentic scenarios drawn upon available authentic data at www.data.gov.sg, which students can subsequently easily utilize in their argumentative inquiry.

As indicated in Fig. 7.1, the sequence of the pedagogical process afforded by the web platform represents a knowledge building cycle (Leitão, 2000). First, learners are introduced to the problem narrative. They are then introduced to a set of mini tasks which aims to elicit prior conceptual construals that the students may already have which in turn, facilitate teachers' addressing of students' misconceptions, if any. Students then move on to participate in their first argument phase on the platform. By constructing arguments, it is intended that students' will self-explain the learning material and integrate new knowledge into their existing cognitive structures. Following argument construction, students can engage in group work to construct counterarguments in order to challenge the initial positions. Construction of counterarguments facilitates meta-cognitive activities and engages a rethinking of students' primary positions with a view to not only refining their initial position but so too in constructing integrative arguments to strengthen their argument narrative. The process of interweaving personal arguments and peer counterarguments in order to solve the authentic problem set out in the task narrative affords learners with not only the development of argumentation competency, but also domain specific knowledge of the content under consideration (Leitão, 2000), in this case scientific understanding related to the selected topics.

7.6.1 Features and Affordances

The IASA platform is designed to facilitate teachers' pedagogical repertoire in science teaching, specifically in being able to enact the IASA model effectively. Specifically, apart from identifying potential difficulties teachers may experience during the face-to-face teaching, and subsequently designing for how technology can mitigate the identified face-to-face difficulties, we were cognizant that the introduction of technology tools for Science need to meaningfully augment teaching and learning to meet both teachers' and learners' needs.

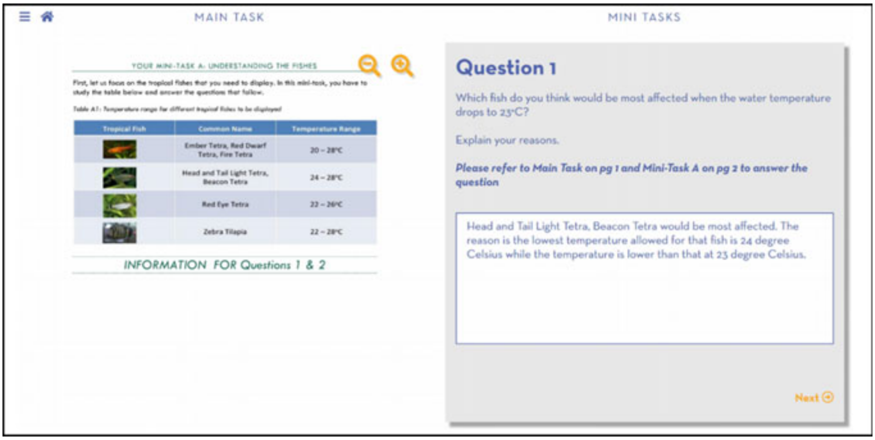

Fig. 7.2 Dual panel interface

7.6.1.1 Overarching Interface: Dual Panel to Mitigate Cognitive Load

The teaching of a scientific topic anchored by an argumentation and inquiry pedagogical orientation entails harnessing multiple resources in its enactment. For example, in teaching a topic such as heat and its related concepts, teachers make use of multiple teaching resources which include include tasks narratives, PowerPoint slides and data sheets. At an overarching level, the IASA platform interface is designed as a dual panel view (see Fig. 7.2) where both teachers and students will be able to easily reference supplemental materials provided at the respective pedagogical stage.

In Fig. 7.2, students are able to reference the heat task on the right pane, scrollable from the introductory narrative to the data source examples. In attempting the mini tasks on the left pane, students are able to easily reference data sets and question options within a single screen view. At the core of such an affordance is an instructional design schema aimed to mitigate cognitive overload in facilitating relations between source and questions, through the use of technology (Sweller, 1988). Table 7.1 further details how the dual panel interface frames the pedagogical process and activities within the IASA platform, elaborating on the functionality that mediates both left and right panels.

As seen from Table 7.1, the pedagogical processes in Fig. 7.1 is not only mirrored in the development of IASA's web platform, but more importantly, the development of the platform is underpinned by desired affordances of technology to mitigate challenges in integrating scientific argumentation with conceptual learning. The designed affordances included the IASA tool:

- As diagnostic assessment:
  - Wherein students will experience the process of unpacking task complexity which includes activation of students' prior knowledge

Table 7.1 Activities and displays information with default pedagogical process flow shown

Activities [Right Panel]	Functionality	Displays [Left Panel]	Functionality
Main Task [Full Display]	Shows the main task question of the lesson and information materials	N/A	N/A
Mini tasks	Answering MCQ/Structured Questions Form where only one question will be shown at a time MCQ questions have to be answered correctly where each wrong choice the student will be provided a feedback	Main task	Same as previous lesson stage for referencing of information regarding questions
First CER	Answering an Individual CER form, which consists of a Claim Question, Evidence Question and a Reasoning Question. Allowed to Save Progress	Infosheet	Shows student's answers to the mini tasks' questions' answers Additional information if the lesson has it
Group pool	Viewable First CER answers from the members of the student's group Allows changing of current answer to any group member's answer including oneself	Infosheet	Same as previous lesson information except that model answers to the structured questions are shown
Concept linking	Answering MCQ/Structured Questions Form where only one question will be shown at a time	Concept slides	Teacher's lesson slides
Second CER	Improving on First CER answers with new information provided Allowed to Save Progress	Concept linking answers	Shows student's concept linking questions and answers
Feedback	Providing feedback to members of the student's group Second CER answers Allow feedback to each group member's answer except oneself	Your second CER	Shows student's Second CER answer

(continued)

Table 7.1 (continued)

Activities [Right Panel]	Functionality	Displays [Left Panel]	Functionality
Final CER	Collaborative CER Form to allow group members to work together to answer the main question of the lesson which includes the Claim, Evidence and Reasoning Questions in previous CER forms	Group pool feedback	Show group members' feedbacks towards other members' Second CER answers Allowed to provide more feedbacks and refresh to get latest feedbacks
		Group pool table	Show group members Second CER answers in a table comparison format

- As formative assessment:
  - Wherein students are likely to use their everyday experience and intuitive knowledge during their initial experience with the task. This allows teachers to access their prior knowledge and possible misconceptions
- As learning analytics:
  - Wherein the tool is able to capture the group CER process. Such collaborative processes are hard to track and capture in face to face settings. Using the tool, teachers are able to track and analyze students' progress in a timely manner as the topic is being taught over the planned period of time in a formative fashion, vis-à-vis tracking of students' progress via workbooks only at the end of the topic.

7.7 Teacher Apprenticeship in IASA Pedagogy

The research team partnered participating teachers in an apprenticeship fashion where teachers were engaged in context setting of the value of scientific argumentation for conceptual learning. The aim of the researcher–practitioner partnership was to facilitate teachers' development as being "peripheral participants" in IASA pedagogy towards being a more central enactor of IASA. Research papers highlighting the importance and value of scientific argumentation were shared with teachers and time was spent in discussing pertinent issues related to science teaching and learning. Teachers were introduced to the tasks—for instance, while the first task on Heat was primarily researcher-driven, it also sets the pathway as an initial model for teachers to "be apprenticed" to how authentic, inquiry oriented tasks may be developed and anchored for the teaching of Science topics. Subsequently the development of the

Fig. 7.3 Teacher interface of IASA Web App

Chemistry and Biology tasks were teacher-driven as teacher participants grew into more central roles in designing for their IASA classroom enactments. Teachers were also introduced to the IASA web tool, where its functionality and affordances were introduced and explained. A hands-on session for the IASA tool was also conducted with the teachers and feedback from their use was subsequently taken into account in the research team's refinement of the platform. A teachers' interface of the IASA web tool was also developed to further catalyze teachers' apprenticeship development towards using the IASA pedagogy in their classroom. The teachers' interface was designed for teachers to be able to formatively assess each students' progress through the development of the topic they were teaching, as indicated by the underlying analytics of the tool. These included the functionality to (i) have an overview of the progress of students, both at the individual and class level based on the IASA pedagogical cycle, (ii) have a quick understanding of students' prior understanding, beliefs about the topic based on their response to the mini-quiz, (iii) have an overview of the group and individual scientific argumentation discourse and the types of feedback exchanged between group members, iv) identify keywords used by students in their CER responses (see Fig. 7.3).

7.8 Impact on Teacher Development

Our sustained engagement with teachers in this research project provides one possible professional development (PD) model for the induction of in-service teachers to an argument-based pedagogy. This PD model consists mainly of: (1) collaborative joint development and/or refinement of the learning tasks; (2) sustained and detailed assessment of students' personal resources for engaging in explanation-driven inquiry (Mikeska, Anderson, & Schwarz, 2009; Zembal-Saul, 2009); and (3) critical reflection on the enactment of the IASA pedagogical model.

Through our collaborative activities for developing the learning tasks, teachers learned how to situate science learning within everyday contexts, as exemplified in the argumentation tasks that were embedded with real-life scenarios. Teachers learned that positioning the argument-based learning task as the central and unifying frame for their teaching afforded foregrounding the relevance of science concepts to real life problems. For example, one teacher remarked: "Because I usually like to bring in (a task) after they have learned the whole concept, then they will be able to see a bigger picture. *But I was thinking maybe we can also try to set it as a trigger to cover what we need to cover … So give them an end in mind. So maybe that could have worked also.*." Despite her initial reservation, the teacher was willing to adopt the task as the central focus of the lesson unit. Such problem-based framing allowed teachers to appreciate science teaching and learning as contextualized and, as such, promotes leaners' interest in and motivation for the lesson. One teacher appreciated the approach we adopted as a concrete example of how teachers can infuse science classrooms with "authentic learning" experiences (Watkins, Coffey, Redish, & Cooke, 2012).

With respect to integrating the practice of argumentation in science lessons, discussions during the curricular development meetings coupled with actual classroom implementation helped teachers gradually understand the various dimensions of the CER framework and how they can be surfaced during lessons. It helped them be aware of and appropriately use teaching prompts for drawing out more reasoned explanations from students (Avraamidou & Zembal-Saul, 2005). Teachers enacted verbal scaffolds as students examined data for patterns, as well as when they substantiated, compared, and evaluated claims. Using teaching slides and reflection logs in science notebooks, teachers also engaged learners to make explicit any emerging understandings of how their argument claim in the learning task is linked to the science concepts they were learning.

Our PD model created a platform for teachers to assess students' ideas and language competencies, and their varying levels of engagement with the learning tasks so that appropriate modes of instructional support could be developed collaboratively and implemented (Zembal-Saul, 2009). Teachers valued our collaborative discussions of students' ideas on a topic because it allowed them to anticipate, identify, and address misconceptions in class. Additionally, assessment of students' language competencies helped teachers refine the language in teaching and learning resources.

We engaged teachers in post-lesson dialogs to facilitate critical reflection on their own development as a teacher who promotes scientific argumentation (Zembal-Saul, 2009). We tapped on the challenges and learning points teachers experienced during classroom enactment to facilitate contextualizing the adoption of the IASA model. One persistent concern among teachers was a felt tension between promoting argumentation while aiming to achieve the specified learning outcomes stipulated in the syllabus (Kapon, Laherto, & Levrini, 2018; Kim et al., 2013). For instance, one teacher observed how some students may appreciate scientific argumentation more "*if the exam had a CER component… [or] if it is part of the curriculum itself*." Despite this concern, most teachers have come to appreciate the value added by our teaching intervention—that students began to better appreciate science concepts in terms of their relevance to everyday experiences and engage in deeper learning of these concepts.

Overall, we believe that our partnership with the teacher participants engendered a sense of ownership (Danielowich, 2007) of the IASA model that could inspire continued adoption and future scaling up to more science classrooms. Moreover, teachers' use of the IASA Web App as a technology-enhanced platform integrated to the pedagogical model helped them promote the tenets of the macro educational policy aims, specifically self-directed learning, collaborative learning and authentic learning as mediated by technology.

7.9 Impact on Student Learning

To assess the impact of teachers' enactment of the IASA pedagogical model on student learning, we analyzed changes in the quality of students' written arguments. With the CER framework and a complementary assessment rubric (i.e., the criteria for good scientific argumentation that teachers elaborated on during instruction), students had a simple and structured guide for attending to the essential qualities of a written scientific argument. We scored the extent to which students brought off the qualities of good scientific argumentation in their individually written arguments (CERs), noted change patterns across the multiple intervention cycles.

In addition, our assessment of impact on student learning included an analysis of students' awareness of the criteria by evaluating the quality of students' feedback on their group mates' draft arguments. We looked out for features of argument writing that were salient in students' feedback and noted any changes in the kind of feedback given across two intervention cycles. Students' feedback was captured using the IASA web app which allowed asynchronous chat among group mates.

7.9.1 Increased Attention to Evidence and Scientific Reasoning

The results of the analysis indicate that the quality of written arguments, on average, improved over the course of the intervention. This is evidenced by the increase in average scores for all argument component from the initial to the final writing samples (Table 7.2). The two argument components with the highest increase in average scores are: (1) students' use of evidence and (2) appropriate language use for scientific reasoning. We found an increase in students citing data for evidence,

Table 7.2 Comparison of the average scores of argument components between initial and last individual written arguments of experimental class

Components	Max score	Initial CER SQ[a], n = 28	Final CER heat Task, n = 34	% Change
Claim	2	1.9	1.9	0.0
Evidence	7	3.0	4.6	22.9
Reasoning	9	6.1	6.4	3.3
Language use	5	3.2	3.9	14.0
Total score	23	14.2	16.8	11.3

[a]The structured question (SQ) is a written argument task used to provide baseline information on students

mobilizing relevant data, and making counterarguments (i.e., comparing across claim options). We also noted an increase in the number of students providing more accurate and relevant reasoning, along with considerable improvement in the appropriate and extensive use of scientific language in their arguments. However, some aspects of scientific reasoning need more instructional attention. For example, most students simply explained the effects of each variable they identified, while a few others clearly elaborated on interrelated effects of multiple variables they considered (Table 7.2).

The above results suggest that with multiple exposure to the task of writing arguments, students gradually appropriate the criteria and conventions for good scientific argumentation (Berland & Reiser, 2009). This was facilitated by teachers' explicit instruction of the ways students could satisfy the criteria. Teachers used the rubrics for a good scientific argument as a heuristic to aid student in complying with the conventions and judging evidence reasonably. The improvement in the quality of students' reasoning in offering valid arguments may also be due to the conceptual instruction that was provided. Conceptual instruction equipped them with the appropriate knowledge resources for making sense of the data and using the appropriate data as evidence for their claim (Grooms, Sampson, & Enderle, 2018; Osborne, 2010).

7.9.2 Improved Peer Feedback During Argument Revision

During argument feedback sessions, we anticipated that students might simply deploy positive and negative assessments (such as compliments and criticisms) without providing their reasons. Some students might be able to give a reasoned critique (based on the rubrics they were asked to use) that could focus on inaccuracies in scientific concepts used, erroneous data interpretation, illogical inferences, insufficiencies in terms of supporting evidence, etc. Others might focus on language errors and incorrect composition formats.

Our analysis noted a decrease in the number of students not giving any feedback across the two learning cycles (Table 7.3). This is a positive outcome as it indicated increased participation in the peer feedback activity. We also found that, in general, students deployed more positive feedback than critical feedback. There was greater tendency among students to give positive feedback that is non-specific or merely citing criterion without justification. In terms of positive feedback across the two activities, there was a decrease in non-specific feedback along with an increase in explained, criteria-based feedback. This indicated that more students have become aware that feedback needs to be specific and reasoned, a point that was emphasized by teachers during instruction.

We found mixed results with respect to critical feedback. There was an increase in the non-specific type that indicates either decreased attention to or emphasis on the proper application of criteria or opting for the convenience of unelaborated feedback. The latter seems to be the case because during the group feedback session for Heat, students experienced weak wi-fi connectivity in the classroom leading to non-completion of the task during the science period. Students were asked to complete the task during free time outside class or at home. Such technical challenge was absent during the Acids group feedback session, which was completed within the class period. The results for critical feedback also show only a slight increase in criteria-based, explained feedback along with a decrease in criteria-based, mentioned only feedback. Nevertheless, critical feedback that targeted specific features of the argument far outnumbered the nonspecific ones, indicating more students being aware of criteria dimensions in deploying their critique.

These findings suggest that sustained engagement in peer feedback activity improves the quality of feedback as students experienced greater awareness of the writing requirements for good scientific argumentation (Berland & McNeill, 2010). Peer feedback activity provided students the opportunity to reflect on their own

Table 7.3 Relative frequencies of peer feedback categories

Category	Sub-category	Acids task (%)	Heat task (%)
No feedback		14.4	2.8
Positive		45.0	43.1
Nonspecific		*19.2*	*11.1*
Criteria-based	*Explained*[a]	*3.4*	*9.7*
	Mere mention	*22.3*	*22.2*
Critical		39.9	40.3
Nonspecific		*4.1*	*8.3*
Criteria-based	*Explained*[a]	*30.9*	*31.9*
	Mere mention	*4.8*	*0.0*
Format		0.7	0.0

[a]Students provided an assessment that elaborates how the relevant criterion is satisfied (positive/critical feedback) or not satisfied (critical feedback) in their peers' argument

writing in terms of how it compares to their peers' arguments, as some shared during the student interviews. The findings also suggest that teachers need to guide and model how student feedback can be made more specific and reasoned. Explicit teaching of the criteria for good scientific argumentation could increase students' awareness of good quality scientific arguments and could lead to appropriation of critical thinking in their own writing (Manz, 2015; Osborne, Erduran, & Simon, 2004). The practice of argumentation in the classroom introduced students to how scientific knowledge is negotiated and engaged them in science discourse.

7.10 Scaling Up IASA

Schools who are interested in adopting an argument-based pedagogy for their Lower Sec science classes can use the IASA pedagogical model. A lesson package—the IASA Toolkit—which contains all the resources for the three learning tasks we have developed is ready for dissemination. The resources include lesson plans, worksheets, sample teacher talk for integrating CER and learning task, sample CERs written by students, and teaching slides. Resources for conducting student workshops on the CER framework are also available. The IASA Web App with its affordances can also be accessed to support students' argument writing tasks and teachers' logistical work.

It is, however, critical to first engage teachers in conversation about the underlying rationale and principles of the model and provide a forum for sharing on-the-ground experiences in implementing the pedagogical innovation (Osborne et al., 2004). While this initial conversation will be helpful in getting teachers started, we believe what would be more beneficial is to have teachers implement the innovation and sustain conversations about the questions, issues, and dilemmas such implementation raises about established practices, not only for pupil learning but also for the school as a learning organization. An evidence and argument lens for teaching could inform how teachers track and analyze student thinking in the classroom as they write and talk science (Zembal-Saul, 2009). However, learning to adopt such lens is not a short-term, linear process of improvement with immediate results. In our view, the teacher-collaborators we worked with took up the new initiative in varying degrees within equally varying time periods: some persistently struggled to work around institutional expectations, while others took up ownership quite quickly, having a clear view of the spaces in the classroom to inject reform. Regardless of their individual learning pace, we found it important to trust them in the validity of their own decision-making around its direction. We acknowledge that their current practice is the only available starting point, and that any change they embrace must make sense to, and benefit, them as individual learners, and not only their students or their school (Czerniawski, 2013).

Sustaining the adoption of the pedagogical innovation will rely heavily on the buy-in of the project's ideals by the participating teachers as well as the school leadership, since the school workplace is the immediate practice setting. In our experience, we found alignment with our participating schools' educational advocacy—Authentic Learning in Science for one school and Critical Thinking for another school. This alignment allowed for a partnership to be forged easily to achieve complementary goals. However, such matching is not outrightly a success formula for the adoption of new initiatives. We can ask, following the ideas of Grossman et al. (2009), can the school also provide a safe, low-risk setting for reform-oriented teachers to acquire and practice diverse pedagogical skills?

Further research will be needed to test the feasibility and efficacy of the pedagogical approach if and when adopted to science classes in primary schools and Upper Secondary Schools.

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Chapter 8
Infusing the Teamwork Innovation My Groupwork Buddy in Schools: Enablers and Impediments

Elizabeth Ruilin Koh, Jennifer Pei-Ling Tan, Helen Hong, Dhivya Suresh, and Yi-Huan Tee

Abstract Teamwork is an important twenty-first-century competency to be nurtured in our young. In this eduLab Information and Communications Technology (ICT) innovation, My Groupwork Buddy (MGB), a techno-pedagogical system, was developed using design-based research for secondary school students in collaborative inquiry projects from any subject domain. Co-designed with a team of researchers, teachers and education officers, MGB aimed to nurture teamwork competency through its blended pedagogical framework, formative assessment measures and a web-based learning analytics system. The innovation was successfully trialled over two and a half years in two schools, across two subjects, and used by 12 teachers and over 200 students. This chapter will examine the enablers and impediments of infusing the innovation from the design team's perspective. Insights of key conditions for the innovation to take root, and its possible infusion in the school system will be discussed. Practical implications for practice and policy will also be described in light of MGB's journey in Singapore's educational context.

Keywords Teamwork · ICT integration · Learning analytics · Design-based research · Design team

8.1 Introduction and Background

Teamwork is an important twenty-first-century competency to be nurtured in our young. While team-based collaborative learning inquiry tasks are now commonplace in Singapore, clear understandings of what constitutes teamwork in such settings and how to effectively nurture teamwork competency remain a challenge for many teachers and students alike. Previous studies have found that students did not value

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collaborative work over time and some had difficulty working with team members (Liu et al., 2009; Järvelä et al., 2015; So, Tan, & Tay, 2012). As for teachers, there is the issue of assessing and nurturing the twenty-first-century competency of teamwork as many are unequipped to help their students in these areas (Griffin & Care, 2014). Also, with large class sizes, it is challenging for teachers to monitor and assess team behaviours (Binkley et al., 2012; Koh, Wang, Tan, Liu, & Ee, 2009).

Supporting the growth of teamwork competency in Singapore secondary schools, a techno-pedagogical system, My Groupwork Buddy (MGB) was designed and integrated in existing collaborative inquiry tasks. Specifically, the project sought to help students learn more about their personal teamwork competencies, and become more purposeful in their teamwork and learning, as well as to support teachers' professional competency in teaching and facilitating group activities particularly in the design and delivery of group-based collaborative inquiry tasks, and be able to track the progress of students and their teamwork competencies for any necessary action.

In this eduLab Information and Communications Technology (ICT) innovation, MGB was developed using design-based research for collaborative inquiry tasks in any subject domain. Co-designed with a team of researchers, teachers and education officers, MGB aimed to nurture teamwork competency through its blended pedagogical framework—the Team and Self-Diagnostic Learning, formative assessment measures, and a web-based learning analytics system (Koh, Hong, & Tan, 2018). In this way, ICT was harnessed as a metacognitive and reflective tool (Soller, Martínez, Jermann, & Muehlenbrock, 2005).

The innovation was trialled over two and a half years in two schools, across two subjects, and used by 12 teachers and 223 students. The innovation journey while successfully trialled has its share of challenges and constraints. In this chapter, we focus on the enablers and impediments of the innovation as it was implemented in the schools from the perspective of the design team. The research in question is, what are the enablers and impediments of MGB's implementation? The findings and implications seek to unpack the conditions and factors that enable the trial and infusion of interventions in the Singapore context. The chapter begins with the theoretical background of MGB and introduces design considerations of MGB. Next, MGB's methodology and implementation in the schools is described. This is followed by the findings, which examine the enablers and impediments of the innovation. Insights of key conditions for the innovation to take root, and its possible infusion in the school system will be discussed. Lastly, practical implications for practice and policy will be deliberated in light of MGB's journey in Singapore's educational context.

8.2 Literature Review

MGB is a techno-pedagogical learning analytics tool based on the pedagogical framework of Team and Self-Diagnostic Learning (TSDL; Koh et al., 2018) and serves as a digital formative assessment tool and approach to nurturing teamwork competency. Four teamwork competency dimensions were synthesized to create the formative assessment tool. This review describes learning analytics design considerations, the theoretical background of the MGB primarily the teamwork competency dimensions and TSDL.

8.2.1 Design Considerations for Using Learning Analytics

Learning analytics (LA) is a relatively new field and area of ICT development and innovation. In putting forth a learning analytics system, the design considerations of the innovation were primarily theoretical alignment, affordance engagement and stakeholder usability.

In many LA systems, the sparsity of pedagogic theory has been highlighted (Knight, Buckingham Shum, Littleton, 2014; Ferguson, 2012). However, no system can be pedagogically agnostic (Koh, Shibani, Tan, & Hong, 2016) and learning designs and principles are needed and embedded in educational technology innovations, even if they are somewhat general in nature (Lockyer, Heathcote, & Dawson, 2013). Knight and colleagues (2014) emphasize the importance of pedagogical and epistemological lenses in LA design. These determine the LA and approach that is used and developed. For example, from an epistemological lens of constructivism, mastering content is generally focused on, while from a more connectivistic and/or pragmatist lens, participation and usage of system is key. In a seminal paper on learning analytics intervention design, Wise et al. (2014) proposed that LA designs for pedagogical intervention are rooted in the epistemological base of constructivism, metacognition, and self-regulated learning. This is translated into four principles of LA interventions—integration, agency, reference frame and dialogue, as well as three processes that occur, namely, grounding, goal-setting and reflection. Such theoretical frameworks align ICT with learning processes and outcomes and show the clear value of LA in supporting educators in curriculum instruction and student learning. Therefore, considerations of theoretical and pedagogical principles provides the necessary foundation for LA systems, and enables them to become techno-pedagogical systems, systems that are theoretical aligned.

Affordance engagement refers to how a specific LA function is harnessed to benefit stakeholders. For LA, Buckingham Shum and Ferguson (2012) highlight the social analytics available in LA, namely: disposition, discourse, social network, context and content. In particular, such social analytics can be provided as feedback to stakeholders through dashboards.

Duval (2011) emphasizes the affordance of LA designs to visualize information in dashboards. Information visualization deals with the representation of data. Encompassed in student-facing learning dashboards, these information visualizations generally provide an overview of students' activities in the system relating to their learning experience. It is one specific affordance in which abundant data in LA systems can be brought to the attention of learners. In line with the quantified self approach, the tracking of a person's own data makes one more aware of one's own actions and gives one the impetus to make changes in how he is behaving in life

(Duval, 2011). Also termed goal-oriented visualizations, these graphics provide a representation in LA systems to help learners see their progress or lack of progress towards their goals. These visualizations can also compare others' progress and/or help make recommendations.

Moreover, such information visualizations can be developed to be shown almost instantaneously. These LA systems then provide the affordance of timely feedback to learners (Spector et al., 2016).

Stakeholder usability pertains to the ease of use of LA systems. LA systems need to be designed to be easily accessed and navigated by all stakeholders of the system including learners, teachers and administrators. Systems have been known to fail if their users do not want to use it due to usability issues. Thus, the user experience of LA systems is an important design consideration.

These design considerations were part of the process in designing MGB as detailed in the next few sections.

8.2.2 Teamwork Competency Dimensions

While teamwork is understood in many ways, an essential understanding is that teamwork competency is a multidimensional construct examining the process of members working in a team (Salas, Rosen, Burke, & Goodwin, 2009; Valentine, Nemdbhard, & Edmondson, 2015). For example, Valentine et al (2015) reviewed 35 teamwork survey studies in health care and synthesized three important aspects of teamwork: communication, coordination and respect. Cannon-Bowers, Tannenbaum, Salas and Volpe (1995) drew on various teamwork literature and developed eight dimensions that applied to most teams, namely: adaptability, shared situational awareness, performance monitoring and feedback, leadership/team management, interpersonal relations, coordination, communication and decision-making. One of the forerunners of the teamwork construct, Salas, Burke, and Cannon-Bowers (2000) has theorized teamwork competencies that can be used across tasks and teams. These are broadly categorized as context-driven, team contingent, task contingent and transportable competencies. According to their research, competencies that depend on both task and team are known as context-driven and those that do not depend on either one of these are called transportable competencies. Competencies specific to either task or the team are called team contingent and task contingent, respectively. The paper posits that transportable competencies include teamwork skills such as morale building, conflict resolution, information exchange and cooperation.

As can be seen in the literature depending on several contexts, there has been various conceptualizations of the teamwork and its dimensions. Based on a broad review, a synthesis of literature and pilot tests, teamwork competency for a secondary school context was conceptualized as a six-dimensional measure (Koh et al., 2018). However, subsequent trials found it more valuable and efficient to focus on four dimensions of teamwork (Suresh, Lek, & Koh, 2018). The four dimensions are coordination (COD), mutual performance monitoring (MPM), constructive conflict

(CCF) and team emotional support (TES). In short, the dimensions are defined as follows (for more information about the dimensions, see an upcoming work by Koh et al. (2009).

(1) Coordination—organizing team activities to complete a task on time (Chang, Lin, Chen, & Ho, 2017; Kraut, Fussell, Lerch, & Espinosa, 2005; Stevens & Campion, 1994);
(2) Mutual Performance Monitoring—tracking the performance of team members (Fransen, Weinberger, & Kirschner, 2013; Jehn & Shah, 1997);
(3) Constructive Conflict—dealing with differences in interpretation between team members through discussion and clarification (Kankanhalli et al., 2007; Van den Bossche et al., 2006; Van der Haar et al., 2014); and
(4) Team Emotional Support—supporting team members emotionally and psychologically (Bennett & Kane, 2014; Drach-Zahavy & Somech, 2002; Sargent & Sue-Chan, 2001).

8.2.3 Team and Self-diagnostic Learning Framework

While the preceding section focused on the teamwork measure, which is what to assess, this sub-section highlights the pedagogical approach to facilitating teamwork. The TSDL framework (Koh et al., 2018, 2016) is a four-staged approach to help students grow in their teamwork competency. It is underpinned by experiential learning (Kolb, 1984), collaborative learning (Vygotsky, 1978), learning analytics process model (Verbert, Duval, Klerkx, Govaerts, & Santos, 2013) and socially shared regulation (Hadwin & Oshige, 2011; Järvelä & Hadwin, 2013).

The four stages of TSDL are:

(1) team-based concrete experiences that involves students engaging in collaborative activities to gain understandings of working with the members of their team;
(2) self- and team awareness building through the visualization of self- and peer ratings of teamwork behaviours;
(3) team and self-reflection and sensemaking where students reflect and set goals based on the insights from the visual analytic; and
(4) team and self-growth and change to enable students improve their teamwork competency by monitoring the teamwork goals they have set.

The TSDL is in line with work that encourages the development of twenty-first-century skills through formative pedagogy (National Research Council, 2012; Spector et al., 2016). For example, in a study to examine the effects of a peer feedback and reflection tool, students were provided with a visualization of peer assessment in the process of group work to help them be more aware of their collaborative behaviours (Phielix, Prins, Kirschner, Erkens, & Jaspers, 2011; Phielix, Prins, & Kirschner, 2010). The findings of the study show that the use of tools for peer feedback and reflection can provide students with greater awareness of their behaviours in a group which in turn enhances the satisfaction and performance of the group. Näykki, Isohätälä, Järvelä, Pöysä-Tarhonen and Häkkine (2017) using a macro script with prompting questions that highlights the teams' socio-cognitive and socio-emotional monitoring processes formatively during a collaborative task and showed its usefulness for the orientation of the task. Other studies build in experiential teamwork learning with various group exercises and debrief students with feedback emphasizing teamwork principles during a course (O'Neill et al., 2017). Moreover, TSDL's focus on awareness building, reflection and monitoring of goals is related to metacognitive mechanisms that are associated with deeper learning and transfer (Ford et al., 1998; Georghiades, 2004; Scharff et al., 2017).

In essence, the TSDL is a digital formative assessment approach to help students gain awareness of their teamwork competencies, monitor and improve them, thereby using ICT systems as metacognitive and reflective tools (Soller et al., 2005).

8.3 Methodology and Implementation

8.3.1 Methodology

Design-based research (DBR) was the overall methodology of the innovation as it focuses on the iterative process of analysis, design, development and implementation of systems aimed at enhancing educational practices (Wang & Hannafin, 2005). The key tenants of DBR are that it is iterative, involving multiple trial cycles in authentic contexts to enhance practice; collaborative, involving co-designers of various stakeholders such as teachers and researchers; design and intervention oriented in order to change practices; and grounded in theory and research as well as adding to the theoretical literature (Reimann, 2011; Ford, McNally & Ford, 2017). Following DBR, MGB was developed over multiple iterations with refinement of the techno-pedagogical system after each trial cycle. Importantly, the tool was co-designed with a team of researchers, educators and education officers (who are government officers) to support and enhance the existing collaborative inquiry learning programmes in schools. The theoretical grounding of MGB for its goal of facilitating the growth of students' teamwork competency is based on the Team and Self-Diagnostic Learning (TSDL) Pedagogical Framework (Koh et al., 2018).

Alongside the DBR approach, the convergent parallel mixed methods design was used to collect data to address the research questions. The mixed methods design requires the collection of both quantitative and qualitative data concurrently during the intervention. Quantitative data designed and collected included pre and post surveys and self- and peer teamwork competency ratings. Qualitative data, on the other hand, were meeting notes, student reflections, audio and video recordings of student focus group discussions and lessons, field notes, teacher feedback and email and student chat logs. Data for this chapter is drawn from a subset of the total data collected. Primarily, qualitative data from approximately 25 meeting notes, 12 teacher

Table 8.1 Details of the trial cycles

Trial cycle	Year	Secondary school	No. of intervention classes	Subject
1a	2016	Opal	1	Interdisciplinary Project Work
1b	2016–2017	Opal	1	Interdisciplinary Project Work
1c	2016	Ruby	2	Design and Technology
2a	2017	Ruby	4	Design and Technology
2b	2017	Opal	2	Interdisciplinary Project Work

feedback notes/emails and 33 student focus group transcripts were referred to. Open coding was performed guided by the research question on enablers and impediment of the intervention. Two researchers analysed the various data adopting a reflexive perspective and themes were discussed in the larger team.

8.3.2 MGB Trials and Participants

MGB was trialled with two partner co-ed schools across two years, 2016 and 2017. Table 8.1 details the trials and participants. There were a total of five trial cycles, with three in Opal Secondary and two in Ruby Secondary, all with different classes. After accounting for consenting student participants, a total of 223 students trialled MGB. Each trial ranged from six months to a year in blended learning classrooms. Two main teachers from each school were part of the design team. These teacher were the pioneers to carry out the innovation in their respective schools. In addition to these two key teachers, ten other teachers were also involved in the innovation and participated in various trials.

8.3.3 MGB Design and Implementation

MGB is designed and integrated into the schools' collaborative inquiry project based on TSDL. The following describes the four stages of the TSDL and how it was generally implemented in the trials. After the four stages of TSDL are completed, the stages are repeated. About two to three rounds of TSDL stages are implemented in one subject's collaborative inquiry project that spans across six to twelve months.

Fig. 8.1 TSDL Stage 1: Students working together to gain experiences of working in a team

8.3.3.1 Stage 1: Team-Based Concrete Experiences

In stage 1 of the TSDL, students work as a team in collaborative inquiry tasks to gain concrete experiences of working in a team. The collaborative inquiry task can include any activity where students will perform individual work while at the same time engage with other team members and learn from one another. Examples of some collaborative tasks can be team-building icebreaker activity, collaborative report writing or group brainstorming. This was done in a blended learning environment and many activities were performed face-to-face while some were computer-based.

Figure 8.1 shows students working in teams as part of collaborative inquiry task. On the left is a picture from trial 1a where students worked in teams to search for primary sources, collect data and test the quality of water at Bedok Reservoir. The picture on the right from trial 2 shows students working in teams to create a persona to represent the typical elderly for whom they created a solution for a problem they were facing. During this stage of the project, students could use MGB lesson pages to refer to relevant information provided by the teacher on the project they were working on. Students could also use the team chat on MGB to converse with their teammates (Fig. 8.2).

8.3.3.2 Stage 2: Self- and Team Awareness Building

After students gained some concrete experience of working in teams, students are asked to perform self- and peer ratings of their teamwork competency. Students rated themselves and their peers on a scale of one to five based on questions corresponding to the four teamwork dimensions (Figs. 8.3 and 8.4).

This data is then visualized to them almost in real-time in a visual analytic, in order to make them aware of their teamwork behaviours. The visual analytic of students' ratings is termed a 'micro-profile' to connote that their teamwork competency can change and is not a permanent representation of their teamwork processes. It is based

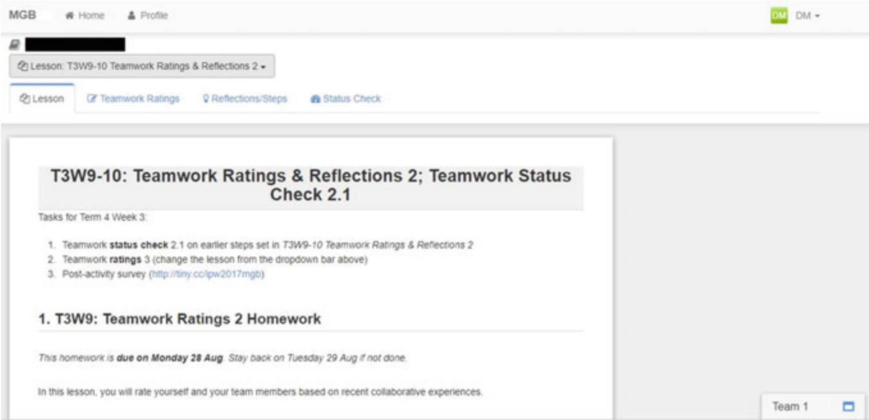


Fig. 8.2 Screenshot of lesson pages and team chat (bottom right corner)

Fig. 8.3 TSDL Stage 2: Students performing self- and peer ratings of their teamwork

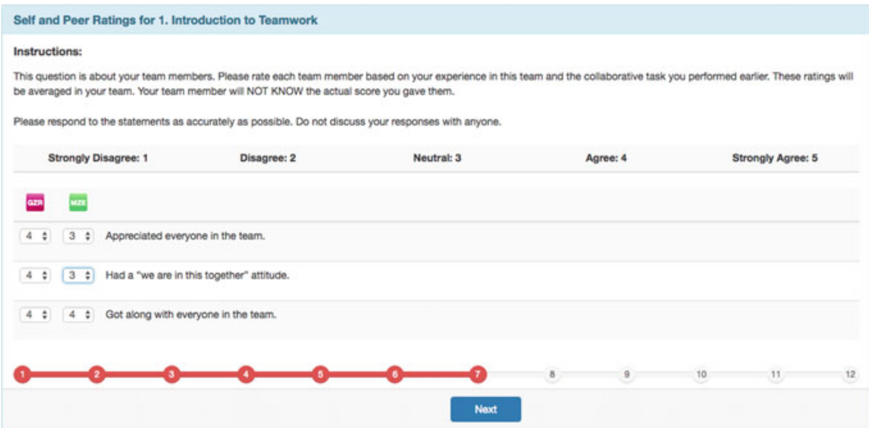


Fig. 8.4 Screenshot of peer ratings on MGB

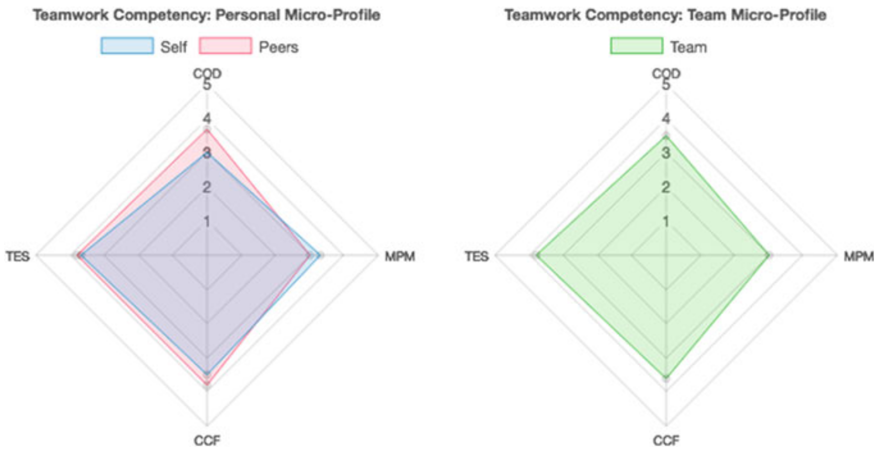
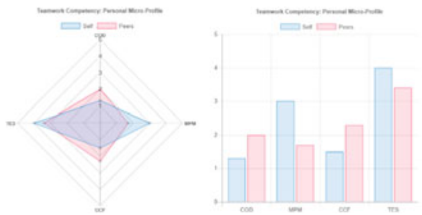


Fig. 8.5 Screenshot of the two types of micro-profiles—Personal (left) and team (right)



Dimension	Self	Peers	Difference ❶
Coordination ❶	1.3	2.0	-0.7
Mutual Performance Monitoring ❶	3.0	1.7	1.3
Constructive Conflict ❶	1.5	2.3	-0.8
Team Emotional Support ❶	4.0	3.4	0.6

Fig. 8.6 Screenshot of different representations of the personal micro-profiles

on the micro-time context (Chiu, 2008). The micro-profile visualization is designed for the individual student as well as for the whole team, namely, the personal micro-profile and the team micro-profile (Fig. 8.5). The micro-profile is also shown in multiple representations—in radar, bar and table form (Fig. 8.6). Through making visible their self- and peer feedback about the teamwork behaviours in such multiple representations, students are able to be more attuned to their personal and teams' teamwork strengths and weaknesses (Fig. 8.7).

8.3.3.3 Stage 3: Self- and Team Reflection and Sensemaking

For stage 3 of TSDL, students proceed to make greater sense of their micro-profiles through personal and team reflections. A series of reflection questions are given to them to help them focus on a teamwork dimension and assess their teamwork behaviours. Based on the insights generated, students then set targeted steps to improve that particular dimension of teamwork, both individually and as a team (Fig. 8.8). Figure 8.9 shows students reflecting individually and in a team. The MGB system instructs students to reflect personally first. This is then followed by team

Fig. 8.7 Student viewing his personal micro-profile

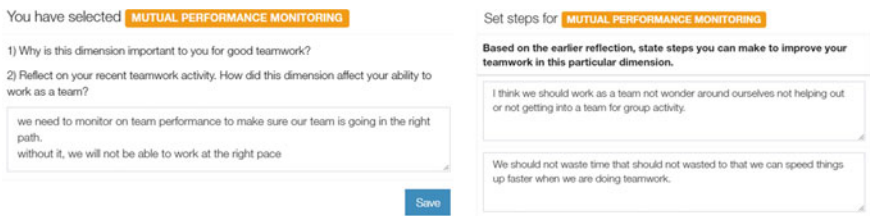


Fig. 8.8 Screenshot of personal reflection and steps set by a student

Fig. 8.9 Students reflecting and goal setting personally and in their teams

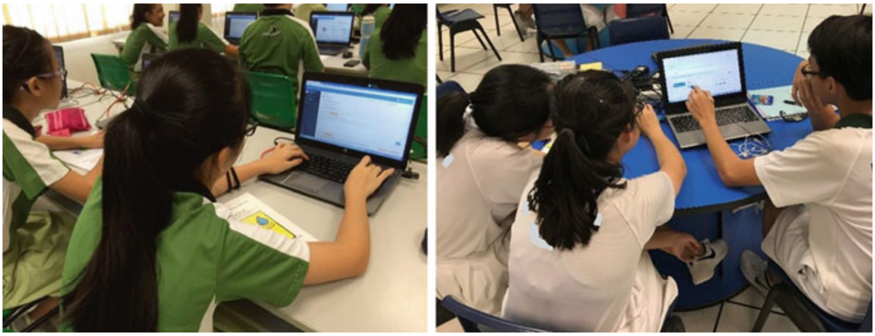


Fig. 8.10 Picture of students doing status check and personal reflection and steps set by a student

reflections, where the students gather as a team to discuss as well as to look back and forward as they reflect on their teams' micro-profile.

8.3.3.4 Stage 4: Team and Self-growth and Change

This final stage focuses on the monitoring of teamwork behaviours after students have a deeper understanding of their teamwork competency in the earlier stage 3. As students have set goals to improve their teamwork, in this stage, the students are guided to check and update the status of their teamwork steps. Students can choose from three option provided: (1) Still trying (2) Almost there and (3) I did it. Figure 8.10 shows students updating the status of their personal steps followed by which they gather as a team and perform the team status check. This conscious and deliberate design reminds students of their teamwork steps that decided on and encourages them to work on it if they have not been doing so. In other words, MGB helps students to self-regulate and co-regulate their team behaviours by providing an intentional update function.

After this stage, students continue working in their teams for the collaborative inquiry task. The TSDL round (stage 1–4) is repeated again. For the final round of TSDL, stage 4, which involves the monitoring of teamwork goals, does not need to be carried out as the intention is for the goals set to be for a future team task and it is out of scope of the students' current collaborative projects to monitor the steps for that.

8.4 Findings

The enablers and impediments of the innovation are summed into three key themes. As each impediment may concurrently be seen as an enabler, through each theme we present these findings in light of conditions which helped to mitigate the constraints of the impediment.

8.4.1 Student-Centred Orientation of the Innovation

A key enabler of the innovation was the focus on the value of the innovation for students' twenty-first-century competency development, specifically teamwork. The innovation constantly emphasized the outcomes that students could derive from this innovation and had a deep consideration of student' views and perspective. This was a potential impediment if the innovation was not seen in this way, as stakeholders such as students and teachers would have less inclination to participate in this. The design of the innovation was premised on its usefulness for students' teamwork and shown through the affordances and benefits of the system on students as heard from student voices. Two key benefits for students were:

(1) Providing a safe space and opportunity for teamwork expression and communication

One key benefit highlighted by students was that through MGB, it created the opportunity and space for them to express their thoughts about working in a team. The following transcript highlights this:

> Student 2B34: The reflections and the ratings, it helps me to express my feelings towards my groupmates. It also can let me know what my groupmates feel about me… Because when we interact in class, we won't know what the others feel about us, because we won't express it. So through My Groupwork Buddy, they'll express it but stay anonymous.
>
> Interviewer: So without this, there may not be a chance to talk?
>
> Student 2B35: [Yes] and the conversation will be very short.

Another student, 2B25 shared the difficulty of doing this face-to-face, *'It is because people may try to confront you and say it straight to your face, but with this, they can just type it out and it may not be as offensive when you type it out'*. Student 2A31 echoed a similar view, saying *'there's a part of the reflections that is the feedback part … it would be a bit offensive and awkward to tell each other what we should or should not do, so it provides us with a platform … and it keeps us anonymous [when we] give suggestions on how to improve and things like that'*.

These suggest that the techno-pedagogical design of MGB including the anonymity of peer feedback allowed students to feel safe and provide an intentional platform for students to develop and share their thoughts about their own team's behaviours.

(2) Helping students to be cognitively aware and monitor their teamwork steps

Through the intentional design of status checks where students had to update the status of their teamwork steps, this activity led students to be more cognitively aware of their teamwork. It directed students to regulate and monitor their teamwork competency targets. Students described this monitoring:

> At the end of every process, we will go check, and since we made the steps ourselves, we should be able to follow it. Student 2A15

> The status check reminds us of what we did previously, and how we improved or deproved from that aspect. So that we can work on that particular thing in the future. Student 2A05

Also, student 2B02 thought that '*the status check is useful, because we can check into see if we're improving or not in what we're doing, and reflect..., we can try to improve*". It can be seen that the techno-pedagogical design in the status checks helps students to regulate their teamwork behaviours.

In all, these two benefits for students' teamwork learning as voiced by them, created leverage for the innovation to continue its trial and infusion in the schools. Corollary, students' feedback if overly negative or critical, would also impact and influence the uptake of the innovation.

8.4.2 Pedagogical Ownership

Pedagogical ownership by the teachers involved in the intervention was a key enabler. We observed that teachers' attitudes towards his/her role and ownership of the project affected their behaviours. When they saw themselves as a teacher-participant, they tended not to put too much thought into the intervention. This was an impediment in certain classes. On the other hand, if teachers recognized that they were co-designers and/or forerunners in the intervention, more consideration into the intervention was placed. For instance, the teachers would adapt and personalize the slides provided by the research team, and/or create new slides or related activities on teamwork.

Pedagogical ownership was seen when the teacher grew in his/her role from a participant to teacher leader and/or co-designer and felt a sense of pride and achievement of his/her contributions to the research. The following quotation shows the progress of one such teacher:

> [My involvement in MGB has influenced me] as a teacher [in knowing that] there is definitely more to teamwork than just getting students to work in teamwork. Deeper understanding of all members in the group can help in improving their ability to work in a team. As a leader, this [MGB] should be used as a means to know everyone behaviours and tendency toward working in a team. In that way, we will be able to find the root cause and eventually improve each other's ability to do well in a group setting. And as a co-designer of research, [it was] definitely an enriching experience and it felt good to see that my suggestion and lesson ideas are being used in the next batch of implementation for MGB. It felt good to know that my contribution had helped make MGB a better platform for students.

The research team also found that pedagogical ownership is often accompanied by the growth in content mastery of teamwork competency, the "what" of teamwork competency, and expertise development, the "how" of facilitating teamwork competency such as through students discussions and reflections on MGB. An earlier work has found that two teachers who facilitated the intervention grew in the technological pedagogical content knowledges needed for the intervention. These include content knowledge about teamwork dimensions, pedagogical knowledge about facilitating teamwork, technological knowledge of the affordances of MGB, pedagogical content knowledge of how to apply TSDL to facilitate one of the teamwork dimensions (e.g. mutual performance monitoring) and technological pedagogical content knowledge which requires the knowledge and skills of teaching and facilitating teamwork with MGB using TSDL (Koh & Hong, 2017). This also suggests that pedagogical ownership is complemented by the teachers' development of knowledge and skills required for the intervention.

8.4.3 Problem-Solving Technological and Structural Constraints

The design team encountered several technological and structural constraints. Through each constraint, the design team did their best to problem-solve and troubleshoot the issue, adapting where necessary in order to carry out the innovation.

Technologically, there were issues of unavailable ICT hardware and network connectivity when MGB was trialled in the classes. For instance, there were laptops that could not be used as updates were installing or low network bandwidth when many students were tapping on the Internet (including other classes and subjects). When this occurred, the design team would volunteer their own ICT equipment such as laptops and/or smartphones for the students to use and access MGB. Another mitigation strategy was to get students to share their computers or take turns, and teachers at times instructed students to do this.

As for structural issues, the project faced the challenge of finding the optimum integration of MGB with the respective curriculum. In certain trials, this integration was facilitated by planning some aspects of the intervention as homework for students, as well as creating space in the curriculum by removing certain redundant content. However, not all constraints were easily solved and adapted by the design team. Reasons include the inertia inherent in mindsets of teachers, school leaders, insufficient or difficulty of communication and/or rigid scheduling and classroom structures. With the possibility of two or three rounds of TSDL for the collaborative inquiry task, some teachers insisted on three rounds even though there were signs that two rounds were more optimum. Although this helped the intervention to confirm that three rounds of TSDL was too many in a 6-month long student team task, during the process of implementation, it was difficult for the scheme of work to be changed due to mindsets that were fixed and communication difficulties.

8.5 Discussion

In the process of infusing the teamwork innovation MGB into the two schools, three core themes on enablers and impediments were found. As elaborated in the earlier section, they relate to the value for the students, i.e. student-centred orientation of the innovation, to the teachers in terms of pedagogical ownership and to the wider socio-cultural context that required technological and structural problem-solving.

The first thematic finding on student-centredness relates to the students, the key stakeholder. The learning of teamwork for students is part of the key value proposition of MGB. The benefits for students in terms of their practice and expression of teamwork as well as their self-awareness and goal-setting for a relatively abstract skill have been highlighted. It is similar to many experiential learning programmes for students that provide authentic experiences for students to gain the necessary skills and knowledge with the additional affordance of the visual analytic for timely feedback. This focus on its value to the students helps the innovation receive better buy-in and have a greater possibility of taking root in the school.

The second benefit to students in terms of awareness and monitoring in MGB, moreover, is related to the possibility of transfer, applying teamwork knowledge and skills from one context of practice to another. This other context could be in school or out of school. Such transference is also termed deeper learning (National Research Council, 2012) and is what many twenty-first-century programmes hope to nurture among students. However, the extent that this deeper learning is achieved is beyond the scope of the intervention. It does call for further studies examining the trajectory of students in the specific skill development (i.e. teamwork) over their years of studies and even work. Nevertheless, the intervention principles in TSDL awareness building, monitoring and goal-setting which are forms of metacognition have been shown in other studies to be mechanisms which help in transfer (Ford et al., 1998; Scharff et al., 2017) and also are crucial in pedagogical interventions using learning analytics (Wise, 2014). In this regard, we posit that this intervention has provided some basic foundation for students to become better in teamwork in future situations and can be positioned as part of the added value of the innovation. These benefits also shows that the design of MGB had sufficient considerations of theoretical alignment, affordance engagement and stakeholder usability.

Pedagogical ownership is another key finding, and while unsurprising as an enabler of innovation diffusion, reiterates its very importance. Curriculum and programmes can be in place to guide the classes and students' learning but teachers are the facilitators of this learning. As can be seen, MGB's infusion into two schools was not as smooth sailing, as with most interventions. Being a new form of activity and assessment using disposition analytics, there was a slight learning curve for stakeholders involved, especially the teacher. We found that the teacher's ownership of the activity and learning innovation helps establish the intervention in the school. We argue that this ownership will also be critical to sustaining the innovation in the schools, long after the research project ends, as the teachers do not need any help from the researchers, but can be innovators of their own standing. However, it is challenging for teachers to implement these innovations and tensions and trade-offs are required. In line with Koh and Lee (2019), we advocate strong investment in teachers' implementation of innovations. This can be in the form of allocated time and space for teachers to explore and co-design interventions, as well as creating routines and recognition policies to encourage these innovations.

Although this innovation is focused on students and classrooms, the socio-context of the school has played a role in influencing the innovations' diffusion. Technology and structural constraints limit the success of the infusion. There is a need for the design team to constantly be adaptive and resolve the issues. Reflecting back on the challenges of the technological constraints, there was a lack of redundancy. There did not seem to enough extra computers and additional bandwidth in the school system i.e. when computers are down there are not enough spare ones; when network bandwidth is used up by some other users, there is limited additional bandwidth for other users. This lack of redundancy can definitely be mitigated by devising a technological obsolescence plan to cater for the rising demands and changes in technology use, increasing both hardware and bandwidth.

Structures in schools provide an efficient way of organizing large number of stakeholders e.g. students, teachers. However, structures tend to be permanent and/or routinized and are difficult to change. When these structures did not align with the innovation demands, problems arose. As elaborated earlier, it was difficult to change these structures (especially in terms of curricular and timetable structures) and the design team had to work with teachers to customize the innovation to resolve the issues. In addition, the domain neutral nature of the innovation did not have an existing school structure to ride on as many existing structures are domain and subject based e.g. teachers' timetabled time are organized around department subjects. This nature of the innovation which is rather atypical of most interventions which are domain focused could have resulted in greater difficulties in finding support structures. We agree that structures are important for order and organization, but structures should be malleable. We propose that malleable school structures can be designed through providing at least two options or ways for every structure accompanied by the essential reason and benefit. For instance, timetable options of a longer school day or a shorter school day with reasons that students do not need to bring homework back home when it is a longer school day. Another malleable structure could be having teachers' timetabled time not only for subjects, but also for work on non-domain subjects, as part of developing teachers' twenty-first-century competencies. With such malleable structures in schools, it would reduce the rigidity of the system and help to accommodate many, new and innovative interventions.

8.6 Conclusion

Towards cultivating the twenty-first-century competency of teamwork among Singapore students, MGB was developed for secondary school collaborative inquiry projects. It is domain neutral and has been trialled in two different subjects. Three core enablers of the innovation were found relating to the value to students, pedagogical ownership and the problem-solving of constraints. Implications for practice and policy were discussed in the earlier section and pertain to teacher and structural aspects. We hope that systemic changes can be made in order to support the future visions of learning.

In light of the challenges in implementing MGB, we acknowledge that there is more work to be done. Moreover, in terms of the limitations of this study, we focused only on a subset of our entire dataset. This was done to help in managing the data analysis. However, we have other datasets e.g. quantitative surveys which can possibly complement the analysis. Nevertheless, the current findings adopted a reflexive approach to gather greater insights of the completed innovation.

The MGB innovation was developed using DBR and successfully trialled over two and a half years in two schools and used by a dozen over teachers and hundreds of students. It is one of the first few innovations to employ learning analytics as a digital formative assessment tool for teamwork with relevant theoretical alignment and stakeholder usability. The study has revealed key enabling conditions of the intervention and demonstrates the possibilities of infusing innovations to nurture Singapore students for the future.

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Chapter 9
Developing Signature Labs in Humanities Education: Ground-Up Educational Innovation in a Top-Down System

Mark Baildon, Suhaimi Afandi, Tricia Seow, and Kim Irvine

Abstract This chapter shares efforts to conceptualize, develop, and implement two signature labs to support Humanities education in Singapore—the *Historian's Lab* and the *Sustainability Learning Lab*. In particular, we focus on lessons learned in innovation (e.g., the necessity of creative and collaborative synergies among disciplinary experts, curriculum specialists, ICT designers, and teacher leaders, among others) and managing the challenges and constraints of educational innovation in a centralized, results-oriented system that at the same time continually encourages innovation.

9.1 Introduction

The launch of *Thinking Schools, Learning Nation* (*TSLN*) in 1997 heralded a significant educational reform effort in Singapore's education system. Calling for "a nation of thinking and committed citizens capable of meeting the challenges of the future, and an education system geared to the needs of the twenty-first century" (MOE, 2019), schools were expected to educate students to be critical and creative thinkers with the necessary skills for 21st work and citizenship, and to develop a culture of lifelong learning and adaptability to meet changing economic demands. There were three main thrusts to *TSLN*, systematic introduction of information technologies (IT) into curriculum and classroom practice, as represented in successive IT masterplans following *TSLN*; the introduction of critical and creative thinking skills in national curricula; and *National Education*, a citizenship education program to instill the values and knowledge necessary to create a strong sense of Singaporean identity and social cohesion (Deng, 2004).

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TSLN was followed by the *Teach Less, Learn More* (*TLLM*) initiative in 2006 to reduce curriculum content and provide teachers with more scope for innovation in their teaching. Subsequently, inquiry-based learning became the preferred approach in school curricula. In Humanities education, the major thrust of inquiry-based learning was targeted at getting students to "appreciate the underpinnings" of the Humanities disciplines (MOE, 2012, p. 12). Major initiatives in Singapore's curriculum reforms focused on the need for innovation in the system to more fully enact inquiry-based learning, greater use of technology, the development of twenty-first century skills, and greater emphasis on educational processes rather than outcomes (Gopinathan, 2007).

Our project, *Signature Programmes in Humanities Education: The Historian's Lab and the Sustainability Learning Lab*, was designed to directly address these reform efforts. We emphasized inquiry-based learning by developing discipline-based curriculum tasks and signature pedagogical approaches (Shulman, 2005) to support Singapore's secondary History and Geography syllabuses. To support the curriculum resources and pedagogical approaches developed in the project, we also designed technology tools to support disciplinary inquiry in classrooms and fieldwork. In this chapter, we highlight the work we did along these lines.

Calls for educational innovation have been a constant from Singapore's education officials. Despite success as a top-performing education system (based on international measures, such as PISA scores), Singapore's Ministry of Education (MOE) desires innovation in the system. However, while significant reform efforts have been initiated since 1997, researchers continue to find limited impact of innovation in classrooms (Deng & Gopinathan, 2016; Hogan, Kwek, Towndrow, Rahim, Tan, Yang, & Chan, 2014). As Hogan et al. (2014) concluded, the impact of reforms like *TLLM* "on instructional practice was very limited despite evidence here and there of some imaginative pedagogical innovation" and "this occurred for a variety of reasons, including neglect of the tight coupling of the national assessment system and classroom instruction, a pervasive folk culture of teaching and learning across the system that impeded sustainable and effective instructional innovation, an implementation strategy unable to support substantial and sustainable pedagogical improvement, and the weak professional authority of teachers" (p. 121). Similarly, Deng and Gopinathan (2016) found Singapore's educational system continues to be oriented toward supposedly meritocratic national examinations that encourage content coverage, the transmission of skills and knowledge, and emphasis on correct answers with limited opportunities for interpretive work, extended discussion, and critical or creative thinking.

In response to some of these concerns, Singapore's Ministry of Education (MOE) and National Institute of Education (NIE), supported by the National Research Foundation, launched the eduLab initiative in 2011 to spur educational innovation. eduLab projects were expected to have at least two or more school partners, feature an ICT-based innovation that would change classroom practice, involve teachers in the design, development, and implementation of the innovation as well as research, and be sustainable. The eduLab initiative was considered "a key programme for teachers, researchers, and MOE HQ [Head Quarters] officers to develop ICT innovations for learning that can potentially be adopted or adapted by different schools across the system" (edulab Funding Programme, n.d.). eduLab began as an MOE-NIE initiative supported by the National Research Foundation (NRF) in 2011. From 2016 onwards, new eduLab projects were funded by MOE and administered by the Office of Education Research (OER), NIE.

The purpose of this chapter is to examine particular successes and tensions arising in a project to design and develop innovative curriculum, pedagogy, and ICT in Humanities education, specifically summarizing what we have learned about educational innovation in a centralized, results-oriented education system. We begin by providing a brief summary of the two innovations, the *Historian's Lab* and the *Sustainability Learning Lab*, and the theories of action (Argyris & Schön, 1978) that guided our work in the project. We then highlight some of the challenges we faced in this process and the lessons learned in educational innovation. We conclude by sharing ideas for how usable educational innovation can be better leveraged and implemented to support educational reform.

9.2 Theories of Action Guiding Innovation

The project, *Signature Programmes in Humanities Education: The Historian's Lab and the Sustainability Learning Lab*, was designed and developed with several underlying theories of action (Argyris & Schön, 1978) to guide innovation: (a) all resources had to be specifically aligned with and support MOE curriculum, intended pedagogical practice, and desired learning goals; (b) specific problems of practice were identified from research that the project sought to address; and (c) strong conceptual frameworks would guide every facet of design and development. These reflected operating assumptions we had about inquiry-based curriculum, pedagogy, ICT, and how innovation might improve classroom practice and bring about educational change. For example, our project was grounded in what we identified to be a core problem of practice: while teachers generally believe in inquiry-based approaches, they have difficulty enacting inquiry due to multiple and often competing priorities. These include managing classrooms with high student numbers, little class time to fully enact inquiry-based learning, high stakes examinations that require drill and practice or "teaching to the test," and a lack of resources that could better support more authentic forms of inquiry.

The background of the project, then, was based on our view that teachers faced many challenges utilizing an inquiry-based approach in classrooms due to particular constraints and challenges. This view was based on extant research (e.g., Hogan, 2009; Kwek, et al., 2015; Deng & Gopinathan, 2016) as well as on our own work with teachers that identified some of the challenges they faced in implementing the relatively new inquiry-based curriculum in both History and Geography. For example, Seow, Chang, and Irvine (2019) found that while Lower Secondary Geography teachers in Singapore were committed to the idea of inquiry-based learning (IBL) through geographic fieldwork (Geographical Investigation, GI), they viewed it as an "experience" rather than authentic disciplinary work (e.g., using scientific processes), and demonstrated gaps in understanding the nature of fieldwork, how to carry it out, and necessary content understanding (e.g., related to water quality GI). Teachers expressed the need for resources, such as the SLL, to support these gaps (e.g., learning resources for both teachers and students, geographic data, guides to discipline-based methods and IBL, etc.). Similarly, Afandi and Baildon (in press) found Secondary History teachers generally supported IBL (as expressed in curriculum documents, teacher education courses, and as an ideal), but identified institutional constraints to carry out more authentic forms of IBL. These included rigid exam structures that did not align well with the spirit of inquiry, issues related to student readiness (i.e., lack of sufficient content knowledge and skills), as well as their own readiness (i.e., lack of sufficient content knowledge and inquiry pedagogy to carry out IBL in the classroom). Based on this research, we believed we could address these issues of classroom practice by developing and providing necessary curricular, pedagogical, and ICT resources. These resources would align with MOE's conceptions of inquiry in the Humanities and provide inquiry-based teaching approaches, curriculum materials, ICT, and specific pedagogical strategies to support teachers' conceptions and classroom practice of disciplinary inquiry in classrooms and fieldwork. Research in the project would examine the efficacy of these resources in supporting teachers' conceptions and implementation of inquiry-based classroom practice.

Several conceptual frameworks served as theories of action. First, we were guided by Shulman's (2005) notion of signature pedagogies that emphasize aligning pedagogical practice with the ways knowledge is constructed in the disciplines. This notion of signature pedagogies meant that teachers must understand the nature of disciplinary work (i.e., what it means to reason, read, write, and talk in the disciplines) and have the necessary pedagogical content knowledge that integrates knowledge of the subject with pedagogy. A core guiding principle of the project was that teachers needed strong disciplinary knowledge of their Humanities subjects, including both the substantive (conceptual structure) and the syntactic (methods used to generate and evaluate knowledge) structure of their disciplines (Schwab, 1978), so they would be able to organize, represent, and adapt particular topics, problems, or issues for the diverse interests and abilities of their learners. Such an approach was not simply a matter of technique and required particular professional dispositions, beliefs, and attitudes about teaching as a craft (Shulman, 2005); it required a particular orientation to teaching that understood how subject matter (both inquiry methods and key concepts) could be made accessible, appropriate, and supportive of students' construction of knowledge in classrooms and fieldwork. A guiding premise was that we could design rich curriculum tasks based on these disciplinary structures and the types of problems and issues investigated in disciplinary work to provide immersive inquiry-based learning experiences. And, because the project team consisted of academic specialists in Geography and History (one geographer; one historian) and curriculum and pedagogy experts (in history education and geography education), we were well-suited to provide expertise in discipline-based development through our collaborative efforts. For example, in the SLL, this would include water quality fieldwork investigations using the disciplinary methods (e.g., scientific processes), types of instrumentation (for data collection at sites), and data analysis procedures used by geographers in the field. In the HL, it included students working with a task set that gave them competing accounts by historians about an episode in Singapore history along with primary documents and scaffolding to enable students to develop their own conclusions about an historical controversy. The design of these rich curriculum materials was based on research suggesting that this is what teachers have students do in class that matters most in the learning process (Hattie, 2009).

Our approach was also based on the idea that learning is social and interactional in nature, and that knowledge-construction occurs best if students are involved in processes of meaning-making or through participation in a collaborative knowledge-building community. Purposefully designed resources—in the form of expert-guidance, learning scaffolds, pedagogical devices, and discipline-focused instruction—would play an important supporting role in: (a) facilitating knowledge-building endeavors and (b) strengthening conceptual clarity. We adopted the view that knowledge-construction activities are not "solely individualistic endeavours," but instead are "inextricably social" and dependent "upon the use of social resources" (Phillips, 1997 p.191). Consequently, in designing the learning resources for the two labs, an important consideration was for students to be placed in a situation where they could construct their conceptions and understandings within a learning environment that provided the necessary resources to build knowledge. Professional development work in the project sought to guide teachers in the use of these resources.

Another important concept that we wanted to explore (through our activities and resources) was the idea that learner competency can be progressively developed and supported in ways that can push them towards more advanced understandings about the nature of the disciplines. By placing the focus on disciplinary practices that shape/guide the construction of disciplinary knowledge, we designed learning modules and cognitive tools that were specifically aimed at moving students' ideas towards more sophisticated understandings. This would include improving students' capacity to think and reason in disciplinary ways, building their level of disciplinary literacy through explicit teaching of core concepts and modes of disciplinary practice, increasing their competency at handling rigorous, challenging, and authentic disciplinary problems (for the purpose of knowledge- and skills-building), and helping them develop proficiency to engage in discussion-based routines or conversational exchanges (e.g., in the form of disputational, cumulative, and exploratory talk) (Mercer, 2000). In short, we wanted to shift practice toward discipline-based instruction and constructivist practice by providing resources and guidance to illustrate and demonstrate such practices.

9.3 Project Highlights

The development of the project was actually quite organic and interactive. While grounded in the above theories of action, we worked closely with our partner teachers to identify areas of need, design curriculum tasks and resources, and to pilot materials and approaches in the schools. We followed an iterative design process of engaging partner teachers to ensure materials were designed and developed in ways that the teachers thought would support classroom or fieldwork practices, and we piloted, observed, and sought input from teachers about revisions to the materials. We also built on other work that we had done. For example, a former pre-service teacher had designed a water quality App (as part of his final year project) that was distributed freely through the App Store, prior to the project. This App provided the inspiration for the *Waterscope* App developed in the eduLab project. The *Waterscope* App facilitated collection and analysis of geospatially referenced water quality data (including the automated calculation of a Water Quality Index) as part of a water quality GI. A raingarden project and an IoT project (e.g., Chang et al., 2018) were separate yet simultaneous initiatives developed in parallel with the SLL; but the *SLL* became an organizational frame for these other developments and ultimately were folded into the SLL portal (http://sll.hsse.nie.edu.sg/). Our work with teachers under the *SLL* focused on one area of challenge noted by the teachers—carrying out water quality and weather and climate Geographical Investigations that are part of the secondary MOE Geography syllabuses. In response to finding that teachers had less familiarity with the scientific processes and concepts central to these GIs, the academic Geographer (whose area of expertise was in water quality research) worked with a pre-service teacher to develop several water quality videos. These included "how to" guides on lab and fieldwork techniques, such as how to measure and interpret dissolved oxygen, pH levels, E.coli, turbidity, and nutrients in water, sampling techniques, and an introduction to raingardens. Based on teacher needs, the academic Geographer also wrote a *Teacher Handbook of Water Quality for the Singapore Geography Curriculum*, and guides on Water Quality Index (WQI) calculations and charts that would help teachers and students understand graphic representations of water quality data in each of the areas of measurement (noted above as video resources). In coordination with the "how to" videos, the curriculum specialist in Geography education, working with the Geographer and teacher partners, developed lesson packages (including a video series on sparking curiosity as part of pre-fieldwork preparation, fieldwork techniques with students, and post-fieldwork data interpretation) to support Geographical Investigations of water quality. The SLL portal also included resources developed by partner teachers.

The *SLL* team established one outdoor lab space for fieldwork at the Jurong Eco Garden (JEG, Fig. 9.1), used the NIE Raingarden as another fieldwork site (Fig. 9.2), and developed a geospatial data portal and a dedicated website to house teaching and learning resources (see http://sll.hsse.nie.edu.sg/). A Drone, and water quality testing kits were purchased and made available to schools to support Geographical Investigations related to water quality issues (Fig. 9.3), and a YSI datasonde (Fig. 9.4) and linked meteorological station were deployed to collect continuous, long-term time series data (Fig. 9.5) that provided context for the single-day grab sampling done by students at the partner schools as part of their GIs. We found the teacher handbook, written by Irvine (2017) during the project, was also of interest to other academic geographers and received over 1,795 downloads/reads on *ResearchGate* between September, 2017 and February, 2019. As part of professional development efforts,

Fig. 9.1 NIE pre-service student teachers testing water quality with a YSI datasonde at the Jurong Eco Garden cleansing biotope (photo by authors)

Fig. 9.2 NIE pre-service student teachers measuring infiltration rates in the NIE Raingarden (left) and explaining the IoT meteorologic instrumentation at the NIE Raingarden (right) to Thammasat University (Thailand) students (right) (photos from authors)

Fig. 9.3 Learning is social and interactional in nature. Secondary School students working in collaborative groups at Jurong Eco Garden with the water quality test kits provided by the SLL (photo by authors)

five workshops, including integrated physical and human geography field techniques for water-oriented inquiry (Parts 1 and 2) were conducted for teachers, along with two in-service workshops done in collaboration with an external consultant that focused on the use of ICT in geography classrooms.

Seow et al. (2019) found that in implementing GIs, teachers "did attempt to induct students into the knowledge, skills, and values of geography disciplinary practitioners" (p. 8). The project also revealed particular challenges of developing discipline-based pedagogical content knowledge and of teachers learning to manage the inherent "messiness" of conducting field work as well as handling the variability of data. This likely contributed to "adaptive anxiety" (Shulman, 2005, p. 57) and teachers being less willing to engage in more student-directed approaches to field-based inquiry. However, developing a range of resources to guide teachers and students in field work holds promise for helping teachers manage these uncertainties.

Similarly, the *HL* developed and implemented a website (see Fig. 9.6) housing resources and an "ask the historian" History Forum (see Fig. 9.7), three inquiry-based curriculum packages with video resources focused on particular historical problems: historical controversy, *Operation Coldstore*; Singapore's early history, *What is Temasek?*; and understanding historiography, *Introduction to the Historian's Craft*. These lesson packages were designed to help teachers and students understand

Fig. 9.4 Deploying a YSI datasonde at the outlet of the Jurong Eco Garden to provide continuous, long-term water quality data accessible through the SLL data portal (photo by authors)

the nature of history as a discipline, to demonstrate different aspects of the historian's craft, and to help learners understand the constructed nature of historical knowledge.

The history education specialist also constructed useful pedagogical devices and learning tools, such as the *Chronologer* (see Fig. 9.8) to help students identify chronological patterns in history and to see how historical events in Singapore were related to broader chronologies in regional and world history. The team, together with a game designer collaborator, designed, developed, and piloted an interactive game named *Singapore Surrenders!* (see Fig. 9.9), designed to help students develop conceptual understanding of chronology and causation in their study of the Japanese occupation of Singapore during World War II. These curriculum and pedagogical resources were used as cognitive devices to support historical reasoning and enabled students to engage in activities that facilitated debate, discussion, and deliberation.

Several video cases of historical thinking featuring historians were developed as well as video cases of teachers and teacher educators sharing views on historical inquiry, conceptual understanding, and the teaching of history. Five workshops using these curricular and pedagogical resources were conducted for in-service teachers. These workshops emphasized approaches to cultivate historical reasoning and argumentation, develop understanding of the discipline as an interpersonal practice (of dialogue, exchange, and interpretation), and to demonstrate how history's interpretive nature shaped the way knowledge about the past is constructed as well as how

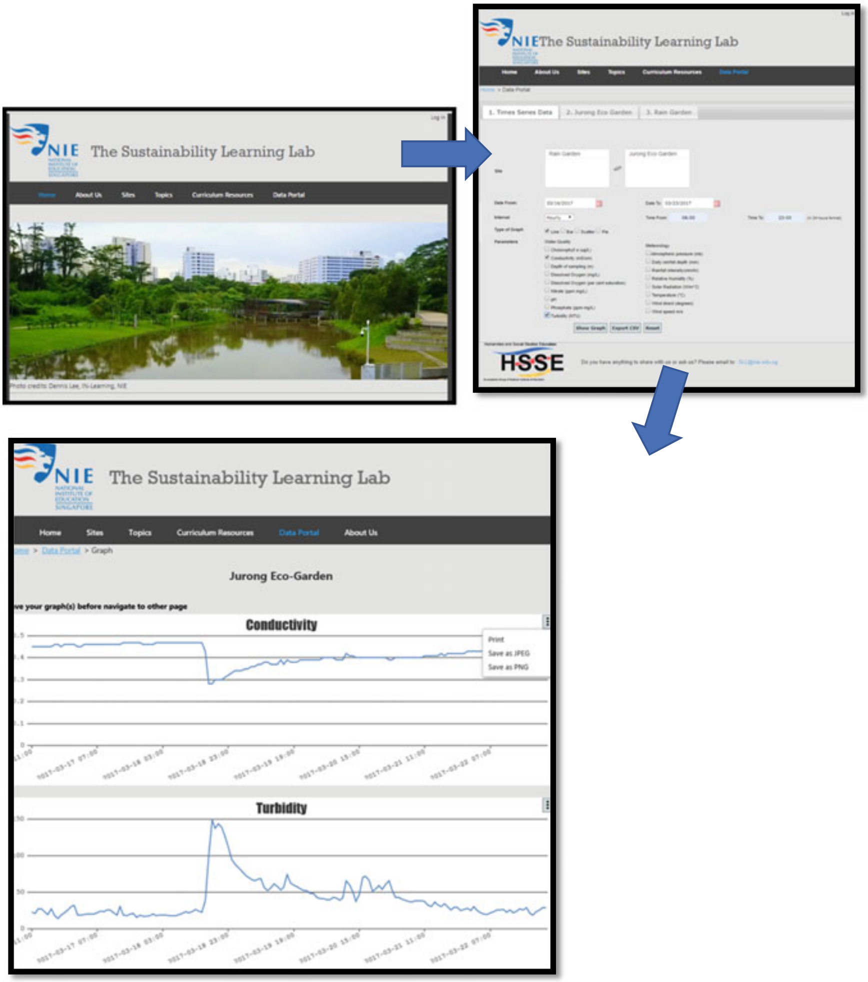

Fig. 9.5 SLL website with data portal, showing the long-term water quality data (here, conductivity and turbidity) available from the YSI datasonde deployed at the Jurong Eco Garden. Data can be automatically graphed at hourly, daily, or weekly time steps and saved in a.png or.jpg format. The raw data also can be downloaded in a.csv format for other types of graphing or statistical analysis

claims about the past can be tested, arbitrated, and adjudicated. Along these lines, the team developed a discussion forum that facilitated an exchange of ideas between students and academic historians, while facilitating the work of building historical knowledge in a collective and collaborative way. The forum design allowed teachers and students to interact within the boundaries of each classroom/school on selected historical issues with direct access to academic historians offering guidance and clarification on those issues.

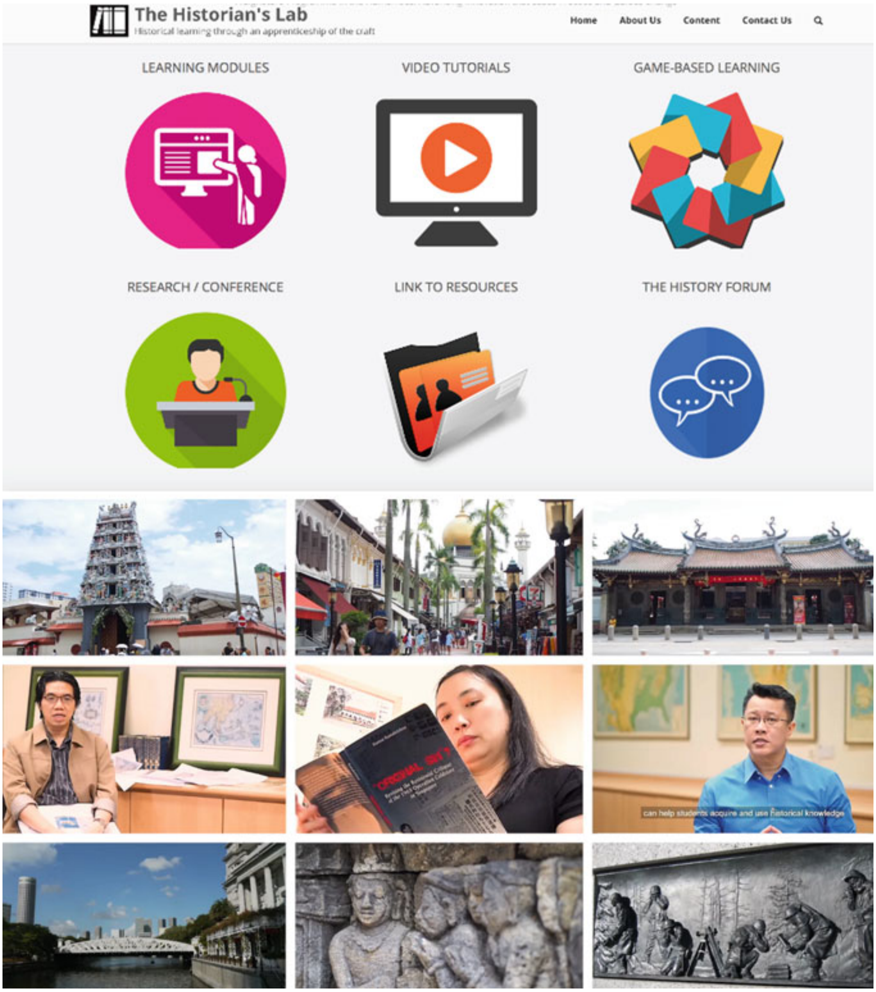

Fig. 9.6 Screenshots of the *Historian's Lab* website featuring a range of learning resources, such as video tutorials on historical reasoning and inquiry-based learning, curriculum packages, and the *History Forum*

Research findings from the *HL* found that students have a range of preconceptions about historical concepts, such as chronology, causation, and accounts, and often draw on default "everyday" ideas about the past to explain events in history, unless properly guided to develop more sophisticated conceptions of history. Rich cognitive tasks and pedagogical devices that provide appropriate scaffolding can support students to develop historical understanding. For example, we found that students developed better means of establishing and explaining cause–effect links when tackling specific cognitive tasks using the *Chronologer* and the game. These specially designed concept-based learning tools were able to help students move

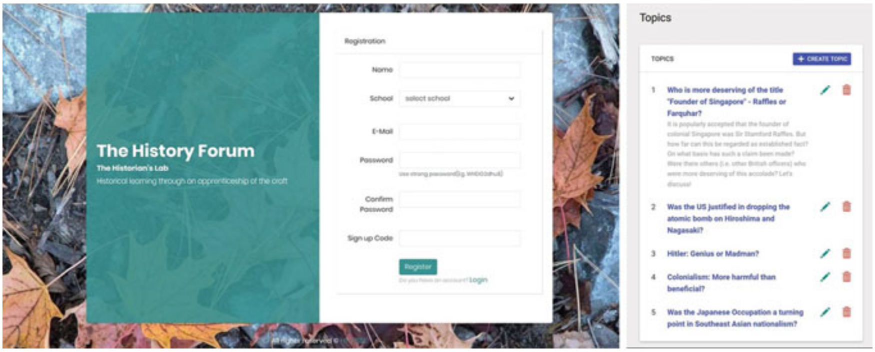

Fig. 9.7 *The History Forum* where classes can "ask an historian" about a problem in history. Students could ask historians about their views on a particular event or issue in history, ask about matters of historical interpretation, or ask questions to support their own inquiries in class

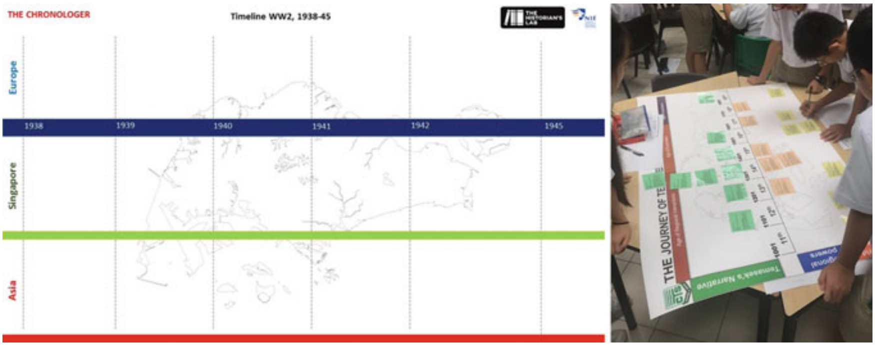

Fig. 9.8 The *Chronologer*, a learning device designed to support students' chronological thinking by situating events in broader regional and global contexts in order to understand historical patterns or relationships between different scales of time and space

Fig. 9.9 The *Singapore Surrenders!* game designed to support students' thinking about chronology and significance in an interactive game environment to learn about the surrender of Singapore during World War II

beyond single (mono-causal) or non-related listing of factors, to manifold (multi-causal) or multi-layered explanations to how and why events occurred. We also found that engaging teachers and students in authentic historical problems, like historical controversies or real debates between historians, increased their awareness of the nature of history as a discipline and how historians work to construct arguments and historical knowledge. We found that the rich curriculum tasks led to more active and collaborative learning, stimulated the use of students' prior knowledge, and kept students interested and engaged in learning history.

While teachers across both labs have highlighted the many challenges to engaging students in authentic forms of inquiry-based learning due to limited curriculum time for inquiry, exam structures and the frequency of assessment cycles, and perceived knowledge deficits among teachers and students, the two labs suggest that the main approaches and principles guiding the work in the labs can assist Humanities educators in Singapore to develop a culture of inquiry in classrooms.

9.4 Project Challenges

Although the *Signature Programmes in Humanities Education* project developed a range of curricular, pedagogical, and ICT resources that were utilized in our partners' classrooms and in teacher education courses, and resulted in several scholarly publications and conference presentations, including some with or by our partner teachers, there were several challenges in doing this work. Many of these challenges are supported by literatures suggesting that accomplishing significant educational innovation and change is difficult, often constrained or rejected by local norms, routines, and practices, especially making difficult the sustainability and scalability of university-based projects (Blumenfeld, Fishman, Krajcik, Marx, & Solloway, 2000; Kwek, et al., 2015; Tyack & Cuban, 1995). For example, Blumenfeld et al. (2000) argue that top-down reforms that have tried to affect classroom practice by changing policy, school governance and organization, and standards and assessment, have not necessarily changed content-based instruction. There is also great difficulty in changes to classroom practice being sustained and scaled up. They highlight that there are often cultural impediments to lasting change, noting that instructional practices that are inconsistent with local norms, routines, and practices are often dismissed or subverted. The work of Kwek, et al. (2015) has similarly found the persistence of institutional rules and folk pedagogies in perpetuating teacher-centered pedagogies and the transmission of skills and knowledge for exam purposes.

Our reflections on project work point to the profound challenge and time commitment that the collaborative development of curricular and technological innovation entails. For example, developing video resources involved collaborating with learning designers and media or video specialists who helped us storyboard the videos and then shoot and produce the videos in a professional manner. Website development, the development of digital learning resources, and curriculum development were concerted efforts among academic specialists, curriculum specialists, partner teachers, learning designers, and technology or media specialists. It included trial and error, continual ad hoc adjustments as new problems arose in development, learning from mistakes, and persistent iterative work to revise and refine what was being developed.

Another key challenge we faced was working with technology and media specialists. For example, we started with one external vendor who proved either unable or unwilling to develop what the project team and teachers had envisioned as the geospatial data portal and website for the *SLL*. While the *SLL* was eventually able to draw on NIE expertise to develop the geospatial portal and website, the *HL* team had to find another vendor we could work with to complete the development of the *HL* website, including the *Historian's Forum*. The absence of a dedicated educational technologist to support this work, likely hampered efforts to a certain degree. We also recognized the need for media specialists to support development of video resources that would support teachers' understandings of disciplinary practice and how it might be enacted in classrooms or at field sites. In sum, conceptualizing, designing, developing, and implementing innovative approaches required a highly collaborative effort, time, and space for professional sharing across areas of expertise, risk-taking, continual problem solving, and iterative cycles of development, trialing, and revision or refinement.

While we are certainly appreciative of the opportunities the eduLab funding provided us to do this work, policy-makers and grant administrators who may have little experience in the actual design, development, and implementation of educational innovation to support Humanities education may under-appreciate the time and effort such collaborative and innovative work among different stakeholders and areas of expertise entails. Similar to the problem of having to juggle competing demands or priorities that teachers face, there were particular demands made by the eduLab committee and grant administrators overseeing the project that provided challenges for the project team to manage. For example, while the project team understood the project as primarily focused on developing the above-mentioned resources, the eduLab committee seemed to have different expectations for project work. This included the continued insistence for the development of the two labs under an interdisciplinary/multi-disciplinary experiential learning framework, an imposition that suggested limited respect in terms of signature pedagogies that intentionally acknowledged the distinctiveness of the two disciplines and that sought to harness the power of discipline-based pedagogical approaches to learning. The eduLab committee also insisted on research agendas and value metrics in the early stages of the project, which diverted the intended focus on development work. This meant that the project team members were asked to provide evidence that the products and artifacts were effective while the said products were still being developed and tested.

There were also hiring and purchase delays due to undoubtedly necessary oversight on budgetary matters and to ensure compliance with organizational hiring procedures, but these tended to delay project work. Blumenfeld et al. (2000) have similarly found that bureaucratic procedures can inhibit innovation. For example, innovation is often hampered by lack of administrative knowledge related to equipment purchases and expenditures necessary for maintenance (such as the meteorological stations necessary for the fieldsites). Blumenfeld et al. (2000) conclude by noting, “Divergent demands, priorities, and constraints at different levels of the system will influence how individuals at those levels respond. Building understandings across levels and coordinating efforts is essential for reform to take hold” (p. 152).

9.5 Lessons Learned

Despite the several challenges we outlined above, we were able to manage these fairly effectively, and they proved to be key aspects of learning for us as university researchers and educators hoping to innovate educational artifacts and practices that can be scaled and sustained for impact on the education system. In this section, we highlight the lessons learned from our project as we look ahead to further development of this project as well as to other efforts at educational innovation and impact. First, we highlight the power of educationalists working across different domains of educational expertise and contexts to develop educational innovation. In doing this work, we also found there to be parallels between the constraining factors of inquiry-based learning in schools and efforts to innovate at the university level. We identified competing notions of innovation that may result in some efforts being dismissed by the project review committee and believe there is need for greater clarity of what constitutes innovation and how it can be better supported on the ground. This support would also include measures to scale and sustain innovations.

One of the lessons learned is that there is great innovative power in bringing together people across different domains of expertise. Again, academic staff and curriculum studies staff collaboration enabled us to design rich, discipline-based curriculum, pedagogical, and ICT resources. Being able to work closely with teachers, technology and media specialists, and game designers can be a powerful learning experience for everyone involved. This work requires translating expertise across domains of knowledge and making it practically usable and accessible to collaborators, teachers, and students in the design of resources. The curriculum specialists and partner teachers played a key role in this translational work, to ensure that the work was grounded in official curriculum and the realities of classroom practice. The concept of pedagogical content knowledge (Shulman, 1987) was particularly useful to our academic geographer, since this enabled him to think about how to frame what he wrote in the teacher handbook on water quality, how to make data collection and analysis methods accessible to teachers (e.g., by working with a pre-service teacher to develop video guides), and how to help non-experts think about the hydro-social dynamics of fieldwork sites. Similarly, both labs had to help technologists understand the disciplinary background of what we wanted for our website designs and for the app that was developed under the SLL. We believe this “translation” work that enables conversation across different domains of expertise is extremely important for innovative work.

We also learned that barriers to inquiry-based classroom practice and innovation are quite similar. These include expectations from administrators and policy-makers that compete with educational priorities. Many of these are top-down accountability measures that require reporting, results, and KPIs rather than enabling greater autonomy and initiative, creative explorations, and experimentation. Cornbleth (2001) has written of climates of constraint that include highly bureaucratic cultures that emphasize order, hierarchy, and intolerance for experimentation and alternatives; conservative climates where there is perceived pressure to conform and avoid controversy; and competitive climates that emphasize testing and school rankings. As Madaus (1988) has argued, “the more a quantitative indicator is used for social decision making, the more it distorts and corrupts social processes it is intended to monitor” (p. 90). It is our view that top-down, results-oriented organizational cultures can stifle inquiry, risk-taking, and innovation. However, inquiry-based curriculum in the Humanities does offer an opportunity for there to be variation in practice, for experimentation, for creating new practices, such as those of Geographical Investigation or for tackling authentic intellectual problems in History (e.g., encouraging students to develop their own conclusions about a controversial event in history).

Another aspect of this problem is that dynamic educational systems, like Singapore’s, are constantly tweaking and adding new innovations at multiple levels. Recently, MOE has called for a plethora of changes in assessment practice and greater attention to differentiated instruction, inquiry-based learning, and technology enabled learning. Each of these, while significant in their own right, add competing demands on teachers, unless understood under a broader conceptual framework to guide classroom practice. As Hargreaves (1994) has noted, for teachers and teacher educators “the sheer cumulative impact of the multiple, complex, non-negotiable innovations on teachers’ time, energy, motivation…[challenges] their very capacity to cope” (Hargreaves, 1994, p. 6). They must manage the contradictions and tensions that arise in efforts to implement new practices called for by reforms. Delandshere and Petrosky (2004) have noted a significant contradiction in these reform efforts: while couched in constructivist learning rhetoric that emphasizes inquiry, critical thinking, and other twenty-first century skills, “reform policies and practices remain hopelessly entrenched in deterministic perspectives where teaching and learning are pre-specified and handed down to teacher educators and teachers for implementation or execution” (p. 12). It will be important for the system as a whole to move away from this view of top-down implementation to allow for more ground-up innovation.

In our project, we began to see a successful integration of top-down and bottom-up efforts at educational change. The teachers in the project largely embraced the inquiry-based approach that is core to Singapore’s Humanities syllabuses. For example, while the Geography teachers found enacting GI to be challenging, they were supportive of GI and fieldwork as a requirement in the Geography curriculum. GI has also become a component of assessment in Geography and can be a viable option to testing. This is an example of how top-down curriculum and assessment reform and bottom-up efforts, such as this initiative at NIE, can work in tandem.

This leads us to another, albeit related, lesson learned. The idea of "innovation" is not something that is universally understood: what counts as innovative pedagogy, curriculum, or educational technology is open to challenge and interpretation. For example, as part of the eduLab committee review of the project, they commented that,

> Resources produced thus far are in standard media formats such as texts, videos, graphs, card games and traditional discussion forums. Not much interactive technologies were used and the resources produced generally are for instructional purposes except the games and some of the data charts for analysis. While there are some tasks developed to engage students in active learning, the number seems insufficient to sustain students learning interests and exposures to develop student's disciplinary thinking, dispositions and skill sets.

This suggested they did not see the project as innovative, since it did not involve much in the way of interactive technologies, and that while there were some tasks developed to engage students in active learning, the number was deemed insufficient. It was not clear what model of innovation the eduLab committee was operating by, but our view of educational technology was that new technologies alone have not moved traditional pedagogies toward more student-centered, inquiry-based approaches, and in fact often tend to support traditional, teacher-centered instruction, unless teachers change their theoretical and pedagogical orientations (Baildon & Damico, 2011; Swan & Hofer, 2008). Swan and Hicks (2007), for example, found that when history teachers were guided by pedagogical approaches that emphasized historical inquiry, the development of historical reasoning, and constructing historical knowledge through the analysis of primary sources, they leveraged technology in innovative ways to support these pedagogical goals. The project chose to innovate in developing curricular materials and pedagogical approaches that we thought would change teacher mindsets and practices, but at the end of the project, we wonder to what extent our work had led to "educational innovation." It would be good for funders and project teams to develop a shared understanding of what constitutes innovation, as well as develop understandings about what might have an impact on classroom practice.

The final lesson learned is related to issues of sustaining and scaling project products. We are still working on this and will likely seek more funding to help us think about how we can better sustain and scale what our teacher partners found to be worthwhile innovations. Blumenfeld et al. (2000) highlight the importance of school cultures that support professionalism and provide opportunities for sharing, experimentation, risk-taking, and reflection among teachers. They also highlight that this is "more likely to take root when there are norms of open communication and cooperation among administrators and teachers about what works and what is needed so that policy and practices that support such pedagogy are established" (p. 151). While educational innovation is seen across the Singapore education system, we believe a more strategic and systemic approach is necessary to shift school cultures so they are more amenable to local, school-, and classroom-based (ground-up) innovations. This would require policy shifts that give greater space, time, and freedom to educators for ground-up innovation.

9.6 Conclusion

This chapter has been an effort to showcase the Singapore education brand in action—as a continually evolving and adapting education system trying to shift educational practice while emphasizing high levels of accountability. In a dynamic educational system, like Singapore's, there are often multiple reform agendas that can create several dilemmas for teachers and teacher educators who have to find ways to prioritize, balance, integrate, and manage various objectives and practices called for in the reforms.

We call for greater support for ground-up energies and innovation to emerge and be allowed to develop in ways that empower teachers and learners. Instead of top-down initiatives and accountabilities, there are forms of bottom-up accountability measures (Morrell, 2017) based on a sense of obligations and commitments to those we work with. This would include the commitments we had to each other on the project team, responsibilities to our partner teachers and their students, and our shared commitment to improving education in Singapore. Instead of top-down accountabilities, in which people are continually monitored, sorted, and exhaustively driven to compete with each other for advancement and to meet the goals of educational officials (Baildon & Alviar-Martin, 2020), educators working in their communities can forge new forms of accountability to hold each other accountable. This is what happens in professional communities of practice where people are treated as professionals who care about their subjects, their students, and work together to improve educational processes, curriculum, pedagogy, student learning.

This highlights the point that developing a culture of inquiry in Singapore's humanities classrooms and schools is first order business that would require educators, curriculum planners, teacher educators, school leaders, and policy-makers to: address impediments to pedagogical creativity and innovation; shift mindsets and prioritize educational (rather than assessment) outcomes; create space for authentic inquiry and cognitive experimentation; build collaborative learning communities that support dialogic exploration of ideas; strengthen inquiry-based teacher education and continuing professional development; and promote teacher dialogue and sharing of best practice. Stakeholders need to find ways to better enable ground-up innovation across the system and to scale and sustain those innovations that hold promise.

Policy is always enacted in particular ways from below, by those on the ground, in ways that arise more from "the interaction among people, their work, and the contexts within which they live" rather than the instrumental, highly rationalized plans desired by policy-makers (Labaree, 2011, p. 631). These enactments may defy the expectations of policy-makers and they are always the result of negotiation and compromise, but they deserve the support of everyone in the system to create cultures of teaching and learning that will lead to inquiry and innovation.

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Chapter 10
Teacher–Researcher Co-designing of a Technology-Enhanced Classroom Inquiry Framework in Promoting Student-Generated Questioning: A Case Study

Longkai Wu and Sujin He

Abstract Questioning has been considered as central in helping students in fostering curiosity and capacity in learning and inquiry. For primary teachers, it remains a challenge to design a science curriculum to both embody classroom inquiry and encourage student questioning. This chapter aims to examine how a learning framework supporting student-generated questioning with technology has been developed through a teacher–researcher co-design process. As a whole, the use of technical platforms has assisted teachers to surface and address students' doubts, which can help students, further their understanding by leading students in the construction of questions. The teacher–researcher co-design practices have also transited into teacher professional learning opportunities as they manage how to effectively access and use inquiry-based pedagogical understandings in their daily practice.

10.1 Introduction

Questioning has been considered as central in helping students in fostering curiosity and capacity in learning and inquiry. In classroom settings, teachers can ask questions to guide students to act in tasks in a more expert-like manner, to make self-justifications, self-explanations, and self-evaluations, and to acquire a better understanding of the kinds of questions they should be addressed in learning and problem-solving practice (Xie & Bradshaw, 2008). However, researchers consistently find that students ask very few questions in schools, even when teachers probe for them (Nystrand, 1997; Chin & Osbourne, 2008). In fact, only a small percentage of questions asked in class are student-generated. For example, having observed classroom

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interactions, Dillon (1988) found that students asked very few questions, and most were clarifications, rather than efforts to gain new knowledge. There are many reasons to believe that traditional learning environments and didactic pedagogies inhibit student questioning. In fact, some teachers may have a teaching philosophy that views their work as transmitting facts and knowledge, leaving little room for student questions. Moreover, even teachers using student-centred pedagogies with the goal to engage students in learning can fail to question students because of larger structural issues. For example, they tend to adopt the techniques of their own teachers—and those exposed to didactic pedagogies during their own schooling are less likely to adopt student-centred pedagogies or invite student questions. Or, as Woodward (1992) explains, teachers who are unsure of the material may actually prevent student questions, to avoid revealing the gaps in their knowledge. There also lies a multifaceted relationship between researchers, policymakers and teachers as pedagogical practitioners. Bishop (1998) has expressed the disjoint regarding ideas stemming from academic research with the actual practice of learning and teaching in classrooms. He argues that it is essential for researchers to relate closely with the practitioners' knowledge and perspectives within the actual situation and constraints.

Meanwhile, the advantages and affordances of technologies, especially mobile devices, make it particularly appropriate to support student-centred learning. Earlier studies have documented how mobile devices can facilitate experimentation in real-world settings, help students collect and record information and allow them to share their experiences and information with peers (Looi et al. 2010; Squire and Klopfer 2007). Looi et al. (2010, p. 156) see significant potential in "the portability and versatility" of mobile devices to promote "a pedagogical shift from didactic teacher-centred to participatory student-centred learning". Yet, past studies have found that when some teachers integrate technology into instruction, this use is to sustain their existing practice and to support a teacher-centred instructional approach (Wu & Huang, 2007). Students have limited opportunities to do an inquiry by themselves and posing questions during their inquiry phases. Moreover, few concrete technological tools or applications have been designed to support inquiry-based pedagogies. Thus the area deserves further research. Looi et al. (2010) stress the need for academic studies to advance our "understanding of how students engage in inquiry-based learning, experiential learning and knowledge building in mobile learning environments" (p. 167).

This chapter aims to examine how a learning framework supporting student-generated questioning with technology has been developed through a teacher–researcher co-design process. The researchers collaborated with the teachers to develop learning packages that integrated the Stanford Mobile Inquiry-based Learning Environment (SMILE), a virtual learning environment into their science lessons, to enhance students' abilities of inquiry. To further promote questioning and inquiry, the teachers incorporated Harvard Project Zero's Think/Puzzle/Explore thinking routine with the lessons and adapted it to include an additional component of "Reflect" to Think/Puzzle/Explore/Reflect. It aims to integrate theory and practice and calls for a closer collaboration and interaction with the teachers in constructive dialogue, consequently leading to the transformation of a teacher-centred to student-centred classroom. This is particularly so especially when the use of technology is integrated with the curriculum. Teachers need guidance in the integration process and a co-design helps to ensure that there is a good fit between the technology and the users of the technology in classroom practice (Albion et al., 2015; Cober et al., 2015).

10.2 Significance of Student-Generated Questioning

To encourage students' questioning is to bring out and sustain the natural curiosity of students—an experience that places students' questions, observations and ideas at the centre of learning. Upon establishing a learning culture that encourages students to continuously question and challenge their own assumptions, students gain knowledge from a position of questioning, to a position of enacted understanding and eventually, further questioning (Scardamalia, 2002).

The significance of student-generated questioning is often disregarded as teachers have a tendency to emphasise proficiency in the answering of questions (Dillon, 1990; Marbach-Ad & Sokolove, 2000). However, Paul and Elder (2000) assert that student-generated questioning is what spurs thinking and the dogged pursuit of getting the right answers will hamper students from reflective thinking. The authors have suggested that teaching and supporting students to formulate questions will establish a positive environment for critical thinking to flourish (Paul & Elder, 2000). For that to happen, teachers need to provide a conducive environment for student question asking, without overemphasising the need to provide only the right responses in class (Toledo, 2015).

In classrooms, the dominant voice remains purely that of the teachers, and students are merely passive recipients of the teacher's discourse. However, for students to gain a deeper understanding of scientific thinking, they should be active participants and should be familiar with the skills to make scientific arguments based on observations and evidence. Besides, when students formulate scientific arguments, it is based on their reasoning and inference skills, thus familiarising themselves with the language of science (Duschl & Osborne, 2002; Eliasson, Karlsson, & Sørensen, 2017).

10.3 Affordances of the SMILE Technological Platform

We chose an existing educational technology platform, the Stanford Mobile Inquiry-based Learning Environment (SMILE) (Fig. 10.1), as it is free, easily available, and designed specially to support student-generated questioning across a variety of disciplines (Buckner & Kim, 2014). With iPads or mobile devices, students will first go to the homepage of SMILE, where they will log into their accounts. Then they can generate questions in either an open-ended or multiple choice formats.

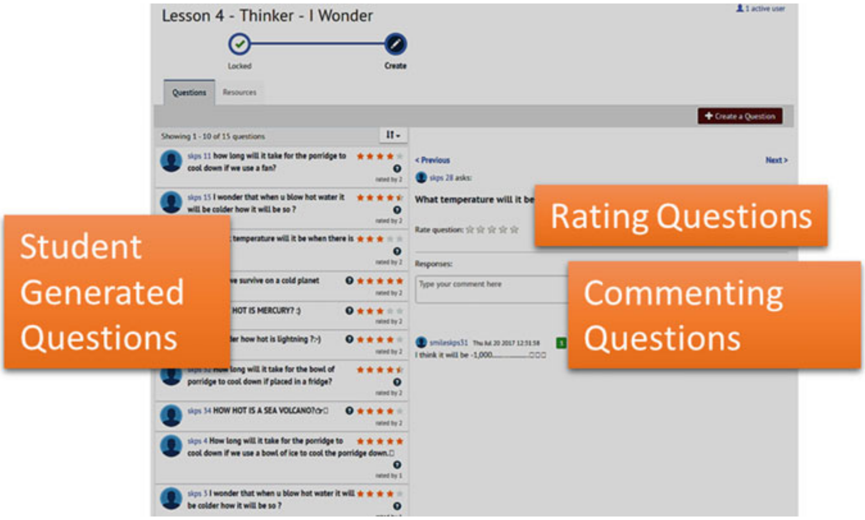

Fig. 10.1 Affordances of SMILE platform

They are given some time to solve or respond to questions generated by their peers and rate the questions on a scale of 1–5, based on what questions they find most intriguing. The entire process is controlled by a teacher using the platform's activity management system interface. The interface collects corresponding data meant for the teachers' analysis and assessment, such as the amount of inquiries generated, average ratings and the percentage of correct responses for each question. There is potential for scalability and sustainability. However, this must go hand-in-hand with the pedagogical practice for it to be effective.

With SMILE, students can review personal and question-related data such as which student answered the most questions accurately and which student created the highest-rated question during their inquiry process. Particularly, when students are observing a scientific phenomenon, they may generate more questions and trigger more discussion. Students respond to and rate each other's questions. In addition, SMILE provides an activity management application for teachers. It allows the teachers to control the progress of the activity in real time and to view all student activity data. SMILE has been tested in various conditions and settings and found positive outcomes (Song, Kim & Karimi, 2012) (see Fig. 10.1).

SMILE could be an appropriate tool for learning because of the identified affordances. SMILE provides unique learning activities that increase learner participation, engagement, motivation, competition, and collaboration, which all lead to better learning and enjoyment. Students specified that they most enjoyed the opportunity to create their own questions and share them with peers. In their study, the participants also reported that they viewed SMILE as a valuable way to review class materials. The students created highly relevant questions for each other with a range of complexity spanning multiple levels of Bloom's Taxonomy (Seol, Sharp, & Kim, 2011).

Fig. 10.2 Students generating questions in the classroom using SMILE

10.4 Objectives of the Study

To address the theoretical understanding of teacher participation in participatory design work, we articulate the following research questions: 1. In what ways did teachers participate in the design process? 2. From the perspective of the teachers in our case studies, what were the conditions that supported them in their participatory design work?

We adopted a case study methodology (Yin, 2009) as an analytical lens to understand a complex mechanism related to structured, yet situated, and emergent practices that characterise the participatory design method. To address the theoretical understanding of teacher participation in participatory design work, we articulate the following research questions:

10.5 Methods

10.5.1 Participants

The study takes place in two primary schools (School X and School Y). The teacher participants are four primary school teachers, one of whom is the Head of Department (HOD) in science. The teachers from the two different schools were developing a shared lesson package for grade four students, centred on the "Think/Puzzle/Explore" thinking routine. For the purpose of this paper, we will examine the teachers' involvement, beliefs and understanding of the process in co-creating the lesson packages, as the efficacy of implementation efforts essentially lie on the teachers. We observed the teachers during the lesson implementation, collected field notes of all lesson design discussions and conducted interviews with them after the study.

10.5.2 Co-designing of a Technology-Enhanced Student-Generated Questioning Approach

The process of moving students beyond their initial curiosity to a cycle of regular questioning can be challenging, especially for educators who are new or have to meet the demands of a heavy curriculum. Certainly, educators will have to formulate their own styles of teaching while engaging in the multiple modes of inquiry in ways that match the students' needs. Utilising an instruction that integrates student questioning is advantageous in that it does not interfere with other forms of pedagogy and can be easily complemented with other pedagogical approaches.

The implementation design comprised a technological component—the SMILE platform (Fig. 10.1), a pedagogical model (Fig. 10.3) and Bloom's taxonomy (Bloom, Engelhart, Furst, Hill, & Krathwohl, 1956). Teachers would first begin the process by introducing students to the concept of scientific inquiry, then by modelling the types of questions students can generate. This process would include guided instructions in small group settings in an attempt to build on students' interests and ideas, ultimately driving students to engage in sustained inquiries of their own.

To examine the theoretical principles of teacher participation in the co-design process, we articulate the following research questions:

- RQ1: What are the teachers' perceptions and issues concerning their current way of teaching?
- RQ2: What are the possible dynamics (considerations, affordances, exchanges) when researchers and teachers co-create lesson packages?

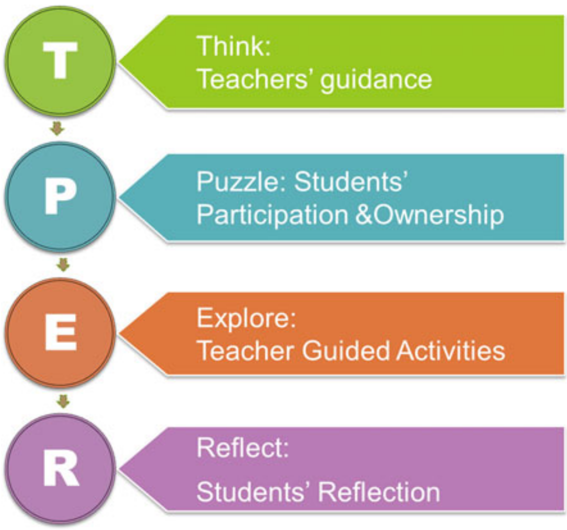

Fig. 10.3 Pedagogical model (TPER) to guide student questioning in SMILE

To address the RQs, we have adopted a case study methodology (Yin, 2009). This approach provides an analytical lens for an in-depth examination of the emergent practices that teachers have adopted to support student questioning through technology. It considers the teachers' goals, motives, their situation and their roles in the research. Additionally, a case study approach could help researchers address the research problem systemically, through the collection, analysis and report of the data (Grauer, 2012).

10.5.3 Data Analysis

The qualitative data were collected from the teacher interviews and discussions. We began with an inductive approach, using line-by-line open coding approach. We identified the emerging patterns and conceptual ideas to code the remaining data.

10.6 Results

In examining the research questions, we will draw on the accounts and excerpts from discussions with the teachers who were involved in the co-creation of the lesson packages. From our discussions, the following implications have been identified.

1. Drawing on teachers' own beliefs for greater ownership

The teachers spoke of their personal experiences and drew upon their and knowledge and beliefs when deciding on joint curriculum decisions. In the collaborative designing of lesson packages, they reflected on their individual school's curriculum and evaluated how they could address some of the misconceptions that students often had. Out of these discussions, they began a process of designing a series of lesson plans that started off with a trigger activity, for instance by examining a phenomenon or conducting an experiment. From the process, the teachers were able to deliver a curriculum that they believed in, one which they had ownership of. These conversations and discussions led to them making shared decisions and choices that reinforced their beliefs in their practice. This is illustrated in teacher C's articulation in her own understanding of designing the lesson packages:

> Generally, our kids are not thinking, they are just receiving a lot of information. But the moment they start to ask questions, it's because they start to think. It's not the questioning that is the thing we want to find out, we want to see how, by giving them inquiry, by giving them puzzlement, getting them to think, what we want is they must automatically become thinkers in everything that they do. It may not be just in science. That is what I want to see in terms of kids thinking more.

In fact, it was teacher M's suggestion of using Harvard Project Zero's Think/Puzzle/Explore thinking routine in the lessons:

> I have some suggestions. This original idea came from the visible thinking framework, which is a pedagogical approach they call TPE. Last year, when we discussed with the teachers, we added another element, R. R is the reflection part, because they need to reflect on what they have learnt.
>
> So the 'P' is What they are puzzled about, the questions they want to ask. They will input questions and the teacher will select those that will lend itself linearly to the lesson outcomes, get students to vote from the preselected questions from the 'P'.
>
> So I see two scenarios in which students will ask questions. First, in every lesson segment, we have a phenomena, we unpack it with them, at the end of that, they will derive a certain concept, so based on that concept, we ask them to generate questions that would apply this concept.

2. Collaborative projects give teachers the chance to dialogue and reflect

Partnerships between schools and researchers can bridge the gap between theory and practice and advance the knowledge base of teaching and learning. Through interactions with researchers, teachers are connected with the research base of the teaching professions. These collaborative projects give both teachers and researchers the opportunity to inquire, reflect and exchange conversations on their practice, enabling theory and practice to mutually inform each other.

Collaborations between educators of different schools are a valuable way of exchanging research knowledge and ideas. Teachers recognise the importance of connecting with other fellow educators, and in learning about ideas that have been implemented elsewhere, teachers can evaluate their own practice, in an on-going process of reflection and decision-making.

> Teacher M: I see this as a collaborative opportunity between our schools for that topic. And a cross cultural exchange. Perhaps what we can do is, let's say discuss and set aside certain meeting times, like once a month
>
> Teacher V: Since two schools are collaborating, can I suggest we do it on a google site, such that they can download the lesson plan directly. Then we can also track what we have done.

One important issue that emerged from the co-creating process was the tensions that arose from the differences in the perceptions and outlooks between researchers and teachers. The researchers were inclined towards more analytical decisions and were looking to hear the teachers' rationale and articulation of their proposed ideas. Teachers, however, were not accustomed to debating and analysing:

> Teacher V: As teachers, our main concern is the scenario we use, and the key questions we need to ask, then the breaking down and capturing of pupils responses. How to make sense of it, we leave it to the experts (researchers).

Teacher V, however, did knowledge that by analysing their decisions and thought processes could be beneficial in their growth as an educator:

> And maybe it can be a learning point for us. Is it because of the way we ask the questions, that we restrict the pupils on asking more questions?

3. The exchange of teaching experience as a resource for mutual learning

While researchers can assist teachers in the design of curricular that supports new insights and new ways of teaching, teachers' classroom experiences play a vital role in advancing the knowledge base of teaching and learning. Rather than adopting an "expert-novice" perspective, this interchange of experience forms a helpful resource for both researchers and teachers. By sharing experiences and expertise, both teachers and researchers engage in a dialogue that informs theory and practice, which is mutually beneficial to one both. Teachers take on a role as "collaborative architects" (Parke & Coble, 1997), where their experiences become integral in informing lesson design, pedagogical approaches, student assessment and choice of methods and materials.

> Teacher C: We don't use the activity book, we have a lesson package that I can send to all. Our package is heat and temperature. We will introduce them to what is source of heat first, then we use the story of Goldilocks and the 3 bears, a continuation. Students have to explore, how to keep goldilocks warm...
>
> Teacher M: We have the resource where we tell students what kind of questions there are, and then we teach them what an investigation is. So it's explicit teaching using the meta language of investigation, for science. So we also emphasize meta language.

It is important for teachers to draw from their own experiences, as it provides applicable and practical support for them in the decision-making process, especially in their assessment of learning resources and how best to redesign and integrate them into their teaching (Markauskaite & Goodyear, 2014). This is illustrated by teacher M's articulation of how she envisioned integrating the TPER model with the SMILE platform in encouraging students to raise more questions during science lessons:

> P, the "puzzlement" aspect, is when the students transform these observations into questions. So it's scaffolded, step by step. Explore is through teacher guided activities in any form, open inquiry, guided inquiry, so the emphasis for explore is the different levels of inquiry based on student's needs. R is their reflection.
>
> We thought of them extending these reflections to application, which is like the students, usually our class is quite differentiated, meaning to say, there are students who are faster in terms of their understanding. So what about the students who are faster……….
>
> ……………. then the SMILE will come in for them to apply these questions into their own questions, that means students ask questions for their peers to answer, for the weaker ones to answer. So if the weaker ones can answer, and then through this collaboration with their peers, then maybe the reflection will be more robust at the end of the day

4. Teachers learn from the process of co-creation

Through the process, teachers build a more informed knowledge base on science teaching and gain insights into how students understand and interpret science concepts. Not only do they share knowledge related to the content of what they may be teaching, they are also able to share and make pedagogical judgements related to the instructional strategies that best befit the culture of their classrooms. As teachers actively discuss their strategies, they gain awareness on how they could confront issues that they may have, with their perspectives on teaching.

As teacher M explains how she conceived the idea of using the TPER model to elicit questions from students:

> Its basis is KWL, but KWL is confrontational. The students will just tell you—I don't know anything. So it's less confrontational when you ask the- what do you think?
>
> If you ask the students—what questions do you have? …No scaffolding, nothing, they cannot move on to the next step. So what you think leads on to what puzzles you(P), based on your observations, and your statements, then you transform them into questions.

Teacher C commented that her students had several misconceptions related to heat and that she had difficulty clearing these misconceptions. Teacher M then explained how she had addressed these misconceptions from her experience:

> C: I don't know how to bring this across to them, that when something is cold, it's just that they have a temperature that is lower than something else. How should I phrase it?
>
> M: When something is cold, it is cold in comparison to its surroundings. It means that its temperature is lower than its surroundings.

5. Using appropriate scaffolding

From our discussions, the teachers recognised that students were not thinking enough, but just "receiving a lot of information", so as a result was not asking relevant questions. Project Zero's thinking routine was a way suggested by teacher M to scaffold the students' questioning process. The students' thoughts, based on their observations, would lead to them being puzzled, and then to be able to transform these observations into questions. As Teacher C shared:

> But the moment they start to ask questions, it's because they start to think. It's not the questioning that is the thing we want to find out, we want to see how, by giving them inquiry, by giving them puzzlement, getting them to think, what we want is they must automatically becoming thinkers in everything that you do. It may not be just in science. That is what I want to see in terms of kids thinking more.

The teachers' rationale and reasoning are aligned with the objectives of the Visible Thinking approach (Project Zero, 2007). The Project Zero researchers devised a set of thinking routines (Think/Puzzle/Explore) that providers offer a distinct structure of sequenced actions that set the path in constructing meaning and awareness of the thinking process in learners (Wolberg & Goff, 2012). Within this predictable context, learners begin to cultivate cognitive awareness in the development of their thinking process (Salmon, 2008). For young learners especially, routines are important as its repetitive nature offers feelings of familiarity and sets them at ease (Wolberg & Goff, 2012). When thinking becomes spontaneous, learners are aware of learning contexts that involve thinking and will develop positive attitudes towards thinking and learning (Salmon, 2008).

The Think/Puzzle/Explore (TPE) routine utilises what students have learnt, urging them to construct linkages with what may already be familiar with, as they inquire about a phenomenon they are interacting with for the first time. In our study, the teacher would start by asking what they already know about heat, following with the prompt, "What puzzles you?" With that, students would conduct an experiment (explore). Our study is unique as the teachers incorporated an additional "reflect" in the routine, where students would write their reflections in their worksheets, or include them in their mind maps. Therefore, this routine sets the stage for students to express their thoughts, participate in dialogue, raising puzzlements on each phenomenon.

10.7 Discussions

Penuel et al. (2017) advocated "co-design" as a suitable methodology for establishing innovations for learning and teaching in real-world classrooms. Teachers' awareness of intentional design and their facilitation to adapt to the profiles of students' questioning tendencies for positive cognitive performance to occur is vital. Teachers must combine the use of the tool with the mindful use of appropriate scaffolding and pedagogy. For it to be sustainable and scaling, teachers must have enough training and willingness to encourage or use students' questions. Teachers must be open and willing to address students' questions that may challenge the teacher's own understanding of issues discussed.

A problem that teachers often face is that they do not have adequate time to grow their instructional design proficiencies beyond just lesson planning (McKenney, Kali, Markauskaite, & Voogt, 2015). For instance, teachers have been critiqued for mostly using design approaches according to past practices that they are familiar with, rather than based on purposefully designed principles and theories (Conole, 2013). Teachers, on the other hand, who are the primary implementers of learning activities, state that they are drained by all the new directives that they have been instructed to implement (Parke & Coble, 1997). Additionally, they regard researchers' perspectives as being too abstract and as a result impractical to put into practice (Shrader, Williams, Lachance-Whitcomb, Finn, & Gomez, 2001).

With the teachers and researchers working alongside each other, co-designing can help the teacher in their professional development and empower them with a sense of agency in decision-making over the curriculum (Penuel et al., 2007). At the same time, researchers can better review the challenges in the co-design process and understand how teachers approach curricular co-design (Penuel et al., 2007; Reiser et al., 2000).

10.8 Conclusion

In this study, the TPER pedagogical framework was designed and implemented through the building of collaborative knowledge environments to move beyond traditional classroom teaching, accommodating more open-ended, learner-centred classrooms to make students play an active role in their own learning and generate their questions and inquiries. As a whole, the technological platform supports the rebalancing of the roles of teachers as facilitators of learning rather than mere transmitters of knowledge. The use of SMILE can assist teachers to surface and address students' doubts, which can help students further their understanding by leading students in the construction of questions. The teacher–researcher co-design practices have also transited into teacher professional learning opportunities as they manage how to effectively access and use inquiry-based pedagogical understandings in their daily practice. Teachers' belief is a critical factor in influencing intentions and implementation for inquiry. Teachers need time and support to effectively develop their skills and beliefs to enable the pedagogical shift required.

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Part III
Meso Layer Ecology—School to School Networks

Chapter 11
A Case of School-to-School Partnership Around Innovation Scaling: Unpacking Failure and Perceiving Growth in Teachers' Capacity for Innovativeness

Mei Ying Tan and Peter Seow

Abstract School partnerships have been put in place to support the decentralization efforts of scaling *technologically mediated pedagogical innovations* in Singapore. This chapter unpacks one such partnership between two schools. Misalignment between the two school contexts (rules, community and division of labour and roles) explain the resulting partnership failure. The case also shows unexpected new partnerships that arose as new roles were enacted at the school or departmental level. The outcome shows that schools' different innovation goals and contexts strongly influence how innovations are implemented at the classroom level. The case identifies key points that should be surfaced in pre-partnership discussions, so that partnerships are better aligned and more synergistic.

Partnerships are crucial for scaling innovations because innovations are by nature disruptive and do not fit with existing ecosystems; therefore, partnerships provide the complementary systems for the innovation to survive and thrive (Adner, 2012). When it comes to implementing and scaling *technologically mediated pedagogical innovations* in schools, partnerships between schools are important as they help to deepen practice—it is the connections *within* and *between* the levels of the communities involved in an innovation (e.g., teachers, school leaders and cross-school partners) that sustain the innovation (Law, Yuen & Lee, 2015; Stein & Coburn, 2008; Toh, Jamaludin, Hung, & Chua, 2014).

The idea that partnerships are important for schools' learning contains the assumption that once partnerships are in place, expected outcomes will automatically follow—but this may not be so in reality (Rincón & Fullen, 2016). Research suggests that breakdowns can happen within and across levels. Stein and Coburn's (2008) four school cases in the United States showed that teachers interacted with subject coaches and specialists but not with leadership at the district level. Law et al.'s (2015) three case schools in Hong Kong mapped the regular platforms for interaction, among

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communities within and across levels (such as teachers and school leaders within and across schools), or between the Ministry (system) level and schools. No interaction was noted for the "district or multi-school organizational" level and other levels (Law et al., 2015, p. 6). These findings suggest that interaction between the district (cluster) and teacher levels may not take place as expected. Thus, in order to fulfil the potential of partnerships for school learning, there is a need to take a closer look at how partnerships are working out.

11.1 Relevance of This Study to the Singapore Context

In Singapore, cross-school partnerships support innovation uptake and scaling. Schools are grouped into "clusters" for the consolidation of resources and sharing of expertise among schools, and each cluster is led by a superintendent (Tan & Ng, 2007, p. 158). This decentralized organizational structure is important as Singapore's education system aims to be both "centralized" and "decentralized" (termed "decentralized centralism" (Tan & Ng, 2007) or "centralized-decentralization" (Chua, Hatch & Faughey, 2014)). There is strong central control in terms of curriculum and assessment, while giving autonomy to schools to make pedagogical decisions (Toh, Hung, Chua, He, & Jamaludin, 2016). Decentralization allows schools "to be creative and responsive" to their students for "greater innovation and variety" (as cited in Tan & Ng, 2007, p. 158). To facilitate such creativity and innovativeness, the central agent, the Ministry of Education (MOE), initiated the *Masterplan for ICT in Education* as the way to encourage schools to use new technology for pedagogical change, and to collaborate over new innovations while retaining control of assessment and accountability measures (Toh, Hung et al., 2016; Hung et al., 2017). Thus, school-to-school partnerships are at the heart of scaling technological innovations in Singapore.

However, in-depth examination of cross-school "laterality" is lacking (Shaari & Hung, 2018, p. 578). This is problematic, since lateral (school-to-school) relationships matter for innovation scaling; an innovation's lateral movement between networks on the ground (such as from researchers to community actors to industry players) also makes it more established in the system (Hung et al., 2017). The possibility of breakdowns in school partnerships needs to be anticipated, otherwise, the spread of innovations among schools will be hindered. Challenges to scaling are not surprising, since pedagogical innovations deviate from the norm and embody new ways of knowing through classroom interactions that are more student-centred, encouraging inquiry and exploration, and self-regulation and critical thinking (Coburn, 2003; Kampylis, Law & Punie, 2013; Toh et al., 2016). Tensions arise in the process of decentralization, as schools work out the enactment of directives from a centralized agency (Hung et al., 2017; Tan & Ng, 2007). Complications that arise include:

> interpretation by schools about the unmovable boundaries established by the central forces… and the means where insights arising from the tactical ground is subsequently consolidated at the central level. (Toh et al., 2016, p. 1248)

Thus, in-depth examination of partnerships is crucial to understanding how they work and where they break down within this complex decentralization process, and how new partnerships may arise as schools' (and teachers') capacity for innovativeness grows.

Current studies use exemplary and successful cases (Hung et al., 2018; Hung et al., 2017; Rincón-Gallardo & Fullan, 2016; Toh et al., 2014). These successful cases have been helpful in identifying the possible factors for successful scaling. However, in-depth analysis of a single case that does not follow expectations can uncover new insights, factors and hypotheses (George & Sennett, 2005).

11.2 Focus of this Chapter

The purpose of this chapter is to unpack what happened in a partnership between two schools in order to explain why the partnership failed. It follows each school beyond the partnership into the establishment of new partnerships. These unexpected developments are then examined in the discussion, especially in terms of school and teacher capacity. The insights gleaned can then be applied for tighter and more productive future partnerships.

This case study was guided by these questions:

- What did the "partnership" look like?
- What was each school's context?
- How did each school's context shape the partnership?

Schools can be loosely connected over an innovation, without giving priority to innovation fidelity, or can be in a process of learning and deepening practice together (Toh, Jamaludin, et al., 2014). This study takes the latter—learning together—as partnership.

Outcomes are qualitative and follow Coburn's (2003) concepts of depth of change in classroom interaction, shift in ownership and spread. These will be described in the case analysis.

11.3 Data and Analysis

"Innovation V" was studied as part of a larger study of innovations funded by *eduLab*, a Singapore MOE program. It ran for 3 years (2015–2018). Innovation V involved 1:1 mobile devices (one for every student) with software applications, enabling students to upload information (such as photographs and comments), and to simultaneously comment on classmates' posts. The innovation was based on inquiry-based learning (IBL). It aimed to help students develop scientific observation skills and dispositions, and to facilitate interaction among students by generating and deepening class discussions.

Four interviews over the two case schools were conducted, with one teacher at each of these levels: (1) a middle manager or experienced teacher, and (2) a teacher who was participating in the implementation. Each interview lasted for about 70 min. The interviews asked about the process of implementation, starting from how the process began, who was involved, and what and how the innovation became more established. The interviewers also probed for details about teachers' own understanding of the innovation and their experiences. An interview was conducted with the Education Technology Officer (ETO) from MOE who was familiar with technology for student-centred pedagogies. The university researchers for the project provided details to clarify the implementation process. These interviews provided a detailed account of how each school embarked on the innovation, the structures for professional development and the roles that various personnel played. The information from the various interviews all contributed to fleshing out details of each school's implementation journey. Additionally, the project proposal provided the purpose and intended outcomes for the innovation implementation.

The accounts of each school were then juxtaposed with meeting notes and teacher reflections. The meeting notes were from planning meetings where the ETO met with teachers of each school. The notes provided insights into how the teachers were making sense of the innovation and what "implementation" looked like during professional learning community (PLC) meetings. The reflections were notes that teachers wrote about their implementation after every lesson, including what went well and the challenges they faced. These personal reflections provided indications of how the innovation was implemented and teachers' perspectives of what did or didn't go well in class. These on-site meeting notes and post-lesson reflections provided indications of how the implementation was progressing. Thus, while teachers used the same terminology to talk about the innovation, what that implementation looked like differed for the two schools. For example, "inquiry-based learning" was one such term used by both schools, but the actual enactment of that approach differed. In particular, the two schools were compared for their goals, school PLC structures, previous efforts to use inquiry-based approaches to teaching and learning, the personnel involved and the roles that they played, how the innovation spread, and what happened after the project ended.

Underlying this case analysis is Piekkari and Welch's (2018) concept of "abductive" data analysis, which rejects the binary of analysing data either inductively or deductively (p. 12). While maintaining an open stance to be surprised by the details of the case, this does not negate the use of theory—in fact, theories are helpful to break through bias and have new insights.

They explain:

> Being able to foster and capitalise on surprises requires an in-depth understanding of existing theories. Prior to entering the field, we need to be familiar with diverse theoretical lenses… This provides us with multiple theoretical resources that allow us to see more than if our observations were guided by a single theory to see the limits of exiting explanations and to provide us with the theoretical resources for novel explanations. (Piekkari & Welch, 2018, pp. 12–13)

This abductive approach to data analysis removes the need to adhere to a single theoretical framework, or having to be totally grounded. In view of this abductive approach, the following theoretical frameworks relevant to this analysis are provided.

11.4 Theoretical Frameworks

Three frameworks were relevant to this study. First, a summary of the characteristics required for successful partnerships to outline the principles that will be applied to this case. The second framework is the *ecosystem metaphor*, which frames the literature on the characteristics of successful partnerships. The third is the *cultural-historical activity theory* (CHAT) which also structures the organization of the findings.

Characteristics of successful partnerships. For partnerships to facilitate teachers' understanding of the innovation, with deep and sustained change in their pedagogical practice and in ways that shift classroom interaction practices (Coburn, 2003), these characteristics should be present: (1) a shared and ambitious vision for student learning; (2) platforms for dialogue and communication; (3) initial trust among potential partners (Rincón & Fullen, 2016; Shaari & Hung, 2018; Toh, Jamaludin, et al., 2014).

The ecosystem framework. This is a hierarchical system with education systems, policies and MOE at the top (Law et al., 2015; Toh et al., 2016). In the middle are schools grouped into the "cluster level" (Toh et al., 2016, p. 207). The levels of the ecological framework (Hung et al., 2017; Toh, Jamaludin, et al., 2014) are shown in Fig. 11.1.

The ecosystem framework emphasizes that the characteristics of successful partnerships should be evident not only among teacher-to-teacher relationships but also across multiple levels of the education ecosystem. For example, teachers learn from

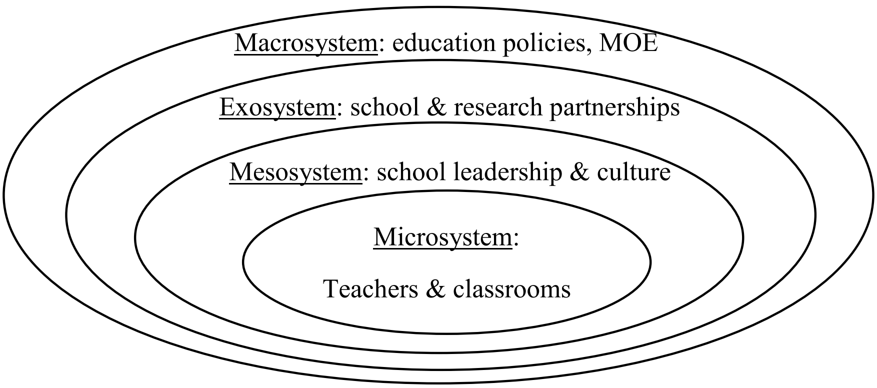

Fig. 11.1 Ecosystem Levels

coaches and specialists, both from within their own school and from other schools as well (Law et al., 2015; Stein & Coburn, 2008).

This ecosystem framework needs to be combined with the cultural-historical activity theory, so that there can be greater attention to each component in the system, and in turn understanding of how these aspects affect the partnership.

The CHAT framework. Human activity involves the use of tools that mediate the objective (Engeström, 1987/2015). Importantly, a tool does not exist in isolation. Cole (1988) strongly emphasized

> the cardinal fact that there is no universal, context-free tool. Rather, all tools embody simultaneously a theory of the activity they have been designed to fulfill and a theory of the human beings who must carry out the activity. (p. 148)

The context consists of “emerging collective traditions, rituals and rules” that arise (Engeström, 1987/2015, p. 63) as the tool is integrated into the collective. Rules include “procedures and policies”, “implicit and explicit beliefs about learning” (Lim & Hang, 2003, p. 57), norms and established practices, as well as assumptions about what is acceptable or valuable.

The process of a tools’ integration into the collective will involve differentiation and “division of labour,” so “a multitude of relatively independent activities” will be carried out simultaneously around the complex task (Engeström, 1987/2015, p. 64). Engeström (2001) points out the multiple historical strands within a system:

> The division of labor in activity creates different positions for the participants, the participants carry their own diverse histories and the activity system itself carried multiple layers and strands of history engraved in its artifacts, rules and conventions. (p. 136)

Historical trajectories of activity systems make it possible to understand why and how the activity came to be carried out in a particular way. This aspect of time can be studied in terms of the “local history of the activity and its objects, and as history of the theoretical ideas and tools that have shaped the activity” (Engeström, 2001, pp. 136–137).

The CHAT framework developed by Engeström is represented by the model shown in Fig. 11.2. The triangle shows where the subject interacts with the tools, rules, community, division of labour, tools and object to achieve the outcomes.

11.5 Analysis of School Cases

This analysis of School A and School B is organized chronologically, beginning from before Innovation V began, its onset and implementation. At each period, certain elements of the activity system are foregrounded: rules, community situation, division of labour, object and outcomes (Engeström, 1987/2015). There will be some overlap in the description; like a glass prism, having one corner in central vision also means that the other elements remain visible, so describing one component may necessitate some description of other elements.

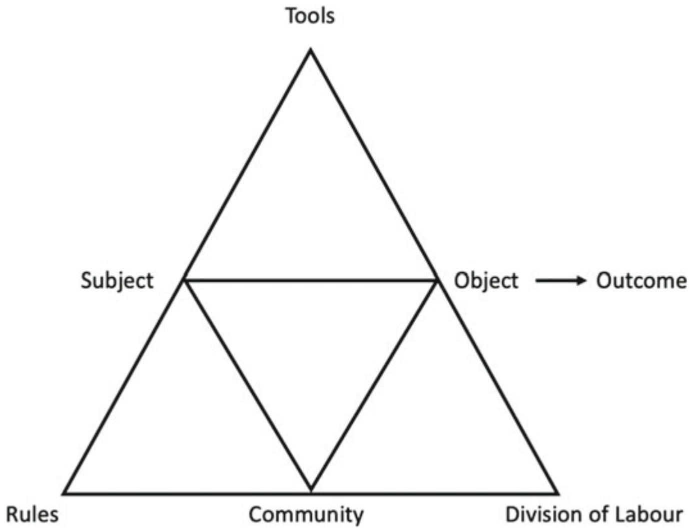

Fig. 11.2 Cultural historical activity theory (Engeström, 2001)

11.6 School A and School B's Partnership Around Innovation V

Innovation V piqued the interest of the cluster superintendent who shared it with several schools in that district. Eventually, two schools, *School A* and *School B*, entered into a partnership to implement Innovation V together. Both schools working and learning together in partnership seemed to be a good idea because it appeared that the characteristics needed for effective partnerships were present (such as mutual trust, as the leaders of both schools were familiar with each other, being members in the same cluster) and other similarities.

Similarities. Both schools were similar in terms of student demographics and composition of student ability levels. Both schools' science departments had already implemented IBL into parts of the Primary Three science lessons, and valued IBL which was core to Innovation V. The same problem was identified: students lacked the interest and observation skills and this was especially problematic for the topic on plants. Thus, there appeared to be a shared vision moving forward.

Both schools had scheduled professional learning communities (PLC) sessions—time for teachers to learn about the innovation together with other teachers (who were teaching the same subject and at the level). The same experts worked with both schools: an Education Technology Officer (ETO) from MOE, and university researchers who were involved in conceptualizing Innovation V. Both schools agreed to work and learn together to implement Innovation V for the Primary Three science curriculum.

Despite these similarities, differences arose between both schools, eventually making it untenable to work together. The schools worked separately, but came together at the end of the project to present to the cluster as if they had been doing the implementation jointly. The rest of this case analysis presents the differences in each school's history; and upon the onset of implementation, differences in rules, community, division of labour (roles) and outcomes.

History. Although both schools had already incorporated IBL into their science curriculum when the decision to implement Innovation V was made, there were differences in how far back in time IBL had been used, and how widely it had been implemented in each school.

In School A, the science department had applied it one year before by re-writing some lesson plans to reflect the 5E (Engage, Explore, Explain, Elaborate, Evaluate) structure for several topics in the science textbook. For School A, the innovation was an opportunity to incorporate technology into the classroom.

School B had started more than 5 years before, implementing IBL across the entire school. Every department was to endeavour to implement IBL. School B had worked on developing a collaborative culture around IBL by having regular cross-department sharing to stimulate interest and encourage conversations about IBL and its application to different subjects.

Onset. When the two schools started to work with each other, friction arose. The *rules* and the *community* reveals misalignments that contributed to the difficulty in working together.

Rules. School A valued being "equitable": all teachers and students in the assigned level should have a chance to try the new technology. School B valued "quality", bringing out the essence of IBL—they wanted to do it "right."

There were more specific rules related to the curriculum. The schools differed in three rules: (1) definitions of IBL and what it meant to "do IBL," (2) a priori commitment to the preservation of existing artefacts (previous years' lesson plans), and (3) how the curriculum is covered.

Definitions of IBL and what it meant to "do IBL". School A saw IBL as walking through the 5E science instructional model. Individual lessons were written to cover each "E": the first lesson on "Engage," the next lesson on "Explore," two lessons on "Explain" and so on, so that each step was "covered" and completed before moving on to the next.

School B acknowledged that their teachers did not know the "right" way to do IBL. Previous attempts to implement IBL were not perceived as "successful" because teachers continued traditional teacher-centred approaches in their classrooms. School B leaders hoped that their teachers could learn IBL anew from the ETO and university researchers in the course of implementing Innovation V. Thus, the school saw Innovation V as a *means* to the *end*—that IBL is fully embodied in classroom teaching and learning.

A priori *commitment to existing artefacts*. School A had gone through one round of re-writing lesson plans to follow the 5E instructional model. These lesson plans could be "tweaked" but not revamped or replaced. Only discrete activities could be replaced, and technological components added, but the structure of the lessons following each "E" in the 5E structure had to remain.

In contrast, School B had no such commitment to previous lesson plans or ways of doing IBL. The vice-principal's (VP) vision was to create new lessons that were true to the philosophy of IBL, lessons that brought out the essence of IBL.

How curriculum is covered. Both schools agreed that Innovation V would be best suited for the chapter on *plants*, to help increase student interest in plants, facilitating observation and discussion on this topic. However, the schedule to cover this chapter on plants differed. This meant that both schools' teachers could not have the (initially anticipated) timely discussion about their implementation experiences, thus affecting their learning together. The different schedule came about because of each science department's way of "covering" the curriculum.

School A covered the science curriculum chapter by chapter. Based on the chapters to be covered by the end of the term, School A could lock down the date when teachers would cover the chapter on plants. In contrast, School B handled the curriculum as whole themes. They deliberated over how they would approach the broad theme on "living and non-living things," including the chapter on plants. The department focused on the big picture first, and they were not yet at the point where they could specify dates for particular chapters. The specific chapter on plants would be addressed during the semester when the time came to cover that theme. School B did not have a specific date for the plants' chapter, but had a broad period where the theme would be covered. Thus, School B's schedule was a direct reflection of how they thought about covering the curriculum.

These differences in the "rules" led to friction. In August 2015, School A communicated to School B the date to teach "plants". This was 6 months before the start of the new school semester in January 2016. School A wanted to start work immediately with School B to complete the joint planning for the plants' lesson, so that the lesson plans would be ready before the new semester began. However, School B was at that time deliberating over the complete revamp of lessons for an entire theme, and how to go bring about deep changes. School A became frustrated with what they perceived to be School B's lack of action. The School A (acting) science head of department (HOD) brought this up to her principal, and the decision was made to move ahead without School B.

Community. The schools' community situation is relevant to their rules. The gap in School A's leadership contrasts with the continuity in School B.

School A's science HOD had helmed the recent re-write of the lesson plans to follow the 5E structure, completed the previous year. She had recently been given a new position as school staff developer (SSD). However, since School A now had no science HOD, she doubled as both SSD and acting science HOD. Her earlier efforts in re-writing the lesson, temporary position as acting science HOD and double workload may have influenced her preference to keep existing lesson plans in their existing form.

The key player in School B's community was the VP who had initiated the whole-school IBL emphasis 5 years before. As the VP neared the end of his tenure in School B (being due for rotation to another school the following year), and recognizing that teachers lacked a deep understanding of IBL, he viewed Innovation V as a wave of opportunity to bring one more surge of change. This round would be different; there would be IBL "experts" (ETO and university researchers) interacting closely with his science teachers. This whole school IBL vision was shared by the incoming VP as well.

Division of Labour (roles). Despite the agreement to work together, when implementation was underway, the ETO and university researchers worked separately with each school. This section describes the roles enacted by personnel at the various ecosystem levels of each school: the *exosystem* (ETO and university researchers), the *mesosytem* (the middle management, such as the acting HOD and experienced teachers) and the *microsystem* (the rest of the teachers).

When School A teachers revised existing lessons, the ETO acted as a *resource person*. He helped the science department to introduce new software applications to the two "tech-savvy" teachers who would later insert the tech-activities into the lesson plans. Meanwhile, the acting science HOD worked with an experienced teacher to decide on what to retain or change in the lesson plans. A few teachers worked on replacing activities. For example, for "Engage," the teachers decided that the historical introduction of the topic that was provided in the curriculum was not "engaging" enough, and suggested a "role play" activity instead, for more active involvement. The process meant the lesson plan had parts replaced or added as it passed down the factory line.

Each week the teachers would meet to discuss their experiences and observations in the enacted lessons. They would review the students' responses submitted on the software applications to better understand how the students were learning. The teachers would make the necessary revisions to improve the lesson plans for better learning outcomes. The acting science HOD maintained existing processes, conducting these PLC meetings and ensuring that the lesson plans were ready by assigning teachers various responsibilities. This role appeared to be that of a *resource manager* coordinating time and human resources to ensure the smooth running of the project.

School B started with a pilot group of two teachers who re-imagined the lesson on "living and non-living things," deepening their understanding of IBL through frequent conversations with the ETO and university researchers, who asked questions to provoke teachers' understanding of what IBL was. They also gave suggestions to help teachers envision possibilities and to help teachers better understand IBL through the embodiment of IBL in their classrooms. The role they played was *knowledgeable other* as they worked on bringing about a deep understanding of IBL. They provided *innovation leadership* to show how Innovation V could bring about engagement with the content and collaboration in class. During this period of interaction, teachers created their own lessons within this interaction with the experts, experimenting on these lessons and reflecting with the experts and each other again—participating as crucial *co-designers* of Innovation V lessons.

School B's VP made refinements to existing school schedule in order to facilitate extended interaction between the experts and teachers. He planned both the work and professional development time so that there would be an additional hour available for one department to have additional PLCs. He chose the two experienced teachers to work with the experts, further reducing their teaching workload by one class so that additional time could be spent to allow for deep exploration of IBL with the experts. He also assured the two experienced teachers that if there was a drop in standardized test scores, this would not be held against them. He recognized that IBL meant less drill and practice and the kind of learning in IBL might not be picked up in the short term by existing tests. As a school *leader*, he strategized for depth in Innovation V implementation and intentionally refined school structures to bring about a pervasive whole-school learning culture.

Outcomes. All School A Primary Three students and their science teachers used the computer tablets for the "plants" chapter. There was heightened interest and engagement as students typed in their observations, took photographs of plants and labelled the parts of the plant. One of the activities on the computer tablet was a set of presentation software (PowerPoint) slides with embedded quizzes and worksheets. Students could walk through the slides and answer the questions at their own pace.

The experienced teachers, however, noted that weaker students had difficulty typing in their observations. These weak students did not know how to "observe", were unable to articulate observations coherently in writing and were confused by the new interface of unfamiliar software applications. Teachers could not make sense of the text that these students had entered, so this student input could not be used to further class discussion. Academically strong students had the writing ability and were able to perform the task of "observation" according to disciplinary expectations. Without as much burden on their cognitive load, they could handle the software applications. This posed an equity issue, which was important to School A—the reason they had decided to use Innovation V with the whole level of Primary Three students was so that it would be "fair" for everyone. However, a new question now arose: The innovation worked—but for whom?

During the Innovation V project funding period, the ETO and university researchers visited School A regularly. Being cognizant of School A's "rules" (described earlier), they did not raise an issue with the lessons, class activities or how students were using the computer tablets. Alongside fulfilling their roles as resource persons for Innovation V implementation, in the spaces between fulfilling this functional obligation, when opportunity allowed, they raised questions. For example, during meetings or at post-lesson discussions, they asked: How might technology help you find out what students are thinking? How can it help you surface misconceptions? How can technology make visible student thinking and clarify concepts that students find difficult to understand?

These questions seemed to fall by the wayside as School A's science department hurried efficiently through the review and execution of lesson plans. However, a "side-effect" when teachers carried out Innovation V lessons was that the teachers began to take notice of what students said or wrote. Previously, they had been listening for the right answers. Now, they began to take note of other answers as well, and would think about where students were coming from—why they were giving these other answers. The teachers began to change their teaching practices as they used technology which helped them to build upon students' ideas.

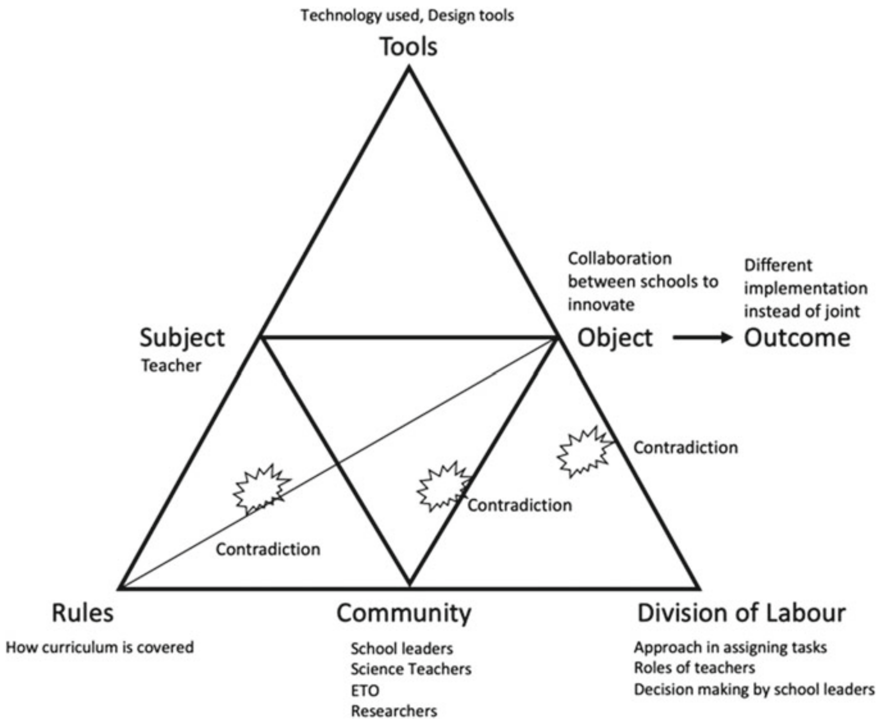

Fig. 11.3 Contradictions in the activity system leading to different outcomes

In School B, the two teachers found that the new IBL approach to teaching science resulted in very different classroom dynamics and interactions. During the inter-departmental sharing, they shared their new insights into IBL and what they were trying out in their science lessons. This piqued the interest of the rest of School B's science teachers.

In Fig. 11.3, the object of the collaboration was to form a fruitful collaboration between the schools to develop education innovation, but the outcome was two different implementations. We explained how contradictions in the rules, community and division of labour led to the different implementation by the schools.

11.7 End of Innovation V Project Funding Period

The next year, School A continued the status quo with the existing revised science lesson plans and maintained the equipment for teachers to use. Implementing Innovation V was optional in this second year. School A ended Innovation V shortly after the end of the funding period while School B continued for a longer period. Eventually, School A and School B gave a joint presentation to the cluster schools on their successful implementation of Innovation V. This seemed to indicate that the partnership was a success as well.

School B continued Innovation V through the second year and into the third year beyond the project funding period. The community (VP, HOD, university researchers and experienced teachers) played overlapping roles (leadership, innovation and curriculum leader).

School B continued to intentionally integrate Innovation V into the professional practice of the next cohort of Primary Three science teachers. The VP carved out one additional hour for professional development hour, which would be rotated fairly among departments. That year, the science department was given the additional hour.

The university researchers continued to be involved, playing the roles of *knowledgeable others* and *innovation leaders*, offering suggestions for possible ways to embody the innovation and participating in the teachers' discussion. For this second run, the science HOD also joined in the PLC meetings.

This second cohort of teachers felt anxious about IBL being implemented over the whole Primary Three level. They were unfamiliar with IBL and worried that without the reduced workload (which the previous pilot group had), they might not be able to master IBL well enough to complete the syllabus in time for the mid-year examinations. Thus, the regular participation of the HOD was crucial. He was a fellow sojourner seeking to understand IBL, so creating a safe environment, a culture of seeking in-depth understanding of IBL. In a small way, he joined in teacher discussions as another *co-designer*. He also suggested ideas, but these were evaluated alongside all other ideas as teachers grappled with how they might do Innovation V in class. At the same time, this HOD had institutional authority and entertained negotiation over assessment matters. This was necessary because the time involved in getting through the curriculum using Innovation V differed from the previous chalk-and-talk method where the teacher could rush efficiently through the content, so this affected what could be covered before the mid-year examinations. Having both knowledge of the curriculum and the authority to decide what was covered in the curriculum made him a *curriculum leader*.

Another experienced teacher was also the *curriculum leader* for the 2017 cohort of Primary Three science teachers. The previous pilot group of two teachers joined in the 2017 PLC to share experience, artefacts (lesson plans) and understanding of IBL, after which the PLC group was on its own. When the semester started, the most experienced teacher taught on Monday, so there was much sharing when the group met mid-week. She taught the students with the highest academic scores. These students asked interesting and thought-provoking questions that would deepen thinking about the topic (e.g., Is hair a "living thing" since it grows?). When she shared these questions in the PLC, her colleagues got excited and they used the questions to arouse interest and stimulate thinking in their own classes, thus building a momentum of excitement and encouraging deeper understanding in the other classes as well. As curriculum leader, this experienced teacher played a major role in helping her cohort of teachers apply IBL meaningfully with their classes.

11.8 Partnership Attempts After End of Innovation V Funding Period

School B no longer gave the science department the additional professional development hour, as that hour had to be rotated to other departments (the English department got the additional hour). Nevertheless, by now a culture of interaction and sharing, of thinking in depth about IBL, was part of the science department. In addition, the science department's work with Innovation V had been shared with the whole school. Therefore, the next (2018) cohort of science teachers for the Primary Three levels had heard about the transformative work that current teachers were engaging in, how IBL transformed classroom interactions and how it encouraged questions and interest in plants. "Inquiry" was increasingly valued and seen to be possible, not only for particular lessons but perhaps even as an approach to teaching that could infuse any topic and be used throughout the year.

Along with the whole school, this third cohort valued a deep understanding of IBL to transform the way they taught science. The third cohort set up their own WhatsApp chat group and identified a time slot where they could meet. This was their own initiative. The science HOD did not join them regularly. Through these interactions with one another, with colleagues and artefacts from Innovation V of the past 2 years, and with off-and-on input from the HOD, this subsequent group made sense of IBL in terms of what it meant and re-envisioned it for their own classes.

Partnership with School C. The cluster superintendent, pleased with the results of the partnership, suggested that School C in the cluster see what School B was doing and learn from the transformative work there. (School C had very different student demographics; its students had much higher test scores and were of higher socio-economic status than Schools A and B.) School C, seeing how School B had three generations of teachers acquire a deep understanding of IBL and hearing about the transformation of student interactions in their classes, was eager to learn more. School C teachers came to sit in School B's science department PLC sessions when they discussed pedagogical issues around Innovation V.

In the fourth year, Schools B and C decided to revamp another set of lesson plans. When this was in place, School A was invited to join in. Each school focused on one of the "E"s of the 5E structure. However, unhappiness arose again; this time in a more public way during a post-lesson briefing when the three schools were present. School A did not find this partnership beneficial to their learning and were unhappy at being asked to join in at such short notice. After that, School A dropped out of the Innovation V network permanently, while School B and C continued.

11.9 Beyond Innovation V: School A's Role Changes and New Partnerships

In the second year, School A sent an experienced science teacher to a management leadership course and then promoted her to science HOD. The SSD no longer served as acting science HOD and no longer helmed the science department's innovation work.

The new science HOD began to engage in conversations with her department colleagues. She took the initiative to stop by their classrooms to chat, share about her lessons and ask about theirs. She raised questions about IBL lessons and listened to their questions and concerns. This effort began to develop a culture of thinking deeply about teaching and learning, where reflecting on teaching with one another was valued. During meetings, she led her colleagues to examine questions such as What is the purpose of technology? What are its affordances and limitations?

The science teachers strongly concluded that in science, it was better to show and touch and observe the actual thing (such as a slimy fish head or a prickly fruit). Technology should only be used if the content could not be accessed first-hand. It could make abstract concepts more concrete. Because teachers began to listen more to students even in other non-IBL lessons, they began to notice where students were confused and to identify misconceptions in other science topics. They realized that it was not the plants' chapter that was most confusing to their students. Rather, their students had difficulty with the chapter on digestion. Students found it difficult to understand the digestive process.

Together, the teachers began working through the questions: How can technology be used? How can technology facilitate the understanding of digestive processes? How might we integrate technology with pedagogy? They explored the idea of using Virtual or Augmented Reality to show how stomach lining cilia reached towards and took in food molecules. Everyone grappled with how this would work. This process differed from the previous "factory line" approach.

Soon the question on resources came up: Where can we get the expertise to help us develop this idea? How might we fund this endeavour? The science HOD reached out to one of the university researchers from connections built during the previous Innovation V efforts, to inquire about possible project partnership and funding. Later, another university with virtual and augmented reality expertise teamed up with School A.

11.10 Discussion

This in-depth case study of a partnership showed the two schools moving along separate paths on the journey to learn and implement an innovation. The detailed analysis revealed many crucial contextual differences at multiple levels of the innovation ecosystem. There were fundamental differences in the history and rules present, governing each school's enactment of the innovation. Although they lay hidden in the background, they contributed to the friction that arose in the partnership. Differences in the roles that each schools' community played shaped the outcomes of the innovation implementation. As a result, the outcomes for the two schools differed greatly, despite it being the same innovation implemented and the same experts helping both schools.

11.11 School Partnerships

This case contributes to our understanding of school partnerships and the roles that shape innovation outcomes. The official partnership that was agreed upon at the cluster (district) level before the start of the innovation was retained as a facade. The friction remained unresolved as each school went their separate ways, but then came back to fulfil their official partnership obligation. They fulfilled this at the end of the funding period by coming together to do the presentation to the cluster. This official partnership expectation remained even after the innovation funding period, and ended abruptly and unhappily. Throughout this partnership, the fundamental contextual differences interfered with the partnership.

It is interesting, however, that while the two partner schools did not work with each other, both developed partnerships with others. School C found School B's work beneficial to their own schools' needs. School A, after the end of Innovation V, explored alternative innovations and sought out partnerships to help them develop their new innovation ideas.

Viewing this phenomena from the innovation perspective, Jamaludin and Hung (2016) used the term "rhizomatic" to describe the trajectory of the innovation:

> a rhizome may be broken but still retains its ability to allow new roots and shoots from its nodes, [so] CIs [curricular innovations] should necessarily be susceptible to fissure based on fluid boundaries and yet affording multiple forms and routes to using and harnessing the CI. (p. 365)

This study examines the phenomenon from a different viewpoint—from within these fissures. It goes beyond description that the phenomenon takes place to explain *why* and *how* these fissures occur.

The "rules" include what each school considered to be IBL in classroom practice: their commitment to historical artefacts (lesson plans), how curriculum was planned and covered, and the procedure that teams follow when undergoing lesson plan revamp. Because learning and implementing an innovation will involve all these areas, rule conflicts can derail a potentially profitable partnership.

Unpacking the roles addresses a crucial gap in existing partnership literature. Rincón-Gallardo and Fullan (2015) identified a characteristic of effective partnerships as "continuously improving practice and systems through cycles of collaborative inquiry" (p. 10). What is missing is the pre-requisite process before such improvement can occur—that the partnership has to first get underway and sustain before such continuous improvement can happen.

Existing studies also state the necessity of platforms for communication, of building trust and having a shared vision for student learning (Rincón-Gallardo & Fullen, 2016; Shaari & Hung, 2018; Toh, Jamaludin, et al., 2014). This study took one step back to address *how* the platforms can be better utilized and *how* trust and shared vision can develop. It unpacked the details that should be communicated during cross-school interaction—what needs to be discussed that would enable better alignment.

11.12 Roles

Existing literature points to leadership as important in scaling innovations (Niederhauser et al., 2018). Their role is "to foster ecological coherence" (Toh, 2016, p. 165). Stating that it is necessary to "have" leadership support for successful scaling cannot be denied, but this framing is limiting because it also suggests that where innovations do not scale, leadership is lacking. And since all schools have leaders, such a framing suggests that leadership is not being provided—which is an unhelpful stance to take. Rather, this study not only unpacks the leadership roles of formal school leaders, it also juxtaposes differing role enactments. Leadership could be *resource managers*, maintaining budget and time resources without affecting the status quo of the innovation. Or *leaders* could be honing and refining systems (such as facilitating within and cross-department sharing) towards a whole-school shift in culture and values. Experienced teachers or middle management could be *curriculum leaders* who participate as fellow learners, using their curriculum expertise, informal authority or official position to encourage deeper engagement and negotiate curriculum coverage and assessment. *Curriculum leadership* is provided by teachers who have a strong understanding of the philosophical underpinnings of the innovation, share the conviction and are able to provide insights on how the innovation will be enacted in their classes. They show other teachers that curriculum and assessment requirements can be fulfilled as they enact the innovation. Thus, leadership responsibility is not only positional, but an attitude shared by other teachers as well, as they work towards the vision for pedagogical transformation (Rincón-Gallardo & Fullan, 2016; Toh, Jamaludin et al., 2014).

Knowledgeable others interact with teachers who are *co-designers* of innovative lessons. There is close involvement of school leaders who provide curriculum leadership and refine professional development structures to facilitate innovation spread and sustainability.

Other roles may be enacted instead. Rather than co-designers, teachers may be *executors* of lessons assigned to them. This approach also scales technology use, with many teachers having the opportunity to try out the innovations, but does not aim for fundamental change in classroom interactions.

This study has unpacked the multiple leadership roles that teachers play apart from their official leadership positions, and shown the changes in roles played by School A's teachers. These findings lead to two key observations. First, a role can be enacted by teachers of different levels. For example, it is not that only middle managers (HODs) can play the role of curriculum leader. Experienced teachers empowered by the school to make decisions on assessment and curriculum can also play this role. Second, a community can shift both in positional leadership (e.g., from experienced teacher to science HOD) and/or have changes in role enactment (e.g., when School A's new science HOD began to ask questions and explore an innovation together with fellow teachers, the roles of leader, co-designer and curriculum leader—even knowledgeable other—were being enacted). Positional leadership and role enactment are related and both affect innovation implementation, but they are not the same thing. Role enactment has the potential to be more fluid (than official leadership positions) if the community is able to make visible and address the rules and history that constrain its actions.

This partnership case shows that it is necessary to find out more about other schools' innovation journeys before deciding to work together. It may be helpful to find out how the other school "did" IBL (or any other innovation). What did it look like? How do they envision it fitting into the curriculum? How do they plan to do it? What are their timelines and goals? Understanding partner school contexts will take deliberate effort through verbal interaction or observation over a period of time. This may mean that school leaders would need to explore partnership possibilities early on.

Future research can use multiple case studies to establish how different types of success are related to particular patterns of role enactment. Rather than ask whether schools and teachers are innovative, or whether the implementation was successful (or not), understanding innovation implementation and scaling across multiple schools should instead seek to understand how that innovativeness and success is being manifested, and how complex school systems (contexts and role combinations and other aspects) contribute to these outcomes.

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Chapter 12
Exploring Teachers' Community-Based Learning: The Case of a Teachers' Knowledge Building Community in Singapore

Chew Lee Teo, Aloysius Kian Keong Ong, and Cera Ying Jing Tan

Abstract The within-school Professional Learning Teams (PLTs) and cross-school Network Learning Communities (NLCs) in Knowledge Building Community (KBC) in Singapore are presented as a principle-based, community-based approach toward teachers' collective effort in advancing knowledge building practice. In this chapter, we explain how Knowledge Building (KB) principles are used to define the work in the community and characterize the trajectories of their practice. By describing activities in the community and examining online discourse, we provide a way to understand the scalability of the design and outcomes in community-based professional development. From 165 teachers' online postings and 12 sets of individual teacher's narrative on KB practice, we report on students' capabilities and learning goals as a recurring problem space for this community. The teachers' reflections on what they gain from the network and on the problem space suggests evidence of a positive impact of the KBC on teachers' practice. With persisting issues of sustaining and scaling innovative practices in education, such principle-based, community-based professional development at both within-school and cross-schools levels emerges as a viable model for sustaining innovative practices. We position the expanding and connecting of communities as a primary condition for sustaining KB practice.

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12.1 Introduction

Knowledge Building (KB) pedagogy is an approach developed from established Learning Sciences theories, specifically knowledge building theories. The theory of Knowledge Building proposes a vision of the classroom as a knowledge creation organization, and KB pedagogy as a non-linear approach to teaching and learning is a corollary of this vision. In KB classrooms, teachers focus on building an authentic culture of collective inquiry. They formulate their procedures and sequences of activities based on what is happening in class. Their focal point is to engage students' ideas and questions daily. KB teachers are more concerned with students' sense-making and interest, rather than merely covering the curriculum script. They also look for student ideas from interactions beyond classroom talk such as listening to what their students are asking during break-time, what intrigued them when they are out on learning journeys, and what are the children thinking of and trying to figure out during classwork.

As student questions and ideas emerge, KB teachers need to understand these ideas and work with students to shape and develop some or all of the ideas. However, the conundrum of supporting idea growth lies in the complexity involved in striking a balance between engaging students' natural curiosity, thoughts, and dispositions during an inquiry and answering the demand of the curriculum script and standardized tests. KB teachers will thus need support to develop open-mindedness with a view to working with students to chart the inquiry process. The basis of this open-mindedness rests on the ability to hold a strong belief in students' capacity to develop intellectually. KB teachers, hence, learn to perceive intelligence as a value that can be developed and not something that is immutable. This belief is often likened to the growth mindset which takes the belief in intelligence as a malleable factor as its starting point in teaching and learning (Claro et al., 2016). As we move further into the twenty-first century where the demand for integrating multi-media teaching tools and extemporizing classroom inquiries seems to be counterweighed by the imperatives of the curricula and examinations, teachers are put under more pressure than ever to address the many and expanding dictates of education. Knowledge Building practice places a high demand on teaching improvisation and certain demands arguably exceed that expected of a competent teacher. As such, extensive community connection and cross-fertilization of ideas are necessary for teachers to remain on the knowledge building trajectory.

This chapter describes our design of community-based learning that aims to provide teachers with a symmetrical experience as knowledge builders as they participate in a Knowledge Building Community (KBC). This community-based learning is designed to embody the KB principles (Scardamalia, 2002) and to facilitate discussion within and across school communities. Foremost, we acknowledge that a KBC is in no way a novel idea given that there are many other knowledge building initiatives in Singapore. However, our KBC illustrates a unique and robust case of KB practice deepening within and spreading through Singapore in the last decade. In brief, we started with two teachers which grew into a community that, at present, includes more than thirty teachers, all of whom engaging in a collective effort to work creatively and productively with students' ideas. We set up localized professional learning teams in each KB school and regularly networked these teachers from different schools in nation-wide KBC events to support them in creating and designing their knowledge building practice. Such network learning has been proven to be beneficial in connecting teachers and helping them sustain and scale up KB knowledge and practice, particularly for those who are sole practitioners in their schools. In the following section, we will unpack the design principles behind KBCs.

12.2 Knowledge Building Communities of Practitioners

Communities of Practice refer to groups of people who are informally bound together by shared expertise and passion for a joint enterprise or to groups of professionals who share knowledge, work together, create common practices, and gather knowledge in a field of mutual interest (Wenger & Snyder, 2000). For example, this can come in the form of a network of surgeons exploring novel techniques or a group of engineers working on similar problems. As Wenger (2011) explained, members in a Community of Practice (CoP) share a concern or a passion for something they do and learn how to do it better during their regular interactions. A CoP, according to Wenger (2011), has three crucial characteristics: domain, community, and practice. A CoP is not merely a network of connections between people but also has an identity defined by a shared domain of interest. In a CoP, members engage in joint activities in order to pursue their interest in their domain and to learn from each other as a community of learners. Rather than being bound by sheer common interest, members of a CoP develop a shared practice through which their domain of interest may be explored further. A CoP is cultivated when the three elements—domain, community, and practice—are developed in parallel.

The concept of a KB community builds on these features of a CoP with a view to extending the boundary of community knowledge. This is achieved through the community's commitment to knowledge advancement. Members of a KB community—who may or may not be bounded by any formal association—are invested in contributing to the collective advancement of knowledge. While individual member's identity, knowledge, and even their personality can be forged through the social processes encouraged in communities of practice (Wenger, 2011), members of a CoP may not see *collective* knowledge advancement as a way of working in the community. In a KBC, on the other hand, members who are neither bound by formal association nor obligation maintain a commitment to the community at two levels: the individual and the collective. Members from a KBC come together not just because they want to gain knowledge as individuals; they are driven primarily by an interest in and a commitment to collective knowledge advancement (Hewitt & Scardamalia, 1998; Zhang, Hong, Scardamalia, Teo, & Morley, 2011). KBCs bring KB principles alive, fostering a common vision which involves mediating the process of idea improvement among members in communities of practice. In the next section, we delineate how KB principles support professional development practices and network activities in a KBC with the intention of nurturing teachers as knowledge builders.

12.3 Design Principles of Knowledge Building Community: 12 Knowledge Building Theories

While a CoP may foster idea-sharing among teachers, it is unlikely to help teachers view themselves as creators of pedagogical knowledge and designers of classroom learning without explicit driving principles that broaden their perspective on the possible roles that can be adopted by an educator. The teachers' limited perspective of themselves as knowledge creators is compounded by the fact that the vocabulary employed in education research, such as 'knowledge creation' and 'designers,' has been rather loosely adopted. A teacher community designed with KB principles can reposition the community's goals not just from individual to collective knowledge advancement but also from teachers as curriculum facilitators to teachers as knowledge creators. In line with Marlene Scardamalia and Carl Bereiter's Knowledge Building (KB) theory, this type of community can sustain "the production and continual improvement of ideas of value to a community, through means that increase the likelihood that what the community accomplishes will be greater than the sum of individual contributions and part of broader cultural efforts" (Scardamalia & Bereiter, 2003, p. 1371).

A teacher community designed with KB principles may be understood as an idea-centric community. In a KB idea-centric community, teachers are positioned as partners alongside researchers and school leaders. They are given the responsibility to claim ownership of and the agency to define their problems in practice. From there, they exercise their autonomy to determine the approach toward the problem they have identified and thereupon set the benchmark against which they will evaluate the success of their practice. This autodidactic process of deriving solutions from self-identified problems trains teachers to learn to be reflective practitioners of knowledge building. KB teachers go beyond discussing and exchanging lesson ideas within their usual social groups; they are driven to continuously improve, build, and reflect on ideas not just for their own practice but also for other members belonging to the community. Keeping the collective in mind, KB teachers work toward helping the expanding community advance in knowledge building, pedagogical practice, and technology design (Zhang et al., 2011).

Building idea-centric professional development constitutes a fundamental aspect of a KBC (see Laferrière et al., 2012). Idea-centric professional development refers to the process by which teachers come together to generate and improve practical and theoretical ideas, to create new solutions to educational problems, and to come up with innovative concepts or ideas about teaching and learning. This idea-centric design is supported by a web-based discussion forum called Knowledge Forum (KF). This online learning environment provides a communal space where teachers' ideas, reference material, results of experiments, and other information can be inputted and continually improved. We explain the rationale and design of this idea-centric professional development according to the 12 KB principles, as shown in Table 12.1.

Each KB principle challenges the community in various aspects of idea-centric practice as well as their idea-centric professional development. The principles of *Real ideas and authentic problems* and *Epistemic agency* challenge teachers to identify problems arising from their practice as a 'knowledge problem'. A 'knowledge problem' may mean broad and open issues that is not easily tackled by ready-made pedagogical packages and 'stop-gap' measures. Hence, in approaching 'knowledge problems', teachers have to constantly think about ways to release agency to students to let them build on solutions. The principles of *Idea diversity*, *Improvable ideas*, *Rise above,* and *Constructive uses of authoritative sources* help teachers appreciate different perspectives of knowledge building, including theories, research, and practices. These principles also challenge teachers to create an idea-rich environment and to develop a keen intuition about which ideas are feasible to pursue in class. Although it may be a struggle to grasp the complexity and messiness of ideas generated by students, teachers will learn to apprehend this struggle as a way of synthesizing new ways of understanding pedagogy and teaching practices. The principles of *Community knowledge, collective responsibility*, *Democratising knowledge*, and *Symmetric knowledge advancement* challenge all teachers to engage in innovating and advancing their practice regardless of their teaching experience in KB. Both novice and experienced KB teachers see the need to connect within and between communities. Finally, the principles of *Knowledge building discourse* and *Concurrent, embedded, and transformative assessment* challenge teachers to continuously refine and transform their KB practice through discussion in the community. From these discussions, teachers engage in creating internal assessments to gauge the success of their practice, which may not just meet but also exceed the expectations held by external mandated assessment.

12.4 Network Activities to Support Teachers' Professional Development in KBC

To support teachers' professional development in KBC, we form professional learning teams (PLTs) in individual schools as well as network learning communities (NLCs) that connect across schools and beyond (see Table 12.2). Within schools, PLTs may involve individual teachers, teacher groups, and school leaders. We conduct the PLTs on a weekly or biweekly basis and design the activities to develop idea-centric practice among teachers. For example, activities in a PLT session may involve teachers in the following: systematically analyzing and discussing about students' ideas, examining KB principles and research, discussing issues and challenges, identifying promising ideas based on broader curriculum or real scientific ideas,

Table 12.1 Applying KB principles (Scardamalia, 2002) as design principles for the professional development of teachers in the KBC

KB principle	Socio-cognitive dynamics	Professional development of the teachers in KBC
Real ideas and authentic problems	Knowledge problems arise from efforts to understand the world. Problems entail ones that learners care about—which are usually very different from textbook problems and puzzles	**Teachers' ownership of the problem**: Teachers see problems arising from KB practice as 'knowledge problems' that they need to figure out on their own rather than to seek ready-made pedagogical packages and 'stop-gap' measures. While teachers might find the process time-consuming, they recognize the work is professionally rewarding. They are motivated to push ahead despite various challenges and sometimes without professional support
Epistemic agency	Participants set forth their ideas and negotiate a fit between personal ideas and ideas of others, using contrasts to spark and sustain knowledge advancement rather than depending on others to chart that course for them	
Idea diversity	To understand an idea is to understand the ideas that surround it, including those that stand in contrast to it	**Teachers' approach to problem**: Teachers appreciate different perspectives of knowledge building, including theories, research and practices. They thrive in an environment rich in ideas and constantly challenge their intuition about what ideas works and do not work in their class. Teachers are comfortable with sharing their raw ideas, and they readily give and take in criticism. Teachers learn to work with complexity and messiness, and they achieve new syntheses out of that
Improvable ideas	Participants work continuously to improve the quality, coherence, and utility of ideas	
Rise above	Creative knowledge building entails working toward more inclusive principles and higher-level formulations of problems	
Constructive uses of authoritative sources	To know a discipline is to be in touch with the present state and growing edge of knowledge in the field	
Community knowledge, collective responsibility	Team members produce ideas of value to others and share responsibility for the overall advancement of knowledge in the community	**Teachers' collective processing of the problem**: All KB teachers, regardless of the number of teaching years under their belt, are empowered to engage in innovating and advancing their practice. Both novice and expert teachers see a need to constantly connect within and between communities
Democratizing knowledge	All participants are legitimate contributors to the shared goals of the community; all take pride in knowledge advances achieved by the group	

(continued)

Table 12.1 (continued)

KB principle	Socio-cognitive dynamics	Professional development of the teachers in KBC
Symmetric knowledge advancement	Symmetry in knowledge advancement results from knowledge exchange and from the fact that to give knowledge is to get knowledge	
Knowledge building discourse	The discourse of knowledge building communities results in more than the sharing of knowledge; as their explicit goal	**Teachers' setting of their benchmark and self-evaluation of their successes**: Teachers continuously refine and transform their KB practice through discussion in the community. Teachers engage in designing their own internal assessment and go beyond expectations from external mandated assessment
Concurrent, embedded, and transformative assessment	Assessment is part of the effort to advance knowledge—it is used to identify problems as the work proceeds and is embedded in the day-to-day work	

sharing practices, and generating critical reflections and dialogues on collegial practices. Through these activities, teachers can deepen their own inquiry process while advancing their knowledge of KB practice collectively as a team by amassing strategies from each other. We conduct network events across schools on a quarterly basis in an effort to broaden our intra-school PLTs to school-to-school professional development. We termed these cross-school communities Network Learning Communities (NLCs). Activities in the NLCs may involve the teachers planning and conducting open classrooms or open Knowledge Forum discussions where visitors can observe KB practices in real time. In the NLCs, teachers and students from different schools also produce and share written reflections (artefacts) after KB sessions. These artefacts, particularly student posters, help to position students' voices at the center of these network learning sessions. In addition, we create a rise-above space on KF for teachers to share and gain new classroom strategies or current knowledge on KB. Taken together, these activities in the PLTs and NLCs work toward *Symmetric Knowledge Advancement* by challenging teachers to constantly connect within and across communities.

12.5 Teachers' Learning from the Network Activities in KBC

To understand the extent to which the design considerations supported teachers in knowledge building within and across communities, we examined the online discourse and network sessions in the PLTs and NLCs. We coded 165 teacher notes

Table 12.2 Designed activities in within-school and cross-schools learning community in the KBC

KBC within school	
PLTs with individual teachers PLTs with teacher groups and school leaders	• Teachers, in subject groups, come together on a weekly basis to systematically analyze and discuss students' ideas—especially the big ideas—in their class. They also discuss possible trajectories of idea growth • Teachers use knowledge building principles to reflect on their collaborative lesson design • Teachers discuss issues and challenges they faced or they might face to instil a commitment among teachers towards KB practices • Teachers identify criteria for promising ideas • Teachers engage in discussion about the curriculum, seeking to understand the bigger ideas and concepts in the curriculum • Teachers share practices and generate critical reflections and dialogues on collegial practices
KBC beyond school	
Network events across schools	• Teachers share design of KB practice and how they focused on putting students' voice at the center of the learning • Teachers invited to plan and conduct open classrooms visits and/or open Knowledge Forum database visits • Teachers engage in learning, chairing, and sharing practices at cross-community NLCs • Teachers and students produce written reflection (artefacts) after sessions • Teachers share and reflect on classroom strategies and understanding of KB through closing discussion or online platform

posted on Knowledge Forum within schools' PLTs and cross-school NLCs. We also examined 12 sets of individual teacher's accounts of their knowledge building practice. Our analyses suggested positive impacts of a KBC on teachers' professional development in terms of the teachers' reflections on their students' capabilities as well as their planning of learning goals. We illustrate these positive findings from a case of within-community PLTs and a case from our cross-community NLCs.

Case 1: Teachers' reflection from professional learning teams (within school)

In one of our schools, the teachers started a PLT session to discuss and analyze students' ideas. The students' ideas were taken from daily classroom practices with the use of Knowledge Forum. By placing the teaching and learning problems within a knowledge building framework, they identified present developmental challenges in the knowledge building activities. From there, the teachers co-constructed a vision for the knowledge building work and they went on to implement knowledge building pedagogy and technology throughout two years from 2017 to 2018. We documented the teachers' discussions in the PLTs for approximately ten months. The team recorded the weekly 2-h PLTs sessions as well as classroom lessons and interviews with teachers and students.

We found that the teachers held positive views about the collective processing in the community. As shown in the quotes below, the teachers reflected positively about how the community has helped them understand ways to bring KB into their classroom.

> I think it is very helpful to see the core design of the lesson as a team. *I can leverage on other teachers' ideas and contribution.* It also helps me learn how to use the kf for facilitating and leading pupils to contribute their ideas. *It also reduces my anxiety* as a novice in using KB for facilitating idea generation from pupils

> *Collaborative energy and knowledge helped me to design lesson to focus on big ideas.* Today's session also allowed me to hear from team members the nitty gritty issues that they face and the creative ways they had addressed or overcome them

Moreover, they showed willingness to test new ideas and changed the course of their knowledge building trajectories as suggested from the quotes below.

> I think I have learnt more about the KB principles that has to be displayed in the lesson. *Sally has provided inputs on my initial draft and it now looks more KB.* My new draft looks much better

> We are always thinking *if we can bring out the KB principles* with the lesson that I have designed?

The teachers' comments also revealed that their reflection on students' capability emerged as a core issue in these discussions. However, within this problem space, we found that the teachers' reflection about students' capabilities shifted in three ways:

- from "attributing difficulties of knowledge building to lack of student capability" to "supporting and seeking possibilities".

> My concerns: *Pupils might not understand that they have two parts to contribute their thoughts (lack of student capability).* I will need to build-on (provide an answer) to the guiding questions based on my class profile and ability. And they have to post at least a short paragraph for their contributions instead of just a one-liner.

> [P]upils will already have some ideas in mind and just have to elaborate on them. *Pupils may not be able to give a quality response on their own. I will have to add more guiding questions to scaffold them (supporting and seeking possibilities).*

- from "dealing with individual differences" to "encouraging student to contribute towards a greater whole" when teachers start to bounce ideas about students' ideas within the community.

> [some] pupils might come up with ideas that *are too broad and diverse (dealing with individual differences) and it is difficult to use them*

> I think I'll discuss with the class what makes a quality/thoughtful post before pupils begin posting. *I'll take a couple of pupils' posts to discuss what else we can build on so that the post is clearer* and richer (*supporting and seeking possibilities, turning higher level agency*)

- attempts to "turn over increasingly levels of agency to students so they can exceed expectations" as they listened to their members' sharing.

> From my member, Jamie's sharing, I have gained some insights into a different way to do idea generation which is more targeted at SBC (Stimulus-Based-Conversation). She gave *sentence frames to help weaker pupils frame their responses* (*turning higher level agency to students*). I may want to try that in my class.

These snippets also highlight how teachers' presuppositions about teaching and learning can constrain their endeavors to work toward an idea-centric practice. The teachers' accounts also illustrate how a community-based professional development has pushed them to see possibilities beyond their own interpretations and experiences. As Lampert (2010) posited, teachers have to face the consequences of their actions every day and the problem space they create tends to rely heavily on the way they rationalize teaching and learning. Moreover, teachers' perspective of students' capability influences the way they rationalize teaching and learning (Lampert, 2005). Thus, a dilemma often shared by KB teachers is that of their students' capability. Teachers who facilitate idea generation on a more surface level and continue to control the inquiry process and to determine the inquiry path may be creating a learning environment in which students are not receiving opportunities to engage in higher-order thinking. Teachers adopting such an approach may think that underlying this approach is the assumption that it is relatively easy to control idea development. However, this misconception may restrict students to didactic learning and limit them from developing learning and thinking agency. It is thus imperative to foster a culture among the teachers that entails constantly breaking away from preconceptions of what their students are capable of achieving.

Case 2: Teachers' design of practice in Network Learning Communities (across schools)

The Network Learning Community (NLC) is a cross-school community session organized every 3 months to promote shared ownership, to support teachers who are sole KB practitioners in their local sites, and to break away from existing culture in individual community.

Design of NLC. The NLC promotes a collective effort by which schools take turns to host the sessions throughout the year. All NLCs are organized with a focus on tackling collective problems of understanding in the knowledge building practice such as idea-centric practice. Each NLC serves to unpack the different theoretical and practical dimensions of this perennial problem of practice. In every session, KB lead teachers help to co-design and bring knowledge building culture to the local school community. Researchers would also spearhead efforts to look into research ideas generated from these problems of understanding. Each session of NLC drew an average of fifty teachers from five to seven schools, which amounted to about 120–150 participants.

Purpose of NLC. As the core purpose of this cross-school knowledge building community is the envisioning and shaping of prospective focus and work in KB classrooms, one of the common features of NLC is to invite participating teachers to share their knowledge building stories. KB stories aimed to capture individual teacher's unique pedagogical moves based on their students' emerging ideas. Participants from different schools are grouped according to their teaching subjects for in-depth discussions surrounding these KB stories. Each sharing session would conclude with a facilitated discussion to help teachers to bring back the focus on a principle-based approach to teaching and learning.

Findings from NLC. Using the teachers' KB stories from one of the NLC (presented as PowerPoint and posters), we surfaced a common thread of problem space on "teachers' learning goals" across all KB stories showing how scaling of practice can take place. Our analysis suggested that the learning goals are strongly connected with how the teachers perceived their students' capabilities. We found three different types of teacher ownership in the process of identifying problems and devising solutions:

- Short-term learning goals
  Goals that focused on increasing and improving specific exam-focused competencies, e.g. students to elaborate on specific points in a composition writing exercise. Such goals tend to reveal a linear progression in the KB story, manifesting the teacher's deficit mindset regarding students' capabilities. This mindset closes up possibilities for KB moves to help develop student ideas and questions organically and authentically.

- Mid-range learning goals
  Goals that focused on learner-centred pedagogy and on students learning to learn, e.g. students to generate different ideas for the story-writing exercise. These mid-range goals can be problematic in the sense that teachers may not actually intend to develop generative 21st century competencies; rather, they may be reducing these competencies to exam-related skills. For example, the success criteria enumerated in a teacher's KB story goes: "students' write-up is in a logical sequence; use 5W1H (Who, What, When, Where, Why, and How) to give details; use interesting and suitable words" (Fig. 12.1). These success criteria, though important, may not always be sufficient to sustain the idea-development and idea-improvement processes.

  Moreover, embracing mid-range learning goals may mean that the learning improvement remained in the hands of the teachers, and seemingly followed fixed and linear stages that students need to progress from one to another. For example, learning improvements mean the teacher giving suggestions for refinements, as shown in the teacher's comment from the same KB story.

  > Pupils have completed idea generation, building on and also written their improved write-up. They have also done the first draft for their individual writing. I am in the midst of marking their compo and will be giving them suggestions for further refinements.

- Long-term vision of idea development
  The long-term vision of idea development involves teachers focusing on developing students' natural curiosity and teachers' ideas on the expansive mindset of students' capabilities in a more organic manner. Figure 12.2 provides an example where the teacher's story depicted a constant challenge to students in extending their learning through exploration, discovery, and discussion. Long-term vision

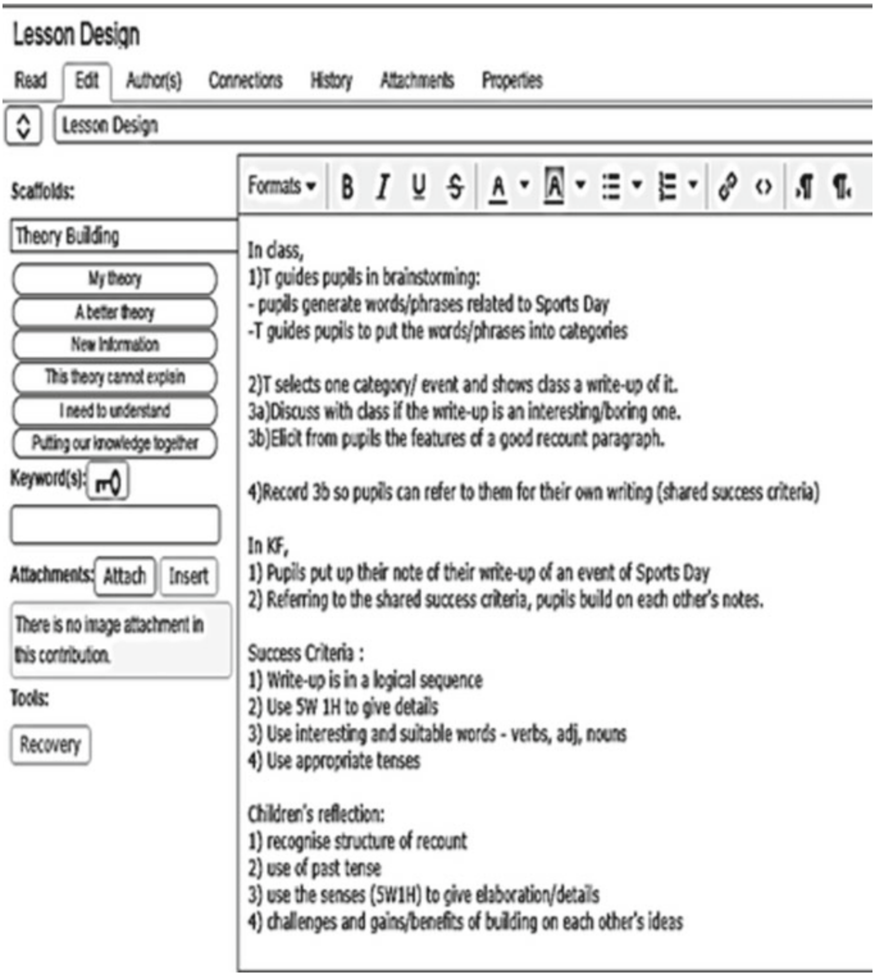

Fig. 12.1 A screenshot of the teacher's KB story depicting a procedural approach to lesson design and little reference to knowledge building principles

of idea development requires teachers to embrace goals aligned to KB principles and involved them asking question such as "Are the ideas brought into the class authentic to the students?" and constantly seeking for opportunities to allow students to pursue higher learning on their own.

Teachers' design of practice in Network Learning Communities: From "show me the full flow of a KB lesson" to "we come together and think together".

Although teachers generally found the sharing of lesson design at NLC useful, some of them continue to seek fixed solutions. An excerpt below illustrates how a teacher is requesting for a conclusive case in which KB has been successfully integrated into the lesson plan:

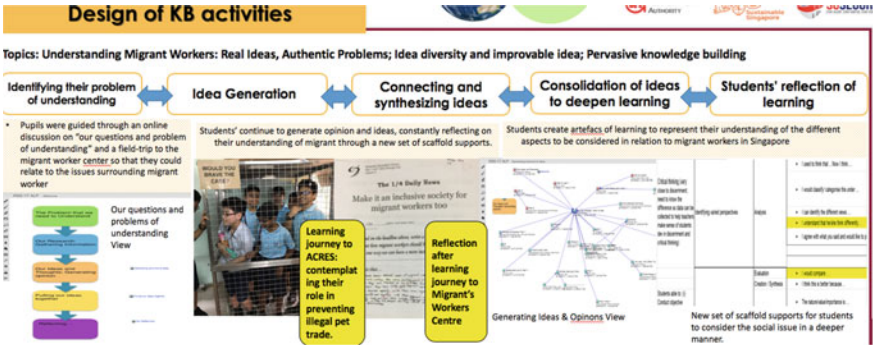

Fig. 12.2 A screenshot of teachers' depiction of a series of KB activities in the class, challenging students to explore the topic of "migrant workers"

> …how more on how it has been applied successfully, in the curriculum, showing the FULL flow of a KB lesson. From KB discourse, to strategies used to facilitate the KB lessons and KF platform, the rise above and evidence of how the pupils have benefitted from this pedagogy... I need it to be an example for how I could conduct my KB lessons.

The teacher's request implies a heavy reliance on tried-and-tested strategies in regard to KB lessons. Rather than looking for suggestions, the teacher in the above excerpt seems to be soliciting for ready-made solutions to potential problems that a KB classroom might anticipate. By regarding a fixed solution as the endpoint of knowledge building, these teachers may struggle with the vision of students' outcome in knowledge building classrooms.

Not every participant reflected positively on their learning at these NLCs but many are challenged to share and reflect on their understanding and practice through connections with other members of the community. Through KBC, any emerging conflicts and tensions can serve as the impetus for generating ideas for solutions to the problem of sustaining and scaling KB work. KBC develops teachers' idea-centric practice whereby they are constantly reviewing and refining their solutions or ideas and approaching problems from multiple viewpoints. We demonstrate the generative impact KBC has made on the teachers from two excerpts below:

> I felt this was something I have been looking for all these years of teaching, bringing the students' ideas into the class, listening to their interpretation, I am really going to try this out in my class. (Excerpt 1)

> … really to teachers the new pedagogy to explain that we can now use immediately with the class, it's amazing. So it's not something that's segmented, isolated and kept in the file, then something we can use later. But everything is happening now, so it's very exciting when you're in it, when you're doing it together and… it all makes a lot of sense…I think when we come together and we think together, and it becomes so comfortable, I can talk about a lesson where it doesn't go so well, and it's okay. My friends will tell me how to improve and how I can do better. So I think the PLT and NLC thing for KB is excellent. It really is the core of us trying to be teachers. (Excerpt 2)

In Excerpt 1, the teacher's reflection shows how her practice has been refreshed with KB. The undercurrent of reinvigoration in the excerpt implies how KBC has provided the teacher a fresh outlook on teaching. Similarly in Excerpt 2, the teacher seems to be reinvested in innovating her practice with the support of PLTs and NLCs. She is particularly struck by the practical immediacy of participating in KBC events.

In summary, our two cases show how the within-school community (PLTs) and cross-school community (NLCs) are necessary to continuously push the boundary of KB work. Both PLTs and NLCs allow regular discourse and interactions between teachers and researchers to understand design and implementation challenges and to advance knowledge such as implementation strategies. Such communities also provide continual and ongoing collegial and professional support which is likely to help teachers gain more confidence in extending the innovation to their individual practice and across departments and schools. The principle-based approach driving our KBC guided teachers and researchers in an idea-centric practice and encourages ongoing reflection on practice. These aspects of KBC may constitute key design considerations for a community-based model to both sustain and scale up innovative design practice in schools.

12.6 Conclusion

Twenty-first century pedagogies, such as knowledge building, require high levels of commitment and conviction from educators to pursue and to make it a reality in their own classrooms. In this chapter, we described a principle-based community approach aimed at supporting knowledge building teachers to take ownership of the problematization of and solutions to their teaching and learning problems. We examined teachers' views on and experiences with KB pedagogy through their participation in professional learning teams (PLTs) within schools and network learning community events (NLCs) across schools. Our findings highlight the importance of the KBC as a ground-up community approach, as the PLTs and NLCs positioned teachers as knowledge builders and provided them a platform to share practices and reflections. These interactions and engagements constantly push them out of their comfort zone so that they may exchange ideas and experiences that refresh their own KB practices.

From our findings, we showed that the persistent tension involved in determining the problem of practice can be resolved through the community-based learning. Not surprisingly, many teachers continued to struggle to utilize knowledge building practice in their class, as the learning goals that they are most familiar with were often different from those endorsed by knowledge building classrooms. Furthermore, they struggled with preconceived notions of students' ability to engage in knowledge building and they found difficulty in letting go of control in student learning processes. Moreover, the teachers tended to have a certain expectation of fixed solutions to problem-solving. These challenges highlight the necessity of community knowledge sharing but also magnify the difficulties of such community-based knowledge building approach to professional development. Through the principle of *Symmetric Knowledge Advancement*, we saw that teachers need to reconsider the presuppositions they carried to KB learning and we also highlight ways in which teachers' reflection about students' capabilities can shift toward a radical idea-centric practice.

A principle-based community approach to KBC can generate opportunities for teachers to shift toward more positive perceptions of student capabilities through community interactions. The analyses from case 2 further showed that teachers can scale up in practice by planning for progressively longer-term goals of teaching and learning which emphasize more on developing students' natural curiosity and expanding students' capabilities in idea-generation. By taking on a long-term vision of idea development, teachers become knowledge builders themselves. This uptake process among teachers is continually supported and enhanced by community-based learning through both PLTs and NLCs. As such, we concluded that school-level and beyond school-level community support coupled with a principle-based approach to guide professional development serve as key aspects for a community-based model with a view to scaling innovation practices or pedagogy.

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Chapter 13
Use of Immersive Environments for Learning in Singapore Schools, 2009–2019: Lessons from a Decade of Scaling and Translation of the Disciplinary Intuitions/Six Learnings Programme

Kenneth Y. T. Lim, Ming-De Yuen, Ahmed Hazyl Hilmy, Sheng Yang Chua, Joshua Lee, and Joel Ng

Abstract This chapter describes the lessons learnt during the initial 10 years of scaling and translating a suite of learning interventions under the collective umbrella of the Disciplinary Intuitions/Six Learnings programme. The Six Learnings curricular design framework has been used in the design and development of lesson units in several schools in a variety of subjects. The programme leverages primarily open-source tools and platforms to help teachers design canvases within which their students can express their emerging conceptual understandings. In this way, students' thinking and intuitions—which would otherwise be largely tacit—are made visible and can be developed through dialogue with peers. Learning is, thus, more enduring as first-principle understanding is built. The chapter analyses the scaling and translation through the SCAEL frame. Through two case studies, principles for wider application to other subsequent interventions are suggested.

13.1 Introduction and Background

Since 2009, the Six Learnings curricular design framework (Lim, 2009) has been used in the design and development of lesson units in several neighbourhood schools in a variety of subjects. The programme leverages primarily open-source tools and platforms to help teachers design canvases within which their students can express

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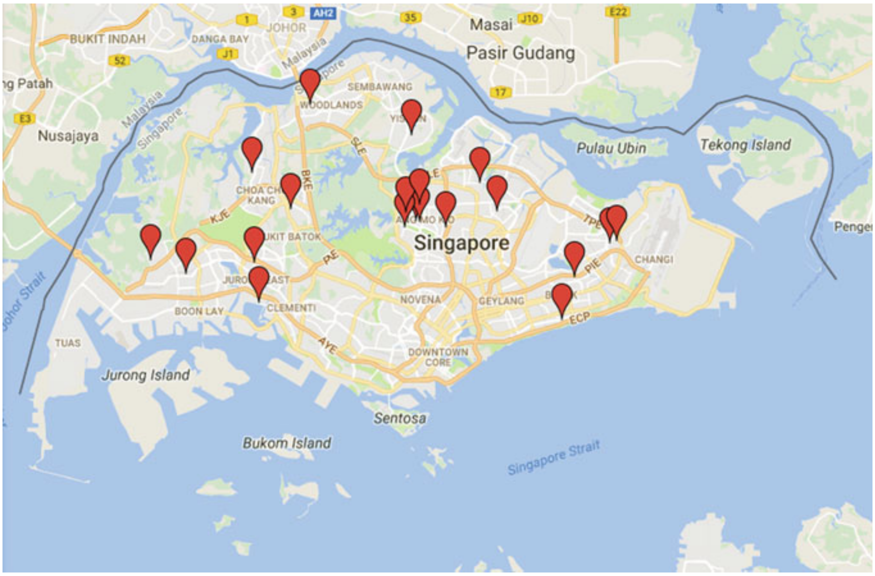

Fig. 13.1 Scaling the disciplinary intuitions/six learnings programme: schools in Singapore in which professional development sessions have been conducted

their emerging conceptual understandings. In this way, students' thinking and intuitions—which would otherwise be largely tacit—are made visible and can be developed through dialogue with peers. Learning is, thus, more enduring as first-principle understanding is built.

By July 2015, more than 100 teachers from 13 different subjects and grade levels—from Grade Five to First-Year Undergraduates—had undergone professional development on the programme. These teachers came from a total of 17 schools across Singapore. The scaling and translation of the programme are depicted in Figs. 13.1 and 13.2.

The objectives of the programme have evolved over time.

Some of the objectives arose from the context of taking the lessons learned from the earliest 2009–2011 curriculum interventions in geography that were conducted using the virtual world of Second Life and extending them in the following ways:

- extend the learning to open-source platforms;
- extend the curriculum design principles to new demographic cohorts;
- extend the design principles by conducting lessons using a greater variety of teacher–learner interactions (e.g., regular classrooms as opposed to computer labs and using the programme in non-formal learning contexts [e.g., after-school settings]);
- extend the design principles to new subject areas;

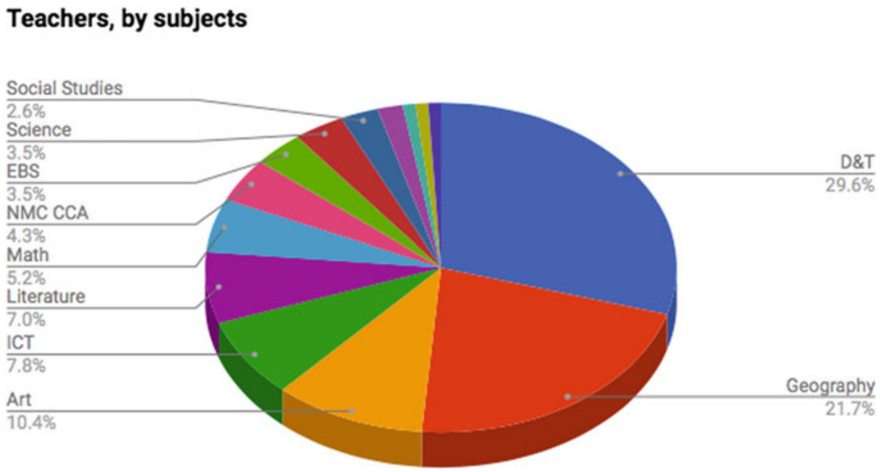

Fig. 13.2 Translating the disciplinary intuitions/six learnings programme: subject domains of teachers who have attended workshops

- explore the possibility of building learner capacity through, for example, working closely with schools' IT Clubs with a view to establishing a model of sustainable school independence from vendors—in terms of building learning resources using generic industry-standard tools operable over a variety of environments and contexts;
- through the latter, conduct inter-cohort peer-tutoring as a model of collaborative learning and socio and self-regulation for at-risk students;
- by doing all of the above, continue to build teacher capacity in designing their own curricular units.

The programme has evolved over the years through teacher-driven adaptation. Teachers in these schools have, of their own accord, conceptualised and designed ways of enacting new pedagogical approaches to meet existing curricular needs—using the theory of Disciplinary Intuitions (Lim, 2015) as a frame.

This chapter discusses scaling and translation in a system of education, using the case of the Disciplinary Intuitions/Six Learnings programme and how it has evolved since 2009. Information about the programme can be found at http://sites.google.com/site/disciplinaryintuitions/.

The chapter advances the argument that successful scaling and translation are predicated upon a set of design principles—wider to the intervention itself—and concludes with discussion of a principle that has emerged over the past 2 years of the programme.

13.2 Designing for Sustained Scaling and Translation

The experience of the programme team looking at the reasons for the success and failure of preceding funded projects tells us that principal investigators are (rightfully) very concerned about lethal mutations, and the "tight-but-loose" debate that lethal mutations engender. How does one represent tight-but-loose in a scaling framework? How can one have the confidence to be loose, and how tight is too tight?

A model of scaling up that can explain the failure of scaling for certain projects is the SCAEL model, a context-sensitive translational framework that can translate theories to practices in educational change. SCAEL, which stands for Scaling Community, Conditions, Culture, and Carry-overs (4Cs which we would represent as C) through Apprenticing and Ecological Leadership, is a translational pathway that is not currently widely used in education today, but its advantage lies in its emphasis on building people capacity (software) for particular innovations and adapting scaling processes to the contexts (hardware) that surrounds particular innovations. By building people capacity, tight-but-loose variations in scaling can be achieved.

Furthermore, certain prior funded projects originating at the National Institute of Education (NIE) failed to scale because—although the theoretical bases were very strong (e.g., Gee, Shaffer, Bakhtin, etc.)—the projects went straight from theory to implementation without due consideration for the curriculum framework supports. The SCAEL model, however, would have required adapting the model to the indigenous context first, which allows the actual stakeholders to grow alongside the growth trajectory of their scaling. After all, the scaling process is a social phenomenon and it requires support from ecological carryover effects to succeed.

From the experience of analyzing the Disciplinary Intuitions/Six Learnings programme (e.g., through the NIE grant OER 13/10 LYT), it could be reasonably posited that scaling can take place along many dimensions, such as age cohorts, academic streams, subject disciplines, between formal and informal learning contexts, etc. All these dimensions constitute potential avenues for scaling.

These dimensions are depicted in Fig. 13.3. As depicted, the strands (representing dimensions of scaling) are tightly clustered near the bottom of the figure, constrained by a robust curriculum framework and Technological Pedagogical Content Knowledge (TPACK) (Koehler and Mishra, 2009) supports. These strands of scaling are founded upon a strong theoretical base (in this case, Disciplinary Intuitions, but it could just as well be other theories of learning). This strong theoretical base provides a constant check-and-balance as to whether the mutation is lethal or not, whether it is valid or not. Likewise, the mutation needs to align within the curriculum framework (in this case, the Six Learnings curriculum framework, but it could well be other curriculum frameworks). If the mutation cannot align with the curriculum framework, then it is likely lethal. Likewise, if the mutation cannot be traced back to being informed by the theory base, it is also likely lethal.

On this point, the SCAEL model again teaches us that in order to have a sustainable model of change, that is, to avoid lethal mutations from corrupting the scaling, we

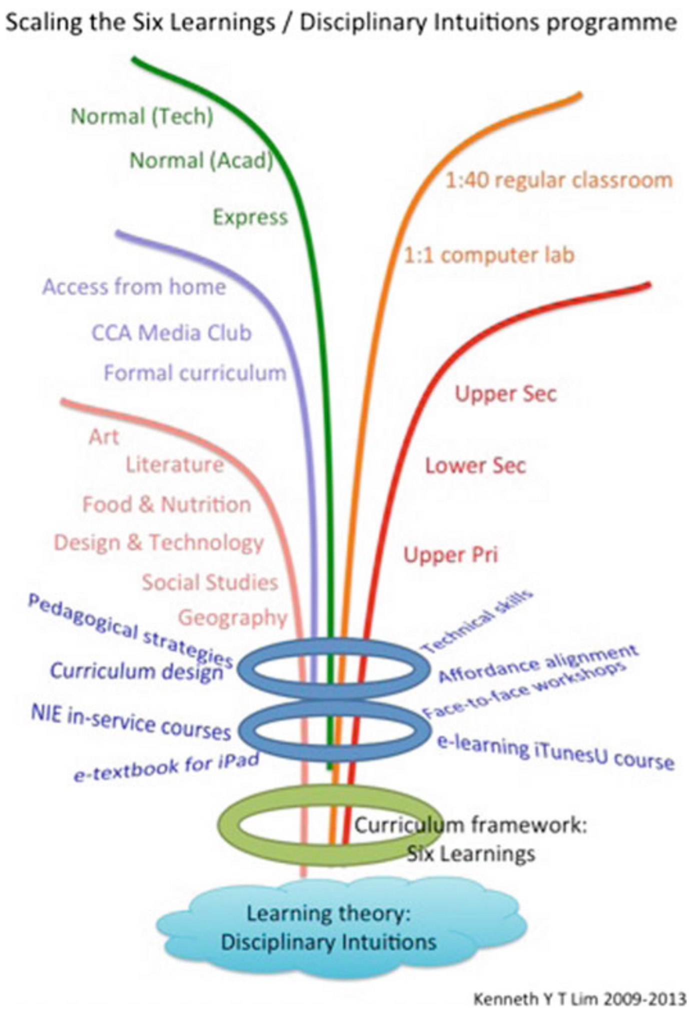

Fig. 13.3 Conceptual framework for scaling and translation

need to adapt the model of change to the indigenous sociocultural context. The SCAEL model proposes a framework of implementation that is context sensitive, with its key strategies being rapid prototyping and iterative design frameworks. Under this framework, it is much harder for unaligned and untracked mutations to form and spread.

The top half of the figure below shows the divergence of the scaling dimensions, representing mutations actively taking place. These mutations can occur along any of the scaling dimensions represented in the figure, instead of being simplistically characterized as “this project scales from one school to five schools.”

The SCAEL model accounts for this non-linearity by acknowledging that change percolates up and down the macro, meso, and micro-layers in any system. Fidelity can be maintained by ecological leadership that is built through apprenticing at the meso layer, which constitutes, for example, teacher leaders championing innovations and/or cultivating other teachers via NLCs/PLCs. The micro-layer refers to the school as a unit, and a teacher from the micro-layer is best suited to be an innovation champion and ecological leader. The macro layer comprises of the school leaders and education ministry.

To sum up, the theoretical base is strongly associated with the curriculum framework, but this is not necessarily exclusively so. Because the lesson units are designed according to six possible ways in which immersive environments and game-based worlds might be used for learning (i.e., in terms of collaboration, in terms of identity-formation, in terms of championing causes, in terms of expressing their learning to external audiences, in terms of design-thinking and prototyping, and in terms of self-directed exploration and interaction), and, because the Six Learnings curriculum framework is itself founded upon a theory of learning which foregrounds the (otherwise tacit) intuitions which students bring to the classroom, the lesson units can withstand much mutability while still remaining true to the overall intent behind the learning outcomes.

13.3 Literature Review

Translation science is relatively young. Academic papers and research reports with an explicit focus on translation seem to have been published in any significant numbers only since the turn of the present century. Much of this early body of literature has arisen from research into issues regarding the translation of research into practice in the related fields of medicine, pharmacology, the health sciences, and health education. Because the field is still new, its nomenclature and key notional definitions are still very much a contested space. It is critical, therefore, that any macro-socio-political system that seeks to foster translation should at least seek to establish commonly shared understandings among all stakeholders from as early a stage as is practicable.

Notwithstanding the preceding argument, implicit in any conceptualization of translation is the notion of bridging across heterogeneities. Expressed another way, once a given research intervention is extended and scaled to any significant degree, it is more likely than otherwise that the socio-cultural contexts within which these subsequent iterations of the intervention are embedded will differ from those of the original. Coburn (2003) makes this very point—that is to say (taking some paraphrasing liberties), scale is more than just the number of schools. Instead, he suggests that other performance indicators of scale (with regards to research innovations) include the nature of the change envisaged, the degree to which it is sustained, and the degree to which practitioners have the knowledge, authority and capacity to evolve the original intervention over time. Coburn, therefore, argues that discussions of scale must be broadened to include the dimensions of depth (in terms of shift in beliefs, norms, and/or pedagogical principles), spread (both outward from, and inward within schools), and shifts in reform ownership. Together, these three dimensions circumscribe a fourth—namely, sustainability—which he acknowledges to be beyond the locus of design control of any single intervention or research team, as this latter dimension speaks towards long-term systemic change. Of note is that these dimensions are process-included where mindsets and "soft" capacities are developed in the social contexts of subsequent iterations.

Returning to the aim of establishing shared common understandings about scaling, Coburn's model is congruent with the SCAEL model of sustainability, which adapts a scaling to the indigenous socio-cultural context. In the SCAEL model, this means that there is recognition of the variations in how education systems function and their historical, national, and regional policy contexts will exert different degrees of influence on the institutions' work and the day to day role of leaders in schools (Day & Sammons, 2013).

In light of the afore-mentioned considerations of context-heterogeneity, Thompson and Wiliam (2008) have raised caution about the tension between the wish to maintain fidelity with the original research design, with the need to be flexible about each successive iteration thereof. Their mantra of "rigour without rigidity" speaks through a glocalized lens as it calls for the research-practice community to stay focused on specifics while "sweeping in the place-based particularities." Because of the challenges inherent in managing these tensions, they frame as critical the need for common understandings by all (local) stakeholders of any given intervention not only of the theory of action itself but also of what is not part of it; in their view, explicating what is not part of the theory of action facilitates informed decision-making about what can and cannot be relaxed "in the face of contextual challenges." These explications need to be clearly codified for the benefit of all members of the research-practice community.

Several prominent figures in translation science have echoed this view, including Croyle (quoted in Glasgow & Emmons, 2007) and Schillinger (2007). Croyle, for instance, has called for the research-practice community to design for "the minimal intensity needed for change," advocating Rose's (1992) position that a population-based approach ("multiple contacts over time through lower-cost strategies") has been consistently demonstrated to be more effective at achieving sustained change across a population than intense, selective, "boutique" projects conducted within a micro-localised homogenized target population. Glasgow and Emmons (2007) have spoken very clearly that "intensive costly interventions and highly selected participants reduce the generalisability of the study and the likelihood of translation." As such, he cautions strongly against researchers placing too much of a design premium of efficacy of the original intervention, at the expense of external validity. Schillinger (2007) acknowledges that such paradigmatic shifts would not occur overnight and need to be encouraged by a corresponding shift in understandings by both funding agencies and grant reviewers. Such views are not discordant to situative stances and they emphasize that we should not overclaim situativity (and hence micro-localized homongenized target populations) in which spread through lower-cost strategies are possible without compromising rigour.

In the translation literature, it is generally accepted that there are two broad thrusts of translation (Institute of Medicine's Clinical Research Roundtable, Sung, Crowley, Genel, & Salber, 2003). These are, namely, translational research (T1) and translation research (T2). T1 refers to deductively derived research interventions, which have been enacted within relatively homogenous and resource-rich contexts. T2 refers to the dissemination, implementation, and diffusion of T1 research into community practice and policy (e.g., Narayan, Gregg, Engelau, & Moore, 2000 and Schillinger, 2007). In turn, dissemination refers to how the targeted distribution of information and intervention materials can be successfully executed, implementation can be thought of as referring to the implementation of content (the interpretation by practitioners of the research evidence and of the codified intervention) within a given (political/professional/socio-economic/organizational/attitudinal) context, through the process of enacting and engaging in strategies for change in (and, and) management practices. As for diffusion, the lens is turned on the factors for successful adoption of the intervention which results in widespread use by the target population. Such "successful adoption" can be further analyzed in terms of the uptake of the practice and/or innovation as well as in terms of the penetration of broad-scale recommendations through dissemination.

Thompson and WIliam (2008) have contributed toward the discussion of factors by reminding the research-practice community to have "a clear idea of what you are trying to enact and why it is worthwhile." Self-evident as such a reminder might seem to be, implicit in it is the caution that time and effort need to be invested in initiating and maintaining dialogue within the community to build a shared vision (Senge, 1990). While it may be a truism, the point is worth making that such dialogue should indeed be multilaterally defined and not monologic. Each member of the respective researcher–practitioner community should be aware of and acknowledge his or her own biases and level of objectivity about this critical tension so that the contextually appropriate balance between fidelity (to the theory of action) and flexibility be striven for and (eventually) attained. Lewis, Perry and Murata (2006) speak to this very issue when they called for a clear articulation of the specification and tools (coherent with the theory of action of the given intervention) in order to support the building of practitioner capacity and expertise. They make the point that this articulation is necessary because of the risk that the surface features of an innovation may sometimes obscure the actual enaction of the theory of action.

Unlike translation science, diffusion research can trace its roots into the mid-twentieth century. Kroeber (1940) and Hägerstrand (1967) have written extensively on the matter, and of particular relevance to the present discussion is the reminder that diffusion needs not necessarily be assumed to originate continually from a single, authoritative source (expansion diffusion), but can also take place through other models such as through contagion and hierarchy. In this regard, consideration should, therefore, be placed on the dispositions of the change agents, particularly according to Rogers's (1964) characterizations of innovators, early adopters, the early majority, the late majority, and laggards. Elaborating, Rogers recognizes that innovators are venturous and cosmopolites who may not necessarily be well respected by other members in a local system. Early adopters are localities and have the highest opinion leadership in their systems. They are well respected by their peers and are generally in a central position in the communication networks of the system. The early majority takes relatively longer than in their adoption decision-making process. They interact frequently with their peers but seldom hold positions of opinion leadership in their system. In contrast, the late majority makes adoption decisions based on both economic necessity and the increasing peer pressure and social norms. Finally, laggards are the most localite in the system. They primarily interact with others who have relatively traditional values. They tend to be suspicious and their adoption decision tends to be lengthy.

Given the preceding description, it is, therefore, critical to acknowledge that T2 requires a different set of research skills than T1 (Woolf, 2008)—again, this has implications on policymakers and the grant-review process. Above all, T2 is predicated upon trust between the researcher and the practitioner, because the analytical lens of T2 is the process by which discoveries and innovations are moved to sustained adoption. Such trust can be fostered by the active involvement of the practitioner at all key stages within the design process. In Singapore, this has implications for (but—equally—can leverage upon) existing efforts in schools on Action Research.

What might some key performance indicators of T2 be? In the translation literature, Glasgow's (1999) articulation of the so-called RE-AIM framework has been frequently cited and speaks authoritatively to this question. The RE-AIM framework was explicitly designed from the outset to be an evaluation framework for translation. It describes five dimensions, which operate at either (or both) the individual and organizational levels. At the individual level, the success of any given translation effort can be evaluated against the criteria of Reach (into members of the target population), effectiveness (ability of the intervention to do more good than harm in a real-world setting (contrasted with Efficacy)), and maintenance (in individuals over time). At the organizational level, the success of any given translation effort can be evaluated against the criteria of adoption (by target settings and target institutions), implementation (consistency across programme components and members in terms of the afore-mentioned aspects of content, context and process), and maintenance (in populations over time; implicit in this notion of maintenance are both sustainability of the innovation/intervention and the adaptation thereof). Typically, the students will be given opportunities to appropriate the epistemic frame of the disciplinary professional (i.e., novices will be given opportunities to understand how experts make decisions and act). The teacher typically constructs learning environments along with an e-workbook metaphor (see the diagram below) in which students are given opportunities to surface their (otherwise tacit) intuitions regarding the topic and helps students dialogue around these shared and emerging artefacts of proto-knowledge.

Using the afore-mentioned RE-AIM framework as a lens to examine the trajectories of diffusion of the Disciplinary Intuitions/Six Learnings programme:

a. Effectiveness: how do practitioners and policymakers take steps to ensure the programme continues to do good as it evolves independently of the original team members? (i.e., preventing so-called "lethal mutations").
b. Adoption: what specific cultural contexts favour/hinder the diffusion of the programme?
c. Maintenance: how do schools and the wider educational system gate-keep and seek to maintain adoption and legitimate adaptation in a self-sustainable way?

13.4 Methodology

Case studies are the preferred mode when there is a need to ask "how" and "why" questions with a focus on the actual situation and when the investigator has little control over events (Yin, 1994). The two cases in our project centre on process-oriented research in which the activities emerge from the conversational, narrative, and performative processes occurring between participants. Case studies are frequently used in educational research when a deep understanding of the context is essential. We choose to use the case study methodology to provide sufficiently thick descriptions and narrative accounts of the significant cultural and contextual factors impacting successful translation. Particular emphasis was accorded to investigating the key issues identified in the framework outlined earlier, such as the identification of the criteria for scaling, the process preparations needed, and evaluating the legitimacy and authenticity of the translation efforts.

We gathered and triangulated our data from a range of sources such as interviews, recordings, and artefacts (such as lesson plans and curricular units designed by the teachers themselves) to provide thick descriptions. The synergies between these various qualitative methods help to organize data into patterns, categories, and basic descriptive units, and this, in turn, helped in the identification and determination of design principles for scaling.

13.4.1 Data Collection and Analysis

Interviews: interviews permit all stakeholders—from school management to classroom teachers, and curriculum officers from the Ministry of Education (MOE)—to communicate their evolving thoughts and reflections regarding their respective roles in translation. On average, participants were interviewed fortnightly. Interview questions were refined along the implementation stages in order to depict rich portraits of data.

Observations: Formal observation was used to document participants' behaviours and interactions. Focus was also given to any "immutable" features of the existing curriculum and schools that may also impact the scalability and extendibility of the projects.

Focus-group discussions: focus-group discussions permit all stakeholders to communicate their evolving thoughts and reflections regarding the subject topics in the translation process and to what extent the schools are able to scale up the efforts. The questions were refined along the implementation stages in order to allow for responsive design modification and to depict rich portraits of data.

We were also interested in the specifications involved in design principles, such as curricular resources, assessment materials, and learning designs, which were derived from the studies; and how decisions were made with respect to diffusing innovation efforts within and across schools.

Artefact analysis: during the course of the data collection period, researchers collected and analyzed data from sources such as teacher reflection logs, threaded discussions, and notes of meetings with officers from the MOE.

Video and audio recording: recording was used to supplement the data collection process and provide a relatively comprehensive record of social interaction. It was used to capture missing information during the interview sessions.

13.5 Results

Example A In 2015/ 2016, a secondary school implemented the Disciplinary Intuitions/Six Learnings programme for their Grade Eight Art curriculum. Three classes were involved in the intervention. The actual roll-out took 5 weeks but the pre- and post-implementation work took about 6 months.

The teachers came together to see how the Scheme of Work might be integrated into the platform. In their own words:

> [the Principal Investigator] invited us to explore the platform on our own—which I think is great! We can put ourselves in our students' shoes and feel how painful it is to go through it and really learn how to use the software. Through this, we managed to pre-empt and resolve certain issues we find, or certain things we're not sure of, and then we met [the Principal Investigator] to clarify with him. That's how we were introduced to the software.

The students started off by sketching on paper, before progressing to drawing on digital sketchpad software. Then, the teachers scaffolded the learning to the third dimension through the use of the open-source immersive environment known as OpenSim. "It is basically a sandbox where students create 3-D models based on the sketches they did," explained a teacher. "As the class is building in the sandbox itself, the students get to see and help each other's work without walking around the class."

A teacher shared that while they previously incorporated digital technology into the class, they were usually one-off sessions and subject-focused. "We used to focus on visual appreciation—digital sketching, stop-motion, simple photography and photo editing—but there was nothing much for them to take away and apply to other subjects," he notes.

With the Disciplinary Intuitions/Six Learnings approach in place, the Art teachers at the school found a positive impact on the students.

> "We can see that student engagement definitely went up. They have a sense of ownership of their own work, product and learning. It certainly helps with their 21CC skills!" said the school's Aesthetics Head of Department.

> "When we introduce the OpenSim platform to the students, we let students explore on their own," a teacher said. "It was important for us to see them become self-directed and independent learners who are willing to make mistakes."

> "They are more confident, self-directed learners, and they're more willing to try and explore. They may not want us to interfere so much, so we don't!" said another teacher. "They'll say, 'Wait, let me try first' and are generally more independent and they want to learn."

The Head of Department noted that the teachers were now open-minded about trying new things. "In terms of teacher capacity, it helps open up the minds of teachers to new learnings, alternative ways of teaching, different modes or mediums they can use. My observation is that teachers are more daring to try new things. They really look like they enjoyed the process and have grown in terms of willingness to embrace new things."

A teacher explained: "For us, it opened up new possibilities to improve our pedagogy, our curriculum, the way we deliver it and improve ourselves, basically. Otherwise, we won't know how well we're doing, we won't know how it is outside the school."

Example B In fact, by 2014, the model of a self-sustainable Six Learnings/Disciplinary Intuitions programme was already actually being enacted in one school.

The school had been on the programme for the longest (since 2009) and had seen the programme through one entire cohort of students (from Grade 7 2010 to Grade 10 2013). That cohort graduated their GCE "O" Level examinations with 93% distinctions in Geography (which was the subject they started with when they were in Grade 7).

The school planned and conducted lessons congruent with the Disciplinary Intuitions approach, independently of consultation with the programme team. The Geography unit in that school also put in place a system of self-initiated professional development to train teachers new to the programme on the approach, independent of the programme team visiting the school to conduct any professional development.

As new teachers posted to the school were inducted into the programme, they did not come under any professional development from the original programme team, and were, in fact, enculturated into the programme by their own colleagues from within the school.

They enacted lessons without the programme team having to go down to help. The school was, therefore, an authentic point-at-able exemplar of how and why the Six Learnings/Disciplinary Intuitions programme could be self-sustainable, given the appropriate scaling supports.

What follows are some verbatim quotations from the teachers in that school, which emerged from an interview.

> "The execution of the lesson is not difficult, but to make it easy, you have to plan. We have to decide what the processes, stages and focus of the lessons are."

> "Decisions on content are very much left to us—how we want to fulfil our objectives through instruction, because we are the practitioners. But [the Principal Investigator] oversees how we can match our goals with the affordances for learning of OpenSim."
>
> "Initially, it was a bit hard," a fellow geography teacher shared. "Students are not used to their teachers not being the one in the classroom talking and giving instructions!"

To ease her students into OpenSim, her first lessons were spent giving clear instructions to her students or demonstrating how they could use OpenSim. They were also given accompanying worksheets to complement the lesson.

The teachers felt that that designing lessons through the lens of Disciplinary Intuitions created a conducive learning environment in the classroom where students were not as apprehensive as before of making mistakes.

The teachers also looked out for learning points when students present their creations in OpenSim. "While they are presenting, we will ask why they chose to do something that way," one of the teachers said. "It could be a mistake that they had made and these are teachable moments."

"Somehow. the atmosphere is less tense," she noted, and students became more receptive about learning from their mistakes.

Some of the students' responses included:

> "It helps us imagine!" said, a Grade Nine student. "For example, our textbook doesn't allow you to see the whole view of a mountain but OpenSim allows that."

A Grade 8 student, said that being able to "see" better enabled him to learn better. "I am a visual learner so when I see things, I can depict the scenes better so it is easier to learn coordinates and gradients," he shared.

The students often surprised their teachers with the representations of their learning. Sometimes, they would model their creations after real ones, such as the Nile or the Mississippi River.

> "I think it is very interesting for teachers to look at how they interpret their learning," a teacher shared. "We can see both creation and creativity at work. Students can figure things out by themselves and it also encourages them to think hard!"

The intervention also taught the teachers themselves to be more creative when planning their lessons. A teacher felt that it had helped her become less stagnant during the process of crafting her teaching materials.

There has, thus, been a powerful combination of open-source-based lesson resources easily portable by teachers ("a world in your pocket") plus regular and ongoing opportunities for school-based sharing conducted by teachers, for teachers.

By October 2017, the programme team had made steady progress with scaling the programme into new contexts of learning, such as in undergraduate education and military education. The team began collaborating with the Mechanical and Aerospace Engineering School of the Nanyang Technological University (NTU), and together they designed for the enaction of a robotics-mediated Mathematics curriculum with a secondary school the following year.

13.6 Discussion: Challenges Faced and Principles for Scaling and Translation

13.6.1 Challenge #1: Mixed Messages and Non-congruent Understandings of Curricular Innovation Among Stakeholders

At the eduLab community event held in November 2016, a teacher on the programme was sharing to the audience of fellow teachers about how the programme had benefitted him, his colleagues, and his students. He was a trained Design & Technology teacher.

He was publicly challenged by a member of the audience, who held a senior appointment in the Curriculum Planning & Development Division of the Ministry of Education, about his understanding of the Design & Technology syllabus.

It was only after the intervention of his principal, in support of the Disciplinary Intuitions/Six Learnings programme, that the matter was settled.

13.6.2 Challenge #2: School Mergers

Changes of senior leadership and the merging of schools—especially from 2017/2018—played a part in the evolution of the project. The programme team had to give teachers time to adjust to their new cultural climates as needs and objectives of the merging schools were realigned. This continued to be a factor in 2018 as teachers from either side come to understand each other's needs.

Notwithstanding the preceding paragraph, the programme team was very heartened when the leadership team and teachers from one half of a recently merged school chose to continue adopting the programme, based on the recommendation of their colleagues (from the other half) to do so.

13.6.3 Challenge #3: Shifting Network Security Goalposts and Non-reporting by Teachers

As the programme matured, the programme team retrospectively discovered that some teachers had initiated sharings without realizing that it would have been useful for the programme team to have learnt about the sessions too (in terms of reporting performance indicators to the eduLab programme management office). On balance, this was taken as a positive sign that teachers did not feel dependent upon the originating programme team.

Instead, the teachers only got in touch with the programme team when they needed technical support, e.g., during school network security reconfiguration.

To elaborate, although schools had enacted several curricular units in 2015 and in 2016 using Sim-on-a-Stick without technical issues, when the programme team tested the software at a school in July 2017, they verified that the software was unable to be run. The school's Technical Assistant (TA) informed the team that this was due to a new security policy that was implemented in May that year, following which student accounts were blocked from running some executable files on their student laptops.

The team then contacted another school on the programme, which confirmed that they were also experiencing the same issue, and could not run the software either.

The team contacted the IT Branch (ITB) of the MOE to seek assistance with this issue. The branch arranged for a roving engineer to come down to the school to help troubleshoot the issue. During the troubleshooting session, the team explained the issue to the engineer who was able to devise a workaround to allow the software to run, by using the Windows Compatibility Toolkit to run Sim-on-a-Stick's executable files, both of which had to be run using the TA's account while logged in to the computer as a teacher. However, the engineer informed the team that this workaround would not be suitable as a long-term solution, and a second troubleshooting session was arranged with a Technical Services Consultant. During this second session, the consultant and the engineer were able to identify the root cause of the issue and to implement a solution.

Following the troubleshooting, the team tested and verified that Sim-on-a-Stick could be run on a school laptop using both teacher and student accounts. The consultant advised the team that schools that want to use Sim-on-a-Stick should inform their TA(s) to raise service requests before running the software, to help ITB track the software usage.

13.7 Principle #1—Emphasis on Teachers' Professional Development

This is the foundational principle undergirding the Disciplinary Intuitions/Six Learnings programme.

Professional development typically is done on a subject-department basis, as it typically takes at least four sessions before meaningful progress can be made in terms of teachers' understanding of the foundations of the Disciplinary Intuitions approach (for some subjects, it takes longer to establish intersubjectivity).

For schools coming onboard to just use existing pedagogical resources already developed, professional development would be shorter, but is still necessary so that the teachers understand how to use the learning resources in the appropriate pedagogical spirit.

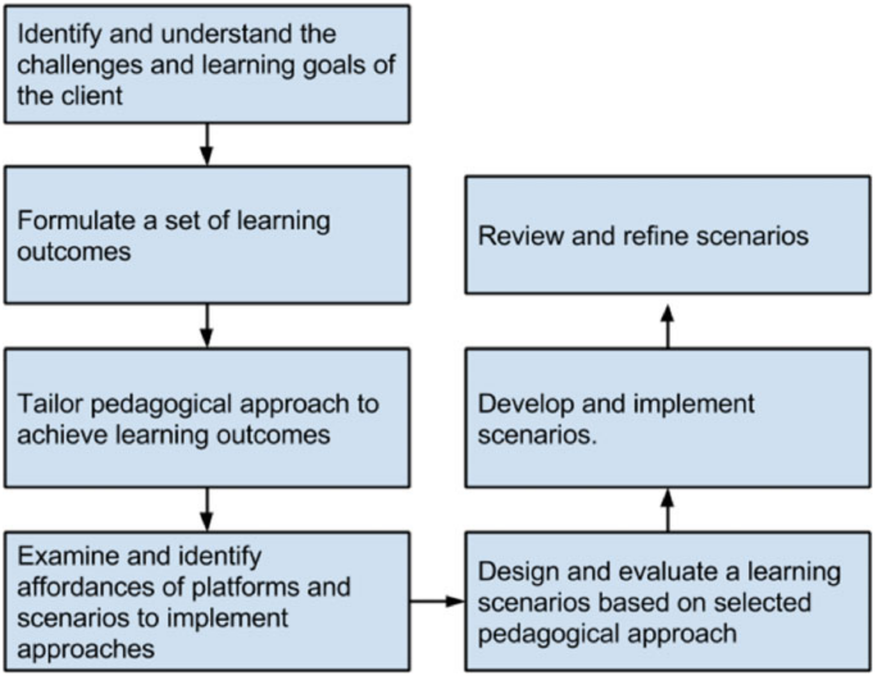

Fig. 13.4 Workflow for co-designing a learning unit through Disciplinary Intuitions

In consultation with the teachers, the programme team typically constructs partially scaffolded learning environments in which learners are given opportunities to surface their (otherwise tacit) intuitions regarding the topic, and which help students dialogue around these shared and emerging artefacts of proto-knowledge. The workflow for co-designing a Disciplinary Intuitions learning unit with teachers is depicted in Fig. 13.4.

Consider the following example, of a learning unit in Electrical and Electronic Engineering (EEE) conducted at a local undergraduate course at the NTU.

Articulation of learning problem: a faculty member of the School of EEE approached the programme team to help him gain deeper insight into the intuitions underlying the misconceptions which first-year college students bring to his course in Analog Electronics.

Learning Goals: students to be able to understand and correctly design analog circuits using the appropriate symbolic codifications.

Approach: students—through their avatars—operate in a “larger-than-life” abstract representation of incomplete analog circuits to share and collaboratively annotate each other’s circuit-designs, in a “flipped” pedagogical approach through which their nascent attempts to circuit representations are discussed during tutorials. We have dubbed this approach “Chart-a-Path.”

Outcomes: through Chart-a-Path, the lecturer was able to have a panoptic understanding of the evolution of misconceptions students bring to class, augmented by annotated commentary from student peers.

As a second example, the team conceptualized a potential collaboration with the Weizmann Institute of Science in Israel on the development of a Computer Science curriculum for high school students in that country, using the Disciplinary Intuitions approach.

Articulation of learning problem: a research scientist from the Weizmann Institute of Science approached the programme team with the intention of designing a Computer Science curriculum for high school students in Israel, from the perspective of Disciplinary Intuitions.

Learning Goals: to help high school Computer Science students understand and apply concepts of a state-based, event-driven programming paradigm.

Approach: a variety of poorly functioning, and/or non-compilable scripts were used as the basis for students to try to modify and "set right"; an example would be scripted in a car, which would make the car only turn to the left instead of properly responding to steering commands.

Outcomes: students learn foundational principles of state-based, event-driven programming through the deconstruction of incomplete, non-compilable scripts emplaced in component objects.

In both these examples, as well as in others, teachers benefitted from strong support from school leadership, such as time set aside to attend professional development sessions, as well as in terms of embarking on the programme as Professional Learning Community (PLC) teams.

13.8 Principle #2—Teachers' Action Research

Since the earliest years of the programme, teachers had been encouraged to share their experiences and reflections among themselves and with their colleagues from other schools. Teachers leveraged professional platforms provided by the MOE, such as ExCEL Fest 2012 and 2013, and eduLab@AST. Thus, for example, during ExCEL Fest 2012, projects associated with the programme won Best PS21 Project Award (Gold) 2012 and the MOE Innergy Award (Silver) 2012. During ExCEL Fest 2013, another two schools on the programme showcased their own curricular innovations in areas different from the previous year. During 2014, three schools conducted sharing sessions in two subject disciplines at eduLab@AST.

It was also in 2014 that the first PLCs among teachers started to study the Disciplinary Intuitions/Six Learnings approach. At least five PLCs had been set up independently of the programme team in 2014.

Two school-led symposia/workshops were organized in 2015. In March that year, one such event was organized for 180 humanities teachers, and later in September, a similar event was organized for art and aesthetics teachers of the N6 School Cluster in Singapore.

More recently, since 2016, art teachers have continued to share the programme spontaneously and without oversight by the programme team. In addition, the programme was also shared during the W3 Cluster board meeting. Teachers from a school who had developed an integrated approach for the subjects of “design and technology” (D&T) and “art” shared during a session organized by the eduLab programme management office. These activities were carried out independently and without any direct intervention from the programme team.

From these events, school leaders expressed the following views:

- The Disciplinary Intuitions approach builds towards lasting first-principle understanding.
- The approach is aligned with the MOE ICT Masterplan Four, and with its emphases on “Future Ready” students and the Singapore “Smart Nation” initiative.
- Through the approach, teachers are afforded greater opportunities for discussion and reflective practice.
- There is deep professional learning; with teachers knowing that they do not function alone.
- The programme has enabled diffusion across a number of disciplinary domains and school subjects, such as from D&T to Art, and on to Science.
- Such diffusion has enabled schools to level up their practice.

As for the teachers themselves, the following were some of their views:

- Students did not feel they were weak, because they were exploring and collaborating.
- Through building, they exercised critical and inventive thinking:

> “in the process of building, they discover that certain things do not happen the way they had anticipated; and they discover this for themselves. In the past, these would have been pointed out by the teacher. The whole philosophy is the surfacing of intuitions, and through self-discovery, they hold the learning better”

- The changes were sustainable because other academic streams and other subjects were adopting the approach, with dialogue between Department Heads and Subject Heads from different departments:

> “the planning is a lot deeper: it makes me go backwards and think about what are the more fundamental knowledge and skills that as a student they require; so this makes me think about what are the little skills they need to build up”

13.9 Principle #3—Fidelity with the Original Design Framework (The Six Learnings)

Because the lesson units are designed according to six possible ways in which immersive environments and game-based worlds might be used for learning (i.e., in terms of collaboration, in terms of identity formation, in terms of championing causes, in terms of expressing their learning to external audiences, in terms of design-thinking and prototyping, and in terms of self-directed exploration and interaction), and, because the Six Learnings curriculum framework is itself founded upon a theory of learning, which foregrounds the (otherwise tacit) intuitions which students bring to the classroom, the lesson units can withstand much mutability while still remaining true to the overall intent behind the learning outcomes.

13.10 Principle #4—Local Adaptations Through Strong Theoretical Grounding

Thus, for example, teachers have—of their own accord—successfully taken the initial lesson units and adapted them from Geography, to Social Studies, to Literature, to Design & Technology, to Food & Nutrition, and also to Art.

In terms of academic stream, the lesson units have been successfully modified (again, by the teachers themselves) across the Express, Normal (Academic) and Normal (Technical) streams.

In terms of age cohorts, the lesson units are being used at the Upper Primary level, as well as from Grades 7 through 10, and at the undergraduate and graduate levels.

In terms of pedagogical approaches, the lesson units are used in prototyping, in fieldwork-planning, in stagecraft and storyboarding, and in collaborative decision-making (to name a few).

The teachers are supported in doing so through a variety of means, including (but not limited to) an in-service course at the NIE, an e-learning course offered through iTunesU, and an interactive e-book available from the iTunes Bookstore.

Disciplinary Intuitions is sufficiently flexible to fit upstream of existing curriculum frameworks such as Teaching for Understanding, and Understanding by Design.

As a theory of learning, Disciplinary Intuitions is also used to undergird a totally separate intervention (separate from the Six Learnings programme), this time to do with surfacing environmental understandings using a networked mesh of open-source hardware.

13.11 Principle #5—Sustained Scaling Through Open-Source Hardware and Software

In this way, the intervention was not dependent on any single platform for successful enaction. There are already significant learning resources developed over the past decade—by teachers and by the students themselves—in an open-source environment.

Likewise, the Six Learnings framework and the theory of Disciplinary Intuitions can be applied to a variety of other game-based worlds such as Minecraft, World of

Warcraft, Lego Mindstorms, and open-source hardware such as Raspberry Pi and/or Arduino.

The push towards open-source happened in 2014, when the infrastructural model was very different. At that time, schools on the programme were dependent on a centralized server hosted at the NIE.

This approach was increasingly untenable, especially as the programme has reached Economies of Scale to the extent that in 2014, the average rate of schools coming onboard the programme is one per month.

The programme team, therefore, proposed a decentralised approach to scale the programme, with the learning environments hosted on USB thumb drives, which could be distributed to all schools and easily plugged into the teacher's computer when needed.

This would reduce the chances of timetabling conflicts and enable even better performance (lower latency times) from the point of view of the students. From a troubleshooting perspective, it was easier since the USB thumb drives would be located within the school's premises.

For the enaction of curricular units involving the use of immersive environments, the programme team provides schools with copies of Sim-on-a-Stick, a portable version of the open-source virtual world hosting platform OpenSim. Sim-on-a-Stick is typically run on a school laptop or desktop, to which students on other school laptops or desktops can connect using a client viewer software. This allows schools to enact such curricular units without having to purchase dedicated hardware to host an OpenSim server or subscribe to an online hosting solution. Sim-on-a-Stick is also easy to use, as it does not require installation, and can be run from a USB thumb drive or from the D:\ drive of a school desktop or laptop.

Each set of USB thumb drives is supported by the school's TA, whom the programme team trained in simple server maintenance (e.g., how to restart a server). Updates to server software are either done by the TA or by site visits by the programme team. As and when adaptations are suggested by teachers, the iterations can easily be cascaded to schools via downloads via email-embedded links.

13.12 A Principle In Emergence—Brokering Across-School Interactions for Learning by the System

Going forward, one possible way to encourage systemic continuity might be through the MOE Senior Specialist Research Fund, of which the Principal Investigator was chosen during 2017 to be the Research Mentor to the Head of the Geography Unit at the Curriculum Planning and Development Division (CPDD) of the MOE, in a joint funding application for Geographical Information Systems research in 2019 between the CPDD and the Educational Technology Division (ETD). Such collaborations can potentially promote continuity at the systems level.

The programme team was also gratified to receive invitations to participate in the 2018 CPDD Geography Symposium, as well as the 2018 Academy of Singapore Teachers/NIE Humanities Education Research Seminar.

In addition, during 2017/2018, the programme benefitted greatly from the close participation of a student–teacher under the Teaching Scholars Programme. His participation was under the auspices of the NTU's Undergraduate Research Experience in Campus programme. His participation complemented the existing strengths and areas of need of the team very well, as he provided valuable pedagogical insight into disciplinary domains such as Mathematics and Physics.

The programme team also strengthened collaborative ties with existing NIE faculty in 2018, with a successful joint application with the Humanities & Social Studies Education Academic Group for an Incentivising ICT-use Innovations grant, to be enacted in pre- and in-service geography education during 2018/2019, with plans for a subsequent phase in 2020.

Finally, the programme team was granted approval by the university to offer a general elective for NTU and NIE undergraduates from the 2018/2019 academic year onwards, themed on "Designing learning environments: a focus on the Internet of Things."

13.13 Conclusion

As elaborated upon in the Literature Review, three dimensions—Effectiveness, Adoption, and Maintenance—of Glasgow's (1999) RE-AIM framework were of particular interest and relevance in the documentation of the evolution of the Disciplinary Intuitions/Six Learnings programme over the past 10 years.

In terms of Effectiveness, this chapter has described some of the steps taken by practitioners and policymakers to ensure the programme maintained fidelity as it evolved. These include being active participants in their own Professional Development, as well as taking care to understand the approach of Disciplinary Intuitions in designing learning environments as canvases for learners to express their nascent and evolving understanding.

In terms of Adoption, this chapter has described the cultural contexts which favour and hinder the diffusion of the Disciplinary Intuitions/Six Learnings programme (and others similar to it), including—for example—the differing understandings of curricular innovation among key stakeholders, and the support of school leadership in building a culture of experimentation.

Finally, in terms of Maintenance, this chapter has described a principle in emergence, based on how the programme has evolved especially since 2017, namely: the importance of brokering across-school interactions through existing systemic mechanisms such as the MOE Teaching Scholars Programme, the NTU Undergraduate Research Experience in Campus Programme, and the MOE Senior Specialist Research Fund.

In ongoing projects helmed by the Principal Investigator, the theory of Disciplinary Intuitions undergirds his work in Team-Based Learning and the use of robots in Math education, the use of Augmented Reality in Chemistry and Physics education, as well as work involving surfacing students' intuitions about local environments and micro-climate using open-source hardware. It is hoped that—together—the preceding structures may continue to evolve to support curricular innovation over the next 10 years and beyond.

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Chapter 14
Does Seamless Learning Translate Seamlessly?: A Decade of Experiences in Adapting Seamless Learning Designs for Various Subjects, Levels and Technological Settings

L.-H. Wong, C.-K. Looi, and G. P. Aw

Abstract Seamless learning is "when a person experiences a continuity of learning, and consciously bridges the multifaceted learning efforts, across a combination of locations (such as in and out of classroom), times, technologies or social settings." It is an opportunity for an integration model of learning to foster deeper connections between multiple learning programs and learning opportunities. The technology-enhanced seamless learning approach was introduced to Singapore schools around 2007. After the initial proof-of-concept on the feasibility of developing a school-based, national curriculum-aligned pedagogy, a series of translation and diffusion efforts ensued over the last decade. Nevertheless, there are still challenges for the learning approach to penetrate the macro layer while keeping the focus on the meso and microlayers of the ecology. Underpinned by the notion of implementation research, this chapter will trace the evolution of the seamless learning practices among participating schools. We discuss the motivations and rationales of developing various translated seamless pedagogical models during different periods of time. In some cases, new translated models were derived not only for the sake of diffusing and spreading the practice to more subjects and levels but also for overcoming the systemic, technological and human (teacher, student and parental) tensions or limitations identified in preceding studies. Lessons drawn from a decade's worth of implementation research can be useful in informing future translational and scaling up efforts of innovative pedagogical and curricular innovations.

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14.1 Introduction

Seamless learning is an emerging learning notion or approach that refers to a person experiencing a continuity of learning across a combination of locations, times, technologies or social settings, and consciously connecting such multifaceted and multimodal learning efforts to achieve deeper learning (Sharples et al., 2012; Wong, 2015). From the perspective of existing policymakers and mainstream school establishment's point of view, the expected key changes in integrating seamless learning to the current school practice are two-fold: (1) to bridge the intent of formal curriculum facilitated by authentic learning opportunities (intended or incidental) outside the classroom; (2) to extensively deploy mobile and cloud technologies throughout their students' cross-contextual learning journeys. These requirements would inevitably result in tensions and challenges for seamless learning to reside inside and thrive in the ecology of the school system.

Seamless learning was introduced to Singapore schools around 2007, hot on the heel of the publication of the seminal paper on seamless learning mediated by 1:1 (one-mobile-device-per-student) settings (Chan et al., 2006). After the initial proof-of-concept on the feasibility of developing a school-based, national curriculum-aligned pedagogy, a series of translation and diffusion efforts ensued over the last decade, making Singapore the leading country in deep penetration of seamless learning into formal curricula—compared with the rest of the world where almost all of the relevant research efforts have either remained at the clinical stage or have been enacting relatively short-term, perhaps ad-hoc teacher-driven practices (Wong, 2015). Underpinned by the notions of implementation research and translational research, this chapter will trace the evolutions of seamless learning practices among participating schools in Singapore. We will discuss the motivations and rationales of developing various translated seamless pedagogical models during different periods of time. In some cases, new translated models were derived not only for the sake of diffusing and spreading the practice to more subjects, grade levels and schools but also for overcoming the systemic, technological and human (teacher, student and parental) tensions or limitations identified in preceding studies. Our journey of research and implementation of seamless learning is a vivid example of a trajectory of design-based research and design-based implementation research that impacts and sustains school practices.

14.2 Underpinning Frameworks

14.2.1 The Techno-Pedagogical Framework: Seamless Learning

Despite owing its conceptual origin to the non-technology-related research niche of the same name in the field of higher education studies (American College Personnel

Association, 1994; Kuh, 1996), the notion of seamless learning was first inducted into the learning technology field with the aim of promoting research on and practice of learning in 1:1 settings (Chan et al., 2006; Wong & Looi, 2011). More precisely, this 2006 framing of seamless learning was motivated by a new phase in the evolution of technology-enhanced learning, marked by a continuity of the learning experience across different scenarios or contexts, and emerging from the availability of one device or more per student (Chan et al., 2006). The research niche is indeed motivated by the infeasibility to equip students with all the knowledge and skills needed for lifelong solely through formal learning (or any other single learning space such as an e-learning portal). Instead, student learning should move beyond the acquisition of canonical knowledge to the development of motivation, metacognitive and cognitive abilities to learn seamlessly (Looi & Xie, 2014).

Further unpacking of seamless learning results in the foregrounding of a salient feature that distinguishes it from other more established learning notions, which are often seen as its "conceptual neighbours," such as self-directed learning, lifelong learning, blended learning and flipped learning. Having a cross-contextual learning trajectory (in whatever combination and sequencing of learning settings as advocated by some other learning notions) alone is not adequate to constitute seamless learning. The two keywords are "bridging" and "recontextualisation" The essence of seamless learning is lying in a learner's continual "recontextualisation" of previously constructed knowledge to facilitate rise-above and elevating sophistication of the knowledge. This should be accomplished through the "bridging" of learning application reflection activities that are situated in various contexts appropriate for specific activities respectively (Wong, Chai, Aw, & King, 2015). In formal settings, knowledge and skills may be taught in the abstract. The more contexts or settings in which learning a concept, skill or otherwise takes place, the more powerful is the learning. Removing or crossing seams (between the contexts) would provide more opportunities for such contextualization and in doing so, the thinking and doing practices of learners are drawn to approximate those from the community of practices (Wong & Looi, 2019).

Given the aforementioned early conception of seamless learning, the mobile devices owned and accessible on 24 × 7 (24 h a day, 7 days a week) basis by individual students serve the role of "learning hub" (Zhang et al., 2010) that integrates all the personal learning tools (apps), resources and self-created artefacts at one place. Thus, these personal devices become a cognitive/metacognitive tool for seamless learners to "do the right thing (suitable learning activities) at the right place and the right time" (Sha, 2015) with the aid of the right tools and resources, and perhaps by building on, repurposing or remixing previous self-created artefacts.

Nevertheless, such an early perception of seamless learning being a special form of mobile learning has been revisited in recent literature (Wong, 2015; Wong & Looi, 2019). Seamless learning is now seen as a learning notion on its own right in which the learners' personal mobile devices are seen as more an enhancer than an enabler. What is advocated in recent literature is human-centric, instead of technology-driven forms of seamless learning. While mobile technology may significantly enhance the fluidity of learning across contexts, a new challenge has been placed on more recent practice-driven seamless learning projects that our team has been working on. The question is: if most young learners do not own mobile devices, can we re-design seamless learning to rely less on 1:1 and mobile technology but leverage more on other digital (such as social media) or even non-digital tools to bridge the learning efforts across different contexts? Be it seamless or mobile learning, what should be held constant or be placed in the centre are the learners, not the technologies.

14.2.2 Implementation Research and Translational Research

The diffusion (or scaling) of techno-pedagogical innovations is often subject to "replica cap", that is, cloning everywhere that worked in the seed school without taking into account individual sites' variations in needs, assets, capacities and commitments (Dede, Honan, & Peters, 2005; Wiske & Perkins, 2005). The effectiveness of diffused innovations is often undermined or jeopardised by variations in implementation contexts (Clarke, Dede, Ketelhut, & Nelson, 2006). Such failures call for the abandonment of the "one-size-fits-all" approach and the empowerment of flexibility of the innovation to foster robust adoption across a wide range of contexts (Looi, Xie, & Chen, 2015).

Thus, the approach of "implementation research" (e.g., Barab & Luehmann, 2003; Farrar, De Sanctis, & Cohen, 1980; Spillane, Reiser, & Reimer, 2002) comes to the picture, which refers to the methods or processes to promote the uptakes of research findings, that is, to explore the challenges that are faced when generalising research "in the real world," or the bridging of research and practice. A key requirement for implementation researchers is to possess the ability to interpret contextual variables and communicate effectively with the local stakeholders to surface the critical success factors of the design that becomes vital for enabling effective appropriation and adaptation while retaining its efficacy (Dede, 2005). During implementation, researchers not only intervene to develop and enhance the attitudes, knowledge and skills of the school practitioners but also to iteratively interpret the structures that facilitate or inhibit sustainable use of the design (Looi et al., 2015).

In the context of the Learning Sciences, implementation research overlaps with the notion of translational research. Translational research in medicine is defined as "effective translation of the new knowledge, mechanisms, and techniques generated by advances in basic science research into new approaches for prevention, diagnosis, and treatment of disease which is essential for improving health" (Fontanarosa & DeAngelis, 2002, p. 1728). Woolf (2008) developed the ontology of Type-1 and Type-2 translational research, which was later mapped onto the Learning Sciences by Pea (2010) who associated the two types to design-based research (DBR) and implementation research, respectively. According to him, Type-1 translation (or DBR) is about translating principles from basic learning research into interventions; while Type-2 translation (or implementation research) involves translating interventions developed in one or a few settings into interventions that are scalable to many settings.

14.3 The Trajectory of Implementation/Translational Research in Seamless Learning in Singapore

The key to the scalability of learning innovation is indeed its "translation-ability." The journey for diffusing a new learning innovation typically begins with Type-1 translation or proof-of-concept, with an implementation-oriented techno-pedagogical model being developed and validated. Such a point-at-able model would become a "gold standard" of the innovation, which could be robustly implemented in other similar settings. The emphasis is fidelity in implementation as the gold standard is regarded as an ideal and supposedly "static" techno-pedagogical blueprint. Nevertheless, as discussed in the previous section, it is a false assumption that all the adopting contexts are similar. Henceforth, Hung, Lee, and Wu (2015) called for the identification of a "sufficing standard" (or, in our words, their "critical success factors") to enable the spreading of innovation and culture throughout different levels of the education system. According to them, teachers need to be able to take innovations to their own respective classrooms (or equivalent) and implement the core ideas of that innovation. Beyond these "mandatory" core ideas, teachers are, in general, given freehand to adapt the lesson activities and/or the use of ICT or non-ICT tools in their lesson designs and enactments, perhaps with the researchers' guidance at the early stage. Such endeavours belong to Type-2 translation. At this stage, the researchers may change their roles from innovators and intervention drivers (during the proof-of-concept) to supporters of and consultants on the teacher-led interventions. They provide guidance to the teachers in interpreting the sufficing standard as well as formatively evaluate the latter's adaptation to ensure that it does not render a deviation from the sufficing standard. To the researchers, the new experience and insight gained, or even unexpected outcomes during the translated interventions might also prompt them to revisit and perhaps revise either or both the sufficing standard and the overall techno-pedagogical model. In this regard, the standard and the techno-pedagogical model are "dynamic" and evolving over time. As such, in adopting schools, teachers' enthusiasm, commitment and readiness about the innovations, and the resources and support available at the school would be crucial (Hung et al., 2015).

Indeed, our decade-long journey of translational research on seamless learning in Singapore schools has resulted in multiple versions of seamless learning models being developed. These were the outcomes of translations of the early model to different school levels (of the same subject), subjects and specifications of techno-pedagogy (including the variations of core learning activities and the ICT infrastructures), which we will refer to as "level translations," "subject translations" and "techno-pedagogical translations," respectively, hereafter. Often, a subject translation and a techno-pedagogical translation come hand-in-hand. This is because it is almost impossible to apply the seamless learning approach to a different subject while holding the core learning activity designs constant, due to the varied epistemological natures and teaching objectives between the subjects. Figure 14.1 depicts the evolutions of the seamless learning models and practices in Singapore over the last decade.

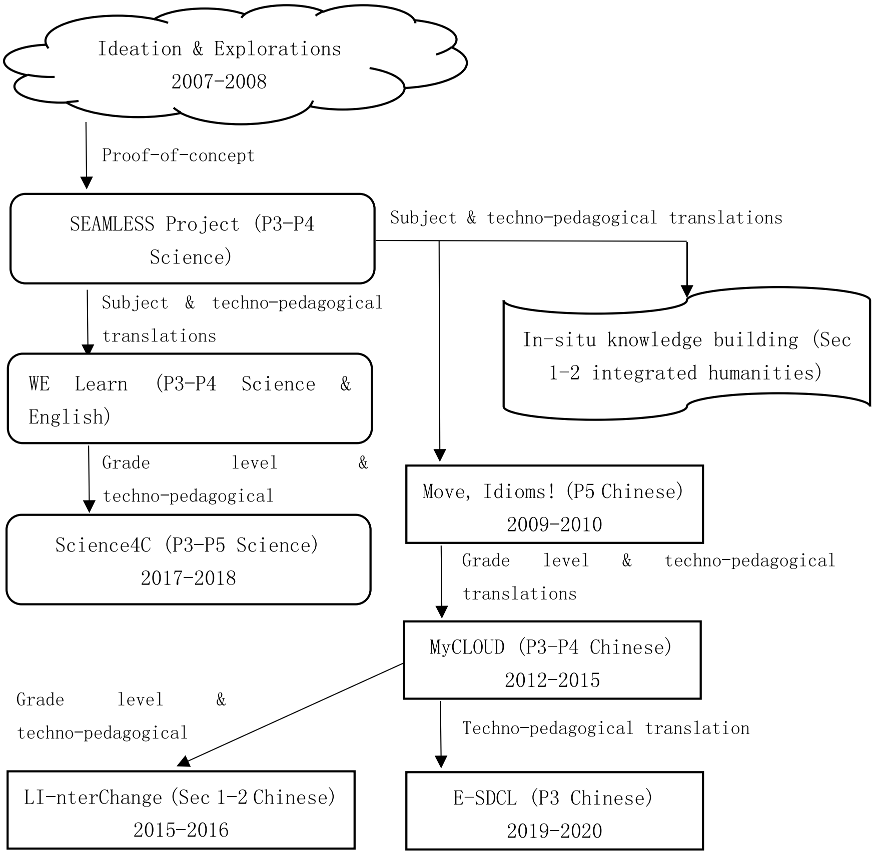

Fig. 14.1 Evolutions of the seamless learning models and practices in Singapore over the period of 2007–2019

14.3.1 Ideation and Exploration (2007–2008): 3R, Labrador Park Learning Journey, Chinatown Heritage Trails and English Preposition Learning

Our seamless learning research program commenced with the mutual interest of our research team and Nan Chiau Primary School in making the latter as the testbed and the seed school for developing a 1:1 ecology. Seamless learning was adopted as the underpinning techno-pedagogical framework so that the subsequent 1:1 curriculum transformation will not fall into the "trap" of restricting the 1:1 learning activities (predominantly) within the classroom. Instead, the emphasis was to leverage more on out-of-class/school contextual affordances to both complement formal learning and develop the dispositions of self-directed learning in the students. Thus, a series of exploratory seamless learning studies were carried out between 2008 and 2009 to help us in gaining crucial experience in ideating, designing, facilitating and managing such mobile learning trajectories with intensive use of ICT (Information and Communication Technology). These studies made use of the school's earlier inventory of Pocket PCs, Personal Digital Assistants (PDAs) or Ultra Mobile Personal Computers (UMPCs) with 3G broadband subscriptions, which were loaned out to the students for episodic seamless learning activities. In the following paragraphs, we will give an account of two of the mini-studies that was more influential and inspiring to our later translational efforts. Two more mini-studies that we conducted prior to the two were 3R learning trail (Seow, Zhang, Chen, Looi, & Tan, 2009) and Labrador Park learning trail (Wong, Chen, & Zhang, 2010).

In 2007, our research team and the school jointly facilitated two Chinatown heritage trails (So, Seow, & Looi, 2009). The first trail (Chinatown 1.0) was predominantly designed by the school teachers by tapping on an experienced tour guide who brought two Primary 4 (4th grade) classes of students to several significant landmarks in the Chinatown district of Singapore. Activities were planned at various landmarks that required them to answer factual questions related to the respective contexts with the UMPCs. Afterwards, they created a web blog to write reflections on the tour. The activity was highly structured. The students were merely entering information individually without engaging or interacting with the environment or their peers.

With our research team's feedback to the school, the trail was redesigned and enacted as Chinatown 2.0 by moving from task completion to deep understanding through making the students engaged in the environment as well as knowledge co-construction. To acquire a deeper understanding through location-based learning, students must be aware of their geographical positioning and the positions of the various landmarks. Thus, we introduced the use of Google Maps and the marking of locations on the map. For each marking, notes, pictures and hyperlinks can be added, providing a platform for the students to compose their location-specific reflections and experiences. The maps can be shared with peers for supporting collaboration by co-editing the content within the location markers. The students were also allowed to create their personal learning goals through asking questions about Chinatown and doing some research prior to the trip. The answers could be based on what they have seen, experienced or researched during or after the trail. Finally, post-trail peer discussions and knowledge co-constructed continued on Google Maps and in the classroom for another 2 weeks. The originally compartmentalised informal and formal learning experiences and individual and social learning efforts were then connected via mobile and Web 2.0 technologies. The design and our analysis on the outcomes of the Chinatown 2.0 (see So, Seow, & Looi, 2009) constituted the basis for our future translation model of "*in-situ* knowledge building" for integrated humanities, and provided the conceptual framing for the seamless Chinese learning models of "Move, Idioms!" and MyCLOUD.

The second exploratory study was anchored on a 2-hour lesson plan on English prepositions for Primary 2 (2nd grade) students (Looi et al., 2009). The study, took place in 2008, was novel back then in the sense that we engaged 8-year-old children in a re-designed "traditional," formal curriculum-centric classroom lesson with the teacher as the key implementor. During the lesson, students from a Primary 2 class were introduced to six prepositions. The students then worked in groups of three to go out of the class and identify authentic contexts or enact scenarios and take photos with PocketPCs (1:1) to illustrate the prepositions. For example, a student hid under a table in the canteen to illustrate the preposition "under." Back to the class, the groups shared their photos and the associated prepositions for peer learning and peer critique. Next, they were given a worksheet on Microsoft Word document stored in the PocketPCs to fill in the blanks (with the six prepositions) that subsequently form a short story, and then illustrated the story by creating a short animation with an app. The techno-pedagogical implications drawn from the design and the students' learning outcomes were (1) multiple entry points and learning pathways, (2) multi-modality, (3) in-situ student improvisation and (4) the sharing and creation of student artefacts on the move. In addition, the first attempt of teacher empowerment in (co-)designing the lesson plan and spearheading the implementation reaffirmed the importance of teachers' professional development in our implementation research. The valuable experience gained through this mini-study had laid the foundation for the SEAMLESS project, where the aforementioned implications had informed the longitudinal curriculum re-design effort. The core activity design of "taking photo to apply what is learnt" had also conceptually inspired, the "Move, Idioms!" project.

14.3.2 Proof-of-Concept (2009–2010): SEAMLESS Project (Primary 3–4 Science)

Armed with the new insights that we had gained from the exploratory studies taken place in 2007–2008, we embarked on our first longitudinal seamless learning project in Nan Chiau Primary School. Two different approaches to designing for seamless learning can be contrasted in relation to the starting point of the design: first fore-grounding learning in formal contexts or learning in informal contexts. The outside-in perspective studies the emergent behaviours of learners in informal settings and considers how such learning can benefit and inform learning in formal settings. The inside-out perspective starts by looking at the formal curriculum and considers ways of extending the learning to informal settings.

In particular, in the curriculum co-design process (the outside-in perspective), we worked with two teachers to revise 2 years' worth of the national curriculum for Primary 3 and 4 Science by considering the opportunities afforded by ubiquitous access to mobile devices. In 2009, one Primary 3 class was engaged as the pilot class to carry out the seamless science curriculum; yet it followed the same class schedule and assessment schemes as the rest of the classes. In 2010, we continued engaging the same pilot class who had by then moved up to Primary 4 and spread the intervention to another Primary 4 class. Activities were designed which sought to extend learning activities beyond the classroom. To support the long-term learning activities, the students were each assigned a smartphone with 24 × 7 access in order to mediate a variety of learning activities such as in-class small-group activities, field trips, data collection and geo-tagging in the neighbourhood, home-based observations or experiments involving parents, online information search and peer discussions, and digital student artefact creation, among others. The GoKnow MLE (Mobile Learning Environment), a commercial tool that consists of a suite of apps to support young students in mobile learning, was installed in all the student smartphones. The apps consist of KWL ("I know; I wonder; I learned"—a scaffold for goal-oriented learning), Stop Watch, Sketchy (animation creator) and Picomap (concept mapping tool).

Each topic in the curriculum was developed in a just-in-time manner for the teachers' enactment in class. We observed the classes and provided feedback to the teachers to improve subsequent lesson design and enactments. In this iterative process, we also deepened our understanding of the design principles for application in the next round of design.

Changes occurred in the experimental class and the teacher involved with evidences from research analysis (Looi et al., 2011; Zhang et al., 2010) during the 2 years of intervention, and from interviews with the stakeholders (school leaders and teachers). With the seamless lessons, we observed students engaging in science learning in personal and engaged ways, and they performed better than other classes as measured by traditional assessments in the science subject (Looi et al., 2011; Sha, Looi, Chen, Seow, & Wong, 2012). We also saw a shift in the teachers' attitudes and behaviours towards science teaching, from a style that saw them pre-occupied with just covering the curriculum to one that allows them to watch over and facilitate students' work on the inquiry activities on their smartphones.

14.3.3 Subject and Techno-Pedagogical Translations (2012–2015): WE Learn (Primary 3–4 Science and English)

When the curricular innovation using mobile devices has been co-developed and studied in the context of two classes in the SEAMLESS Project, and the empirical evaluation of the seamless curriculum has shown its potential for learning effectiveness, the school leaders decided that it was a worthwhile innovation and, in consultation with the researchers and collaborators, would like to scale up the innovation. Thus, in 2011, researchers and teachers discussed, reflected and elaborated the designed lessons, and scaled the curriculum at the entire Primary 3 level in the next year, with about 350 students using smartphones daily for science lessons. Subject translations were also taken place, where seamless learning was applied to English and Chinese lessons—however, as the two language curricula were new and at their piloting stages, only 120 of the 350 students were enrolled in those lessons. Whereas the Chinese seamless curriculum was developed and studied under a separate project known as MyCLOUD (My Chinese Language ubiquitOUs learning Days), which will be elaborated in Sect. 14.3.6, both the translated science and English curricula were lumped under the "WE Learn" project as a follow-up of the SEAMLESS project. The three-subject translations were later spread to Primary 4 in 2013. In 2014, the seamless science curriculum was further diffused to 10 more schools.

Given the different development stages of the three curricula, varied treatments were employed. By 2011, the science curriculum had moved beyond the proof-of-concept stage and was ready for scaling up; and yet we and the school were cognisant that techno-pedagogical translation as well as the "translation" of the approaches of teachers' professional development (PD) and lesson co-designs were inevitable. During the pilot that involved only two teachers, we could have both the content and instructional strategies "looser" and "less-defined"; that would not work when all teachers read, use and interpret the same curriculum. We made the content and the strategies need to be more explicit and transparent for the teachers to enact initially and to adapt subsequently. Furthermore, in contrast to the pilot where typically motivated and top-notched teachers were selected for participation, as innovation goes to scale, all teachers with varied motivation levels and competences must be brought up to speed. Thus, the PD was continuously put in place to help all the teachers, especially the weaker or more "conservative" ones. In addition, we facilitated more collaborative work sessions so the teachers could help each other with suggestions on instructional strategies and lesson planning, and with tweaks to the curriculum. They formed their own PD community for mutual support and relied less on the research team.

In terms of the techno-pedagogical translation, we strived for adapting the curriculum for a more generic mobile technology for sustainability. While initially, the innovation used smartphones, the goal was to create materials—curriculum, instructional strategies and formative assessments that are mobile technology agnostic. Mobile technologies are changing very quickly; thus we do not want our learning resources to be tied to a specific mobile technology. Therefore, our team gave up the GoKnow platform and instead developed a new MyDesk platform with a stronger emphasis in blending mobile and cloud computing technologies. The new direction not only offered a feasible solution to the above-stated challenge of changing technologies but also had the potential to open up new opportunities for developing new affordances to mediate a wider range of seamless learning activities. For example, digital badges were implemented in the new platform to motivate the students in self-directed learning beyond carrying out the teacher-stipulated tasks (Boticki, Baksa, Seow, & Looi, 2015). Furthermore, while the apps on the GoKnow platform were essentially used for students' individual artefact creation, most of the MyDesk apps allow greater teacher–student interactions and peer sharing of artefacts.

On the other hand, in translating our seamless learning model to English lessons, we hybridised the two pedagogical strategies of P4C and Marzano's 6-Steps to Better Vocabulary Instruction and extended the learning trajectory to informal settings (Koh, Loh, & Hong, 2013). P4C (Philosophy for Children) (Lipman, 1976) draws on the Socratic method of learning pioneered initially in Plato's dialogues and focuses on learning how to ask a question and how to respond when asked a question. Marzano's 6-steps to Better Vocabulary Instruction (Marzano & Pickering, 2005) helps children understand words by building relationships and links among the words, by using words in their proper contexts (particularly in authentic, out-of-school contexts).

14.3.4 Techno-Pedagogical Translation (2017–2019): Science4C (Primary 3–5 Science)

Despite the success of the WE Learn Project in diffusing the 1:1 seamless science learning model to 10 more primary schools, we see the challenge of further spreading such a seamless science curriculum as we argue that Singapore primary schools are not ready to implement Bring Your Own Device (BYOD) at least in the next 5–10 years. The reasons are that many students do not possess personal devices; even for those luckier students who do have their own devices, the usage is usually restricted by their parents with the fear of mishandling, addiction or health hazard, among others. Furthermore, throughout the course of the SEAMLESS and WE Learn Projects, we had developed three sets of design principles as reported in Zhang et al. (2010), Wong (2013b), and Looi and Wong (2013) respectively, with six to eight principles being laid out in each set and with the assumption of availability of 1:1, 24 × 7 settings. The motivation of the follow-up techno-pedagogical translation project, code-named Science4C, is to streamline the design principles and mitigate the reliance on 1:1 settings as well as not to overwhelm the teachers in developing the design capacity for seamless learning. The "4C" in Science4C refers to science learning in four types of learning spaces (Classroom, Cyberspace, Common daily life and Community); and constituting four salient features of seamless learning (Connective, Contextualised, Constructivist and Collaborative).

In the Science4C project, we have been guiding three primary schools in piloting the translated seamless science model in selected lesson subtopics of Primary 3–5 science. We continued to apply the PD approach of teacher–researcher co-design of lesson plans, informed by the streamlined design principle set, C^2FIP, denoting **C**onnectivity, socio-**C**onstructivist inquiry learning, **F**ormative assessment, learning in **I**nformal spaces and **P**ersonalised learning (see Table 14.1 for how the three previous sets of design principles were mapped into the new set). The first four principles (C^2FI) constitute the sufficing standard for pedagogical design and lesson planning, while P, with the "idealised" advocate of facilitating individual students to set and pursue their personal learning goals, is a recommended but non-mandatory principle given the teachers' pressure in optimising their limited time and resources available to deliver the full national syllabus with the set of examination-bound lesson objectives.

Grade-level translation also took place as that was the first time seamless science learning was applied to Primary 5 to deliver seamless lessons on certain subtopics, which were vastly different in nature from what was covered in Primary 3–4. That was also where we introduced the alternative model that combines social media and multiple ICT tools (school and home computers, schools' or family members'

Table 14.1 How C^2FIP is mapped to the three existing sets of design principles

Zhang et al. (2010)	Wong (2013a, b)	Looi and Wong (2013)	**C^2FIP**
Integrate formal and informal learning activities	Design spiral-style learning process to reinforce the linkages between past and present lessons	Extend classroom learning to other dimensions	**Connectivity of learning contexts**
• Design student-centred inquiry-based learning activities • Facilitate knowledge co-creation	Design in-class consolidation activities for the students to pick up the critiquing skills for peer reviews and knowledge co-creation	Facilitate social knowledge co-creation and collaborative learning	**Socio-constructivist learning**
Assess student learning formatively	Student artefacts as a means of formative assessment	• Make students' thinking visible and thus shareable • Assess formatively from peers or from the teacher	**Formative assessment with student artefacts**
Making use of community support and resources	Design activities with family involvement	• Design for holistic and authentic learning • Facilitate participatory learning involving the family	**Leveraging resources in informal settings**
–	Encourage students to carry out more open-ended learning activities out of their personal curiosity and learning interests, and trigger their desire to create (promote diversity)	• Incorporate different learning modalities to personalise learning (i.e., to fit students with different learning styles) • Design student-centred learning activities to promote engagement and self-directed learning	**Personalised learning**
Exploit the affordances of mobile technologies	–	Provide a learning hub (mobile device) to integrate multiple learning activities	*(Not explicitly incorporated into C^2FIP—Reason: We will still let the students use mobile devices but not in 24 × 7 basis. Rather than mobile devices, we use social media as the "learning hub.")*

handheld devices or cameras, etc.)—individual students may switch between these devices at their convenience to have access to a common social media space for seamless learning activities. This model is known as "division of labour" (Wong, 2012) as the "1:1, 24 × 7" settings are no longer required. Furthermore, to assist the teachers in developing their design capacity for seamless science learning, we construct a rubric informed by the C^2FIP principles for them to formatively self-evaluate “how seamless” their own lesson plans are (Wong, Looi, & Voon, 2018). The rubric is undergoing a validation process at the time of writing; and we are envisaging customisation of the rubric for evaluating seamless lesson plans of other subjects at different grade levels in K-12 schooling, or a generalised, subject-independent version of it.

14.3.5 Subject Translation (2009–2010): Move, Idioms! (Primary 5 Chinese)

The “Move, Idioms!” project was a conceptual spin-off of the earlier one-off seamless English preposition lesson (see Sect. 14.3.1). The seamless Chinese learning model underwent a 2-month pilot study in late 2009, followed by a full-fledged 10-month intervention in 2010. Whereas a set of Chinese idioms selected from the Primary 5 textbook were adopted as the explicit learning points, what more crucial was to develop the students’ Chinese communication skills through contextualised social media creation and peer interactions/reviews as well as the disposition of self-directed seamless learning. In both rounds of study, our project team loaned out smartphones with 3G broadband subscriptions to the participating students on 1:1, 24 × 7 basis.

An iterative seamless activity process was derived and implemented, which were later generalised (i.e., becoming subject-independent) into the Facilitated Seamless Learning (FSL) design framework as reported in Wong (2013b). Each iteration of the process consists of four activities as summarised below,

Activity 1—in-class idiom learning (designed in the form of a lesson plan): The students recalled a small set of idioms learned before by watching mobile-optimised comical animations on their phones, which depict the meanings and usage of individual idioms. They then worked in groups to brainstorm for suitable contexts and co-create social media (photos and captions that utilised the idioms) within classroom or campus.

Activity 2—out-of-class independent social media creation: The students carried their phones 24 × 7 for a repeat viewing of the animations as well as proactively identified authentic contexts or self-created contexts (e.g., by manipulating objects or enacting scenarios with family members) in their daily lives, which could be associated with one or more idioms learnt, took photos and wrote captions in Chinese, and posted them onto a class wiki space.

Activity 3—online peer learning: The students performed peer reviews on the wiki space by commenting on, correcting or improving their peers’ social media write-ups.

Activity 4—in-class consolidation: The teacher facilitated class-wide or small-group discussions on selected social media to improve both their artefact creation and peer review skills.

During the full-fledged study, the students contributed a total of 920 photo/sentence sets. We found the students' social media creation and commentary activities were relatively "informal", authentic and yet strongly linking to the teachers' instructions. We performed a content analysis on the student artefacts and observed a similar pattern, across most of the students, of language improvement and their more eager interactions with the physical environment in their daily life (Wong, 2013a).

14.3.6 Grade-Level and Techno-Pedagogical Translations (2012–2015): MyCLOUD (Primary 3–4 Chinese)

Despite the encouraging outcomes from the "Move, Idioms!" project, there were challenges in its scalability and sustainability. The learning design was an add-on in relation to the formal Chinese Language curriculum. Thus, it was nice-to-have but too resource-consuming to implement on an ongoing basis. Furthermore, during the study, despite being able to motivate the students to carry out after-school artefact creation activities, most of them did not go beyond creating artefacts pertaining to the idioms, albeit being encouraged to work on other lexical items that they were learning or encountering in formal or informal settings. Idioms constitute a limited and highly context-specific aspect of language learning. Good contextual knowledge of the relatively small set of idioms may enrich the students' oral and written expressions. However, the effects on the students' overall language proficiency are limited. Henceforth, we extended the "Move, Idioms!" model to become MyCLOUD with the intention of integrating seamless Chinese learning into the formal curriculum of Primary 3–4.

Three classes of Primary 3–4 students were involved in the MyCLOUD project for 2 years (2012–2013). Each student was equipped with a Tablet computer with 3G broadband access, co-paid by the school and the parents. The four-activity Facilitated Seamless Learning framework was again deployed for the longer-term learning design, with the major tweaks of (1) connecting each FSL cycle with a textbook passage; (2) that the target vocabulary to learn and apply in each cycle is no longer restricted to idioms but all types of word forms; (3) a stronger emphasis in social network-like interactions (as compared to "Move, Idioms!" where students were only performing peer linguistic reviews). The main intention was to promote a niche environment where they may use Chinese to communicate at ease—i.e., to blend the utilisation of Chinese into their daily lives.

Moreover, we co-designed and developed with teachers the MyCLOUD platform (Wong, Chai, Zhang, & King, 2015), as no single off-the-shelf platform in the market met all the needs of implementing the translated model. The new platform consists of three main components, namely, (1) Mictionary (Mobile dictionary): This is a vocabulary learning e-portfolio where students record vocabulary that they encounter in and out of class, and subsequently build most of the content on their own, such as adding meanings, pooling relevant online resources or creating social media utilising individual words; (2) My e-Textbook: The digitalised textbook passages are associated with the read-aloud function; students may highlight unfamiliar words and those will be automatically added to Mictionary; (3) MyCLOUDNet: This is a social network for students to post social media and respond to others' posts; the students may either directly post their social media here, or the social media that they created in Mictionary will be duplicated to here. In essence, My e-Textbook belongs to the formal learning space while MyCLOUDNet is an informal space. Mictionary provides the means of bridging the two spaces by linking to both My e-Textbook and MyCLOUDNet. The connection between Mictionary and MyCLOUDNet facilitates the bridging of individual and social learning.

The intervention resulted in significant increases of several key indicators of the students' linguistic competencies, self-directedness in learning and activity level and sophistication of online interactions (social networking) (Wong et al., 2015; Wong, King, Chai & Liu, 2016). However, such positive changes typically only prevailed after the first few months of enactment. Indeed, as Nation (2001) argued, language learning from contexts is a cumulative process, which results in small but positive gains in each encounter—this is also true for promoting seamless learning, which requires longer-term enculturation for the students. The MyCLOUD model was later diffused to four more schools since 2014.

14.3.7 Grade-Level and Techno-Pedagogical Translation (2016–2017): LI-NterChange (Secondary 1–2 Chinese)

LI-nterChange marked our team's first attempt to spread seamless Chinese learning to the secondary school level. The "L" and "I" in LI-nterChange" refer to "language" and "ideas" (or "interactions"), respectively; and in a nutshell, "LI-nterChange" refers to the construction of a social network-based environment for "interchange" (exchange) of linguistic artefacts and ideas/meanings. The intention is to design for the bridging of informal discourses (social media creation and online interactions) and formal (teacher-assigned) writing as the socio-pedagogical means to develop students' competencies in meaning-making and communication in Chinese. To guide the interventional design, we proposed the SMILLA (Social MedIa as Language Learning Artefacts) framework, a novel approach involving multiple learning paths within both the contexts of seamless learning and language learning (Wong et al., 2017). To enact this framework, we developed a three-stage Chinese learning process to foster lower secondary school students' communicative abilities in four interactional types: narrative, descriptive, expository and argumentative. Stage 1: enculturating students to the new social media space in Chinese; Stage 2: scaffolding students in improving and enriching their social media by retelling in the four interactional types; Stage 3: connect the social media activities with formal classroom compositions where students are allowed to codevelop materials based on their relevant authentic experiences and personal voices before writing compositions.

Nevertheless, while we believe that the SMILLA framework is academically well-rooted and has been proven worked well at primary schools, we faced inevitable challenges in implementing the approach at secondary schools. Due to external factors and our miscalculation on secondary school teachers' and students' bandwidths in carrying out such longer-term interventions, the interventions were unable to be advanced to Stage 3 and, therefore, did not yield the expected outcomes. In terms of teachers' and students' bandwidths, in particular, the overall curriculum content across all subjects is double of that of primary schools, yet the class time of the Chinese subjects is reduced by half; and there are a lot more Co-Curricular Activities and school events as compared with primary schools. This resulted in frequent postponement of seamless lessons and disrupted the intervention timeline being planned months in advance.

Another hindrance is known as cognitive dissonance in the participating teachers. Teachers are supposed to play the roles of agents and designers, who are making pedagogy relevant and meaningful to their students and themselves. Indeed, the PD sessions that we conducted at both schools aimed to transform their beliefs in Chinese learning and teaching and equip them with the knowledge and skills needed to enact LI-nterChange. However, as SLL is a socio-cultural, constructivist language learning model that defies most teachers' behaviourist belief about language instructions, we noticed that the pilot teachers in both schools had probably been experiencing cognitive dissonance (Festinger, 1957; Frykholm, 2004)—a person performing an action that contradicts personal beliefs, ideals and values. That rendered unintentional distortion of lesson enactment, which jeopardised the critical success factors of seamless learning. Similar situations occurred in the early stage of the MyCLOUD project in Nan Chiau Primary School. However, due to the more intensive lesson activities and PD sessions, we were able to dialogue with the pilot teachers in an ongoing basis. Thus, we had gradually influenced the teachers to reflect upon and change their teaching styles and resolved their cognitive dissonance.

We drew important practical implications from the study as follows. If the intention is to nurture the students' in seamless and self-directed learning dispositions, long-term interventions are required and should commence at primary school where students' disposition in learning is more malleable, and where both the teachers and students have greater bandwidths to sustain their active involvements in such pedagogy. On the contrary,if the intention is to foster other twenty-first century competencies through seamless learning pedagogy, then the intervention design can be episodic (e.g., task/project-based seamless learning)—such seamless learning pedagogy can be applied to secondary/tertiary students without prior seamless learning experience.

14.3.8 Curriculum and Techno-Pedagogical Translation (2019): e-SDCL (Primary 3 Chinese)

Similar to the Science4C project, the e-SDCL (e-Self-Directed Chinese Learning) model was our team's another follow-up attempt to translate the MyCLOUD model to suit typical primary neighbourhood schools without 1:1 settings. Another key motivation is to "update" the MyCLOUD model to suit the 2015 national Chinese curriculum where the development of oral and written skills in authentic contexts is emphasised. Leveraging the existing technological infrastructure of the schools and the students' home computers and devices, Primary 3 students from two schools ensue a year-long e-SDCL journey consisting of two interweaving, recursive components, (1) in-class meaningful, contextualised explicit instructions of words, sentences and paragraphs; (2) learning by doing in authentic settings (i.e., social media creation) adhering to the seamless learning approach. Furthermore, our reflection upon cognitive dissonance faced by the teachers involved in the LI-nterChange project has prompted us to adapt the teachers' PD model for the new project. At the early stage, our team are developing the full teaching packages including the lesson plans so that the teachers may focus on lesson enactment (rather than being overwhelmed by doing both to start with); and we will assist the teachers to make sense of the essence of the learning model through teacher–researcher dialogue on the review of the lesson enactment. Afterwards, we will gradually involve the teachers in co-designing the teaching packages so that they will pick up the relevant skills at a manageable pace and eventually take over the agency. The e-SDCL intervention is still ongoing at the point of writing.

14.3.9 Subject Translation (2010–2012): In-Situ Knowledge Building (Secondary 2 Integrated Humanities)

The "in-situ knowledge building" model (So, Tan, & Tay, 2012) was a conceptual extension of the Chinatown 2.0 learning trail as reported in Sect. 14.3.1. The model was studied in the School of Science and Technology where all staff and students are equipped with personal MacBooks for teaching and learning in all subjects. The model brought together mobile-assisted outdoor learning trails and ongoing Knowledge Building (KB) with on Knowledge Forum (before, during and after the trails). In the design, a majority of student ideas were arisen from the experiential learning activities on Sentosa Island, a tourist attraction in Singapore, for learning of integrated humanities (geography, history and social science), such as through interpretations of the photos taken, tourist interviews, calculation of the gradient of slopes (i.e., to practice geographic and mathematical skills), design thinking of the attractions, accessibility and amenities of Sentosa. Indeed, KB includes the building of knowledge contexts; and such student-generated artefacts offer provisional contexts, which are triggers or bases of idea generation and rise above (Bachmair & Pachler, 2015).

According to the analysis in a subsequent publication by the team (So & Tan, 2014), the overall learning experience was very much adhering to the 12 KB principles identified by Scardamalia (2002) and at the same time demonstrating the salient features of cross-contextual seamless learning.

14.4 Implications and Conclusion

While we have evolved the various designs and adaptions of seamless learning, they can be traced back to a set of design principles, which has also evolved over time. The readers can recognise the assumed stable internal logic that tightly links one stage of cycle of innovation, adaptation or translation to another across levels and contexts, providing the seamlessness with which each translation moves across contexts. Each translation continues to seek to provide a more balanced emphasis to the needs of the learners, the agency of teachers, the readiness of the school leaders, teachers and students to embrace innovation, and the availability and support of the technological infrastructure. The sustained programme of research design and implementation embraces researchers working closely with practitioners to define the problems the latter would like to address in the diverse school settings. As our above narration of the various translations demonstrates, the efficacy of the various innovations and adaptations of seamless learning depends in part on a powerful set of design principles, a process of design-based research and implementation research as well as on the agency, capacity, mindset and culture of the practitioners. Ours is an account of translational research of educational innovations and practices in the praxis of research honed and informed by practice and policy.

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Part IV
Macro Layer Ecology—System Brokers and the Role for Integration

Chapter 15
Diffusion Models of Educational Innovation: System Brokers as Agent of Scaling

Imran Shaari, David Wei Loong Hung, Shu-Shing Lee, Liang-See Tan, Lyna, and Yusuf Osman

Abstract This chapter elaborates role of brokers in scaling educational innovations in a system through partnership models. School leaders make decisions for school change and improvement, and they are encouraged to collaborate beyond their school boundaries. Partnerships are integral to scaling and reform. Three models that illustrate students, teachers, and steering committee as brokers within the partnerships are presented. They are brokers who function vertically and laterally at levels of the system, establishing working relationship with stakeholders and negotiating to diffuse innovations. The models emphasize students, teachers, and steering committee can form partnership beyond school boundaries to aid in the process of mediation to scale innovations. They are positioned as leaders, sustaining innovations beyond seeded schools, negotiating with multiple stakeholders toward consensus, and extending relationships across schools for improvement.

15.1 Introduction

This chapter presents the findings from a three years study that explores partnerships between the schools and different agencies, from in and out of the Singapore's education system. The partnerships are imperative for the teacher professional development, capacity building, and student learning (Shaari & Hung, 2018; Shaari et al., 2018). Three models in conceptualizing the partnerships to assist in scaling Educational Innovations (EI) are presented.

El is described as interventions in schools that seek to achieve goals of twenty-first century student-centered learning that include technology mediated practices. The

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key strategy employed by the schools in driving the scaling of the EI is an establishment of partnerships. There are a large number of domains in which partnerships can be built, and these domains vary with respect to several important dimensions. What is required to be qualified as agents in the partnerships tends to vary accordingly. Previous studies, however, have shown that several common benefits can be manifested from all (or almost all) types of partnerships (P21CS, 2008; Lasky, 2004). However, there is no study that systematically identifies models around these partnerships, particularly in the Singapore education system. The research question is as follows: What are the models practiced by our schools in diffusing of educational innovations?

The models attempt to describe levels of partnerships between departments, teachers, schools and multilateral linkages between the levels, and the external agencies. Partnership or relationship that transpired between these agencies is the unit of analysis. The unit of analysis is not Professional Learning Community, Community of Practices (CoP), Learning Communities, Community Relations, Taskforce Committees, or Community Building. Rather, it is about partnership models which might adopt the above strategies. These units are relevant and have assisted to frame the findings. For example, CoP concepts (Barab, Barnett, & Squire, 2002) was partly used as lens in analyzing how the partnerships developed. They are useful utility tools to better inform the results.

The models in this chapter concern formulation of partnerships by the schools to diffuse EI. By deriving various models of partnership, future research can delve in relating them to teacher and student learning outcomes. The models may be impetus for diffusion of successful innovations in helping the students to undergo different experiences in their schools. The models can assist in understanding how partnerships enable EI enactments in schools that provide approaches to leveling up teachers' professionalism and learning (Toh, 2016).Thus modeling the partnerships from the perspective of scaling innovations is imperative.

15.2 Literature Review

15.2.1 Partnerships for Scaling Educational Innovations

Annenberg Institute for School Reform (2009) has documented several benefits manifested from carefully planned partnerships to include reduced overcrowding, assisted in reallocating resources, increased schools' accountabilities, offered greater educational opportunities to low-income neighborhoods, and stimulated change at the system level for schools reform. Johnson and Crispeels (2010) offer high level common factors in successful partnerships that are useful for schools to include the following: shared values and what constitutes best practices (Lasky, 2004); trust systems (Datnow et al., 2006); communication tools (Lasky, 2004); policies, arrangement designed, organizational (Johnson & Chrispeels, 2010); physical and human resource infrastructures—leveraging to form partnerships.

Partnerships are integral to scaling and reform (Hargreave & Shirley, 2009; Peurach & Glazer, 2011). Partnerships which helped in initiating, developing, and implementing EI to success are central and integral to social and relational underpinnings of scaling. This is because educational reform is more a social and cultural process rather than a science with mechanistic procedures. Linear models of scaling through replications are challenged for their appropriateness in education (Coburn, 2003) since nuances of localized contexts are central in successful scaling. For enactments of EIs at local contexts especially for diverse and differentiated forms of pedagogy and curriculum of inquiry-based learning, teachers need to be adequately prepared to be attuned to actual performance of tasks and activities related to the innovation's desired practice.

To accelerate spread and diffusion of successful innovations, building partnerships in multiple fashions around these innovations is one novel way. This is as opposed to spreading innovations through mechanistic roll out approaches, incrementally implementing innovations to respective schools in a roll-out manner. However, little research on partnership models surrounding educational innovations is available. Partnerships bring schools, teachers, parents, students, and external agencies together. Convergence of these individuals and entities toward scaling the EI only makes partnerships more complex as multifaceted tensions overlap to drive dynamics of the partnerships.

Dynamics and richness of partnerships may be resulted from two inseparable and mutually constitutive elements of the partnership success factors. They are dualities that have potential to productive tensions that in turn may afford adaptive and interactive learning experiences among members where the EIs are localized. This ecology of partnerships are also attributed to partnerships' qualities and influences that could involve families (e.g., time and parental role) (Sheldon, 2002), students (e.g., dispositions, temperament) (Davis-Kean & Eccles, 2005), and schools and external agencies (e.g., resources, professional knowledge) (Hoover-Dempsey, Walker, & Sandler, 2005). Significant research shows that when schools develop cultures that support well-designed partnerships in terms of joint activities and programs (Epstein, 2001), it can minimize some idiosyncratic effects of domineering partners (Hoover-Dempsey et al., 2005).

In summary, there are plethora of partnerships established in schools, ranging from structured to unstructured, this research focuses on both. It study how schools model their partnerships in association with scaling the EIs. Through the models, it is hoped that system brokers such as champion teachers can mediate levels in sustaining innovations beyond the seeded schools, negotiating with multiple stakeholders toward consensus and extending relationships across schools for improvement. The idea behind system brokers is to sustain effectively teaching and learning innovations, transcending power distanceacross hierarchical structures that exist when entities collaborate. System brokers are hoped to assist stakeholders within the partnership to open up to let valuable knowledge flow in facilitating learning across levels, creating opportunities for teachers to experiment and students to exploit new ideas.

15.3 Methodology

The focus of our investigation was on partnerships in schools. Data were gathered through in-depth semi-structured research interviews with schools' leaders, senior stafffrom an education Ministry, teachers, and students. Interview data were complemented by observations and desk research, namely, the analysis of schools structures pertaining to their partnerships, public documents from the education Ministry that elaborated specific schools programme that involved partners, documents about work processes of programme executions, presentations, and artefacts resulted from some of the schools' partnerships.

We identified three models, (1) Farming Out; (2) Distributed; and (3) Consortium, as characterizing partnerships in schools. The goal is to enable readers discern on the partnership operation while at the same time presenting these models in a manner that will provide insight into partnerships intentionally designed to support diffusion of EI. A staging approach was noted in analyzing the data that broadly corresponded to the three models, respectively (See Table X). Although the models are staged separately, they are not sequential and does not exist orthogonal after the next; instead they can coexist and are associated to provide insight into the other. Frequently, when coding data, a particular model's components might be associated with other models. Therefore, although parsing up the partnerships into distinct models may be useful for presentation, it is clearly not representative of the partnerships' complexity in situ. We will describe the models' components and their relationships. Subsequently, we illustrate case study in relation to each model to discuss their structures and interactions toward differing system brokers.

Farming Out Stage 1 (2003–2007)	Distributed Stage 2 (2008–2012)	Consortium Stage 3 (2013 Onwards)
• School partners helming the intervention • In the later part of the 5 years, the school had explored a leadership process to engage in pedagogical innovations • School Principal began to practice a distributed leadership approach • Begins to broaden the partnership to include/engage with industry, e.g., Microsoft	• School Principal adopts a distributed leadership • Adopts a collaborative partnership with university researchers • Expanded on collaborative partnerships • With additional funding sources set up a research center within the school where personnel with Technological Pedagogical Content Knowledge are hired directly into the school-based center • Gradual identification of pedagogical champions	• School begins to engage in partnerships with other schools • Cluster Superintendent is centrally involved • Funding from alternative sources • A seeding-seeding schools' mentorship program structure is set up to enable teacher community and learning across schools • A centralized "committee" is created to steer the directions of the diffusion efforts • Teachers across schools have an accountability structure to govern their work/learning journey

15.4 Findings and Discussion

15.4.1 Farming-Out Model (F-Model)

Figure 15.1 illustrates the Farming-Out model of partnerships and the relationships between the schools entities, EI, and the partner. The school has a boundary that comprises of the School Management (P), team of teachers (T1…Tn), and group of students (S1…Sn). A clear reporting line is depicted. The S1…SL report to T1…Tn which in turn report to the P. The reporting artifacts include the frequency of the students' attendance, habitual absentees, and the teachers' roster pertaining to managing the students, and yearly report. The dotted line linking T1…Tn to the EI and the partner indicates minimal management performed by the teachers on the development of the EI and the overall work processes.

In terms of interactions pertaining to the EI, it is richer within S1…SL and between the partners as oppose to at the T1…Tn level. In other words, the teachers' involvements with the students' learning are minimal. The rich interactions between students and Z1…Zn revolve around the development of the EI, challenges encountered, and the students' roles and respective functions. The model highlights intensive collective interactions between the students and the EI as they directly take ownership of the EI. Within the partners (Z1…Zn), they work to impart industry's best practices

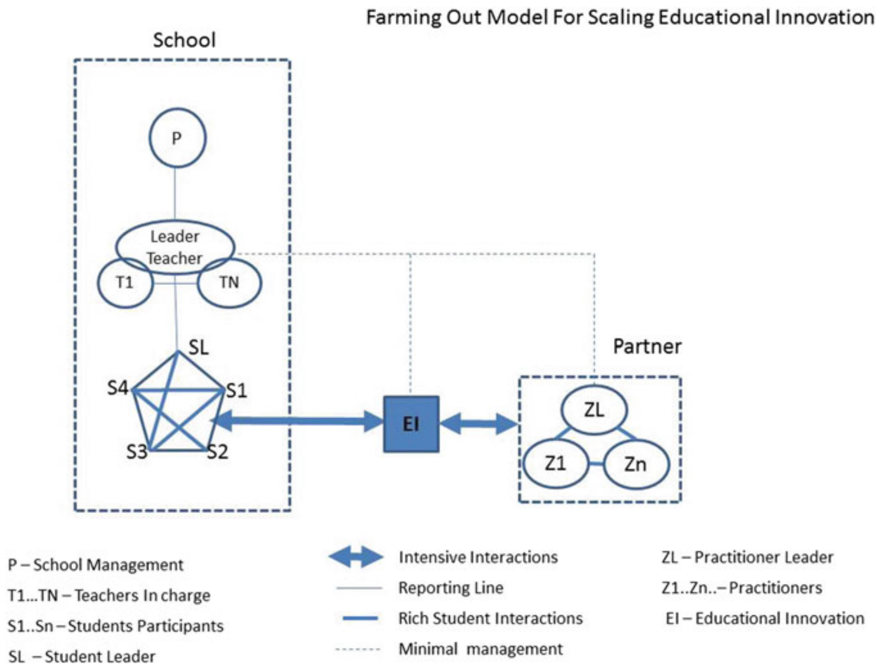

Fig. 15.1 Farming out model

pertaining to the development and management of the EI. The partners are short listed by the teachers at the start of the EI development. They are shortlisted based on their past records that are related to similar EIs, costing and availabilities of funding.

In the Farming-Out model, there is no strong common ideology and hence the trust relationships are short-termed, and potentially end when the partnerships are disbanded. While common purpose is vital during the partnership-cycle to ensure satisfaction in the completion of projects and to gain maximum learning experiences, the partnerships receive casual teachers' attention.

Thus, teacher learning pertaining to the EI is minimal or at the peripheral. Due to high degrees of autonomy given to schools, policies and work arrangements are designed by the decision makers from the school and their external partners. As such, in the farming out model, the school farms out to the external agency to develop students' abilities, and this model is very evident in the CCAs.

This model offers the learners twenty-first century learning opportunities such as negotiation, collaboration, communication and organizing skills. In terms of resources, dedicated budgets and manpower are available from the school given by MOE and other funding sources. There is a good chance of gaining favorable resources from the MOE if a niche area is developed by the school.

In summary, the farming out model has the least dynamic learning interactions between teachers and external agencies, although students do learn from expertise available from outside the school. This model works as it capitalizes on expertise beyond what school teachers can offer, but there may be sustainability concerns such as when funding expires and schools can no longer sub-contract the services out to external vendors. Our recommendation for sustainability is for some means where teachers can also be involved in the dynamic interactions of the EI and transfer of expertise made possible to the teachers.

15.4.2 Case Study Farming-Out Model: Students as a System Broker

A secondary school Design and Innovation Club (DIC) was chosen as the study context because of its active participation in local and global competitions. The club offered a space where educational innovations took place outside the classroom settings for students to take full ownership of the competitions. These competitions were not linked to high stake exams. The teacher-in-charge was directly supporting the students' involvement in the competition from recruitment of students, facilitating registration to monitoring the progress of the students' performance in the competition. Several teams would be formed to participate in the competition.

To infuse students as a broker, first, the context was developed by the teacher who would ensure that each team consisted of both senior and junior students. This arrangement was made intentional to allow the senior student who once participated in the competition to guide the junior students. In each team, a leader or team manager would be appointed amongst the students in the group. The team manager would coordinate the works and the progress of the works of the group in the competition to update the teacher. For example, the student leader needs to inform the teacher-in-charge of every liaison contact that he and his team made to any external entities (e.g., sponsoring companies). The teacher would then update to the relevant Head of Department (HOD). Both HOD and teacher-in-charge would also report to the Principal on the progress of the competitions from time to time.

Second, the student brokering skills—such as the abilities to negotiate and resourcefulness—were tested during preparations toward the competitions. Throughout the preparations, the teacher plays a minimalist role in guiding the students such as negotiations with the sponsors if the students found it difficult. The competitions offered the DIC members exposure to multi-disciplinary global/local platforms where 'teams of students aged 9–19 deploy Computer-Aided Design and Manufacturing (CAD/CAM) software to collaborate, design, analyze, manufacture, test, and then race miniature compressed air powered balsa wood Formula 1 (F1) cars' (F1 in Schools Singapore, 2013). The competitions were organized to offer the students an interesting way to learn Science, Technology, Engineering, and Maths (STEM) related subjects as well as to increase the intake of students taking up Engineering (F1 in Schools Singapore, 2013).The high degree of know-how in engineering concepts and physics witnessed the resourcefulness of the students in garnering collective efforts. The students demonstrated persistent interactions among themselves toward successful completion of the project from initiation, idea conceptualization and refinement to high quality implementation, as testified by the number of times the club has won at the competitions.

Third, as a broker, the students had opportunities to interact with the expert practitioners. Through participation in the competition, the students were given access to a whole networks of practitioners and practitioner leaders such the staff from F1 in Schools company who manned the compulsory workshop that every student participant needs to attend in order to participate in the competition, the companies which the students approached for sponsorship in the course of the competition and fellow participants from overseas universities while they participated in the World Championship. Structured interactions were observed in formal workshops conducted by the practitioners. This workshop was made compulsory by the practitioners' company for all the participants. In this workshop, students were taught how to design and manufacture the car's prototype, creating marketing collaterals to attract sponsors and the simple theories on factors that would affect the speed of the car. Such workshops are held over 4 h on each of three days after formal curriculum hours. Unstructured interactions were observed when the students were in their respective teams, to build the car prototype for the competition.

Fourth, students as system broker to diffuse authentic learning were demonstrated when the senior members took charge of their respective teams to build the car prototype for the competition. In their respective teams, the students were assigned the roles of a design engineer, resource manager, team manager, and graphics designer. These were the fixed roles that the company instituted for each group. In the course of manufacturing the car prototype and coming out with the marketing collaterals to attract sponsorships for their participation in the competition, the students learnt hands on to collaborate, coordinate, and negotiate their works in relation to that of the work of their group mates and the companies that they have approached.

Further, through interacting with other participants and companies in the process of the competition, the students learnt hands on how to improve their car prototype so that it can travel fast. Trips overseas such as the trip to Kuala Lumpur for World Championships had boosted students' self-esteem as they saw themselves on par with students from foreign universities who were also competing on the same platform. The students 'make use' of such opportunity to learn from others who were perceived to be better than them academically to improve their performance in the competition. Participating in such competitions also stretched the students' capacity to manage time and stress as it was deadline bound and took up most of their time after formal schooling hours. The support of the teachers through easing the workload of the students in school as well as words of encouragement helped the students to dedicate their time to the competition as another endeavor apart from their sole endeavor in the academics as a student.

As a system broker, the students offered a sense of drive and ownership that make use of the twenty-first century learning opportunities offered in such a platform to improve their personal dispositions. The teachers, on the hand, only play a minimal role in the learning process as they focus more on doing the emotional support role in encouraging the students to perform in the competition.

15.4.3 Distributed Model (D-Model)

Figure 15.2 presents the Distributed model of diffusion that illustrates partnerships between school, EI, and practitioners. In this model, the school boundary is blurred as the distributed practitioners merge to congregate to work closely within the school. The partners' organizations highlight a cluster of complementary skills. As opposed to the Farming-Out model where the partners are sourced on the basis of administrative needs (e.g., funding), the partners in this model may be seconded, transferred, or assigned by their respective organizations to take part in the diffusion effort. This model has three core groups: the practitioners, school management, and students (see Fig. 15.2). The school management group consists of the principle/vice principle, teacher leaders and teachers, and leaders among the practitioners.

The school management group is identified by their management role. They performed a range of management duties relating to the EI: planning, delegating, monitoring, assessing, and quality control. The continuous lines linking this group to the practitioners and the EI describe the tight management that oversees the partnership and EI. Unlike in the Farming-Out model, the school management has a more direct role and may influence the state of affairs of the partnership. It is perceived that the students' are highly motivated learners who have been carefully selected to be

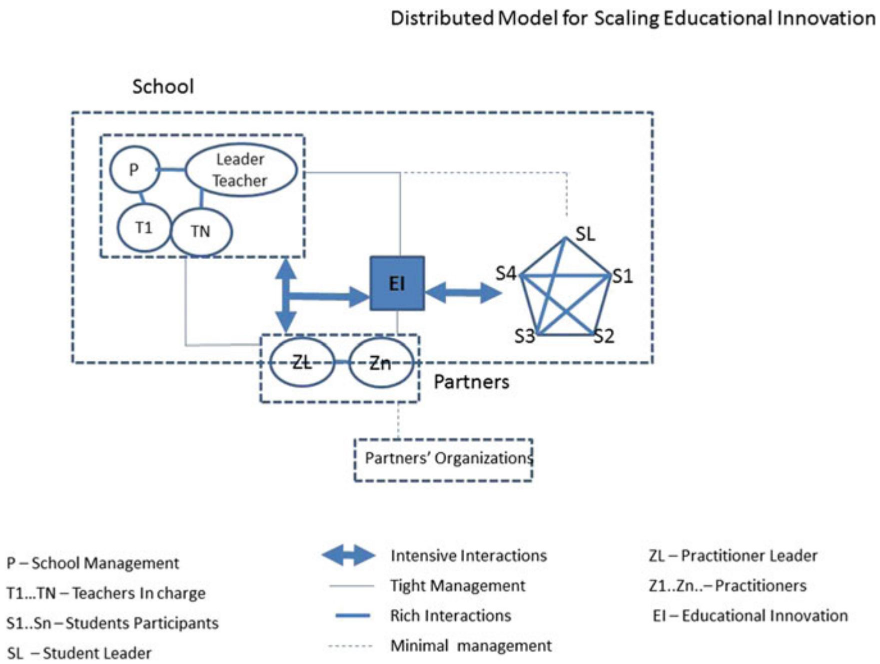

Fig. 15.2 Distributed model

part of the partnership. The students are active and forthcoming to experiment with the EI directly. They are motivated specially chosen to participate based on talent selection and the student own agency to excel experimenting with the EI.

The thick dual-direction arrows in Fig. 15.2 highlight the three ways intensive collective interactions revolving around the EI by the three groups. The arrows indicate interactions that go beyond administrative matters. The interactions include conflicts resolution, idea sharing, and brainstorming that put all the three groups on the same level because they have approximately equal stakes on the EI.

Expectedly, within the groups, the interactions are rich. The interactions at multiple levels range from the school management to teachers to practitioners and to students in addressing the common goal of student concerns as the EL is perceived to be designed from the combination of theory and best practices. Teacher learning pertaining to the EI is dynamic, and they learn to innovate with the constant flows of ideas generated from the different groups' members in tight collaboration. The arrangement appeared to enable tightly coupled two directional partnerships that enculturates teachers' learning.

In a distributed model, a strong ideology is built because the partnership are typically passionate about the EI beyond the school boundary. Since the partnerships comprised of members of diverse background (i.e., practitioners of different expertise and their organizations), the ideology is formed on the basis of shared values and the drive toward best practices. This model requires intensive investment on the onset and trust is developed for a long term relationship. As such, these partnerships are expected to last beyond the student school years.

It is expected that to enact the distributed model, a higher integration between school leaders, teachers and practitioners, and tighter arrangements are needed to advance the EI for the sake of the students learning. In terms of resources, relatively more funding is required and the sharing of infrastructure and resources is not uncommon. This model is consistent to the partnership models evident in schools that specialize in sports, arts, and technology where practicing practitioners are hired directly into the school itself.

15.4.4 Case Study Distributed Model: Teacher-Practitioner as a System Broker

A school specializing in Art that integrate different art form into its academic curriculum was chosen because it aims to identify and nurture the artistic and creative talents of young Singaporeans by providing a learning environment where their artistic and academic potential can be best realized and for its graduates to be better positioned to pursue higher education in the arts or arts-related fields or apply their artistic and creative capabilities in other fields. The school was expected to offer “a completely new paradigm of education in Singapore” through the arts to nurture “the next generation of artists, creative professionals, and individuals who are passionate for and committed to the arts in a multi-cultural society”.

As such, there are pervasive and deliberate efforts from the management teams and teachers to integrate the arts in numerous EI to cultivate connectedness as a way of knowledge. At the school level, the complex interactions manifested the notion of connected curriculum that focuses on the learner to explore diverse perspectives, pose problems, reason, and evaluate metaphorical relationships. The connected curriculum has also afforded spaces that nurture adaptively which is rooted in integrated, imaginative and creative thinking, behavior, and action. The integration of curriculum is conceptualized by teachers and artist-teachers who share similar interests and passion. Together, through consistent interactions, they have created networks that are dynamic, generative, and at the inter- and intra-disciplinary levels. Overtime, some of these networks have become an influential unit within and outside the school.

At the systemic levels, the complex interactions manifested the school to ensure learners are sufficiently immersed in the arts, interacted with meeting the challenges of their future commitments and aspirations. Important changes in the belief systems, opportunity structures, and bodies of knowledge and material resources are constantly discussed to sync with the national policy expectations. The dynamism have witnessed a growing role of the arts for the future growth and maturing of the Singapore as a nation and as a society.

The aforementioned integration impetuses the EI diffusion and was possible through the role of teacher-practitioner as a system broker. For example, the model enables the school to recruit a diverse pool of qualified and experienced practicing artist teachers and academic teachers, from Singapore and overseas. Unlike schools under the Ministry of Education's purview, this school has the autonomy in recruiting the staff. They may be hired as part-time staff, in particular, the Singapore's residence artists who are based in the different art associations. Working closely together with curriculum leaders and teachers, they are differentiated by their artistic creative culture that appropriated the vision of an arts-anchored curriculum. Thus, bringing in the artistic flavors from the artists' world views are deliberate attempts when diffusing the EI.

The teacher-practitioner as a system broker created several social and ecological lubricants that afford flexibility and fluidity within and across the system, emerging within the structures to facilitate the diffusion processes. These complex reciprocal interactions are operating at high level of teacher knowledge and practitioner discretion that lead to professional consensus to accomplish shared goals articulated by the school. Actors in the teacher-practitioner partnershipsnot only engage in intensive interaction but also regulate one another where new ideas and strategies emerged and professional learning takes place. In a way, accountabilities are distributed among numerous networks: the school, the artists, and the students. Such professionalism is working at the high level of trust on the part of the school as well as social commitment on the part of the practitioners and their organizations.

This diffusion model has enabled the school to channel teaching practices so that the curriculum fosters "exploration, experimentation, and discovery" to meet the needs of artistically-inclined learners. In other words, curriculum innovation processes are facilitated by contextual enablers such as curriculum vision, making associations between the human (such as teacher expertise, pedagogical and content knowledge, and expertise from artist communities, etc.) and non-human elements (such as the connected curriculum, Renaissance City Reports, and IB requirements).

15.4.5 Consortium Model (C-Model)

Figure 15.3 illustrates the Consortium model and the relationships within. The model links three groups of partners: the steering committee, the practitioners, and the domain members. The Steering Committee (SC) draws its members from the management of a cluster of schools. The practitioners who performed consultative and offer moral supports draw its members from an institution of higher learning, the school principals, and mentor teachers who had earlier undertaken the endeavor. The

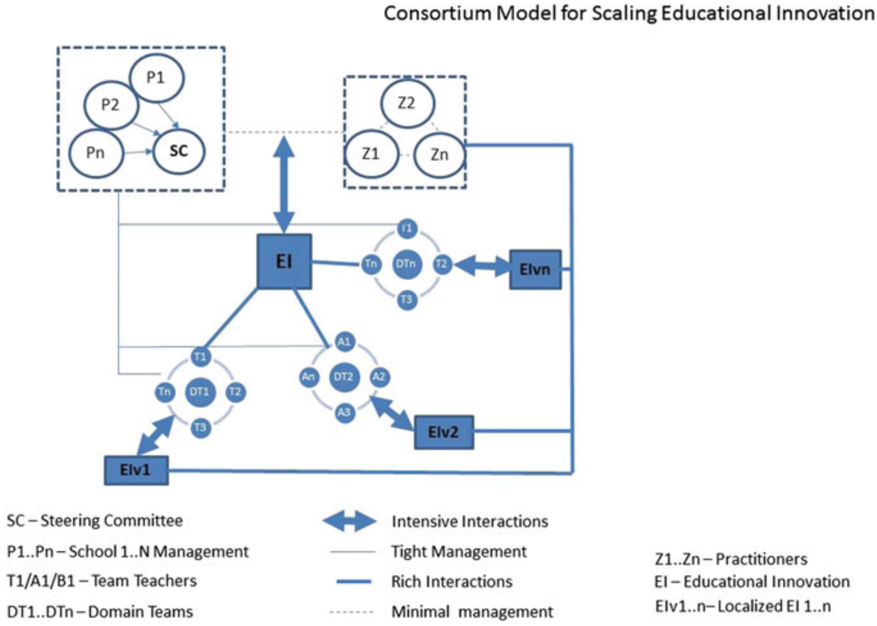

Fig. 15.3 Consortium model

domain members are made of teachers who are specializing in a particular knowledge domain (e.g., assessment, science, and class management). The students' group is conspicuously missing in this model. The SC guides the domain teams operation and management. The three continuous lines linking the SC to the domain teams describe the tight management control, whereas the continuous dotted line linking it to the practitioners describes a more loose relationship. The advantage of the tight control is associated with creation of multiple versions of the EI. That is, different domain teams produce different variations and adaptations of the EI to address the teachers localized needs.

The disparate, collective intensive interactions(presented as three rings) focus on the respective localized EIs (Elv1..Elvn). While the domain teams' interactions are focused in localizing the EI, the practitioners created interactions to merge ideas from the different domains. Taking the interactions together, and through rapid consultative approaches adopted by the SC, a central EI is also created. In our study, the central EI was a publication of the consolidation of localized EIs, the members' reflections and a synthesis of the works by a learning sciences professor. In the consortium model, a similarly strong ideology akin to the distributed model's is crucial. The three group of partners form a learning consortium through specific role that integrate their functioning. For instance, the steering committee have close linkages with the Ministry to ensure information flow seamlessly across levels. On the other hand, the domain teams are highly focused on a particular subject matter and are disciplinary-practice oriented. They work very closely with the expert team members that comprise members from external agencies with complementary skills closely related to the EI. The arrangement produces different versions of the EI as the groups engage in different disciplinary ideas and projects. The multiple versions of the EI enthuse internalization of teacher learning with the intentions to increase their teaching capacity through the collective opportunities espoused. These EIs are self-sustaining and have the possibility to converge. For this to occur, the steering committee can influence on the prioritizations of different EIs to formulate resource allocation across the domain teams. From the steering management perspective, decisions are made to enable schools to collaborate through their teachers.

This model is characterized by higher intensity of inter-intra school communication at multiple levels (steering committee, participants' interactions from IHLs, and domain members). A more integrated work procedure for timely and successful completion of the EI is envisaged. This model is more cost effective as opposed to the distributed model because it utilizes existing school's resource and infrastructure, such as the pooling of resources from the schools to form communities of practices.

15.4.6 Case Study Consortium Model: Steering Committee as a System Broker

NKNK has built a reputation for dispersing educational innovations since its establishment in 2007. It believed on the four principles of CIPS are represented as: **C**ommitment (spirit of community), **I**ntentional (collective learning in a specific domain), **P**roactivity (structured and planned learning), and active **S**ponsorship from School Leaders. NKNK comprised of a cluster of schools that was divided into sub-clusters consisting of around four to five schools each, where primary and secondary school teachers come together, share a concern and deepen their knowledge in the area by interacting with peers within and across schools.

A steering committee (SC) comprised of a superintendent and school principals was at the core in brokering the EI. The SC structured a working arrangement for the teachers to enable school curriculum teams with shared common interests and practices to take ownership of their professional development. The teachers from across the schools interacted to learn from each other, cross-fertilizing new ideas with guidance from consultants and dedicated principals. SC chose consultants to assist the school on the basis of the consultant expertise in a particular domain area.

As a SC brokering the EI, the school principals' direct involvement was telling. They took part in the discussions, made provisions for their teachers to participate and chaired symposium sessions. The domain teams updated the principals about the project regularly. They allocated time into teachers' timetables for teachers to work on their project and for the teachers to interact with other domain teams.

For instance, the SC scheduled mini-learning symposium as part of the domain teams' learning journey. The symposiums were to promote learning through sharing the school-based curriculum innovations and the progress/challenges made or encountered by the teams. In such symposiums, activities were coordinated to engage the teams meaningfully that encouraged sharing. The ethos "what is it in for me" that was extended to "how I can help" was practiced.

As a broker in diffusing the EI, the SC implemented the following system:

- School's membership is voluntary and organic. It is an opt-in system with interested schools sending in their proposals to join the Communities of Practice (CoPs). This is the shared interest that binds everyone to the community both at the school level and the zonal level. The membership was renewed yearly through project proposals received by the SC.
- The sub-cluster (domain teams) were organized according to curriculum knowledge domains. Within each domain there were four to five teachers from different schools. A consultant and a principal facilitator administered the domain team's activities. They guided the teachers in infusing the innovation into their class. The consultant focused on the content knowledge, theories, research literatures (to keep abreast of the latest literature), and research methodology while facilitator focused on the social aspects of the teams.
- The domain teams attended six consultation sessions with the consultant and facilitator to learn and discuss about the EI implementation. The facilitator listened into the conversations to ensure the discussions and questions are focused on the core issues. The domain teams presented their projects in mini-learning symposiums. The symposiums were platforms for teachers to share their endeavors to serve as a form of deliverable.
- The SC produce research paper and reflections about the domain teams learning process to be published in the Ministry publication. Facilitators are also requested to document and reflect on their learning journeys.

15.5 Policy and Leadership Implications

The three models (F-Model; D-Model; C-Model) of diffusion influence the scaling of EI, in particular from the learning perspective of the teachers, students, and schools. The value lies in contributing to improve policy for leaders. The table below summarizes these implications.

Diffusion models	Brokers	Leadership	Policy
F-Model	***Student-Led***: autonomous student centric learning system; student ownerships and accountability	Leaders can strategies to integrate more platforms for tinkering and experimenting beyond a particular context to bridge outcomes in and out of classrooms and school	To intentionally design for sustainability of such model in the long-term by having teachers themselves to participate with students in the learning process To intentionally plan recognizing that there are certain niche programs (out of class such as in Co-Curricular Activities (CCAs) that have connections with formal curriculum more than others and those which facilitate 21st Century Competency (CC) skills
D-Model	***School-Led***: Collective learning and contributions from range of learning domains; high school capacity	Instructional leaders would need to play crucial role in integrating multiplicity of pedagogy to arrive to the desired learning outcome. The leaders' competencies in negotiation to manage uncertainties are equally important	A strategic policy to document the school's trajectory that use this modelvis-à-vis to the demand of expertise organization development To take learnings discern from these schools to develop socio-technological infrastructure in other schools that do not have the same degree of resources and expertise Generalization of key success factors (in area of a specialization) to assist schools in adapting this model Polices to encourage schools in developing long time partnerships with the community agencies should be in place

(continued)

(continued)

Diffusion models	Brokers	Leadership	Policy
C-Model	***Teacher-Led***: Driven by the vision to scale the EI onset in its formation; affinity to existing pedagogical knowledge is strong	Committees like the Steering Committee (SC) enable leaders to enhance their competencies in managing conflicts and interdependencies across departments	Enhancement of policy that encourage and reward the participants Offer platform to integrate the success to be broadcasted and emulated

15.5.1 F-Model

Two key policies can develop the F-Model for diffusion beyond student learning:

1. To intentionally design for sustainability of the model in the long-term by having teachers to themselves participate with students in the learning process.
2. To intentionally plan recognizing that there are certain (out of classroom/school) niche programs that have connections with formal curriculum more than others, e.g., robotics, F1, etc., and those which facilitate 21st CC such as team work and collaboration.

The first policy broadens the F-Model scope to assist leaders in bringing the learning values appropriated by the students to the teachers. We can anticipate resistance from the teachers initially if provisions are not made to account for the additional time needed for them to be directly involved in the EI. To circumvent this concern, the teachers' direct involvement may be viewed and thus assess as their Professional Development (PD) rather than administrative duties. This could be a novel way to which teachers develop professionally by learning from and with the students and practitioners in negotiating real life scenarios. Also, positioning the F-model as such does not incur additional time from them because time for PD has been a part of the teachers' development trajectory. Thus, if the F-model scope is expanded, it can be considered as a new PD avenue for the teachers. However, to enhance the PD with the associated EI, the broadening of F-model requires systematic analyses of how the simple EI reconnects to classroom learning, and this lead us to the second policy suggested.

The second policy is to clearly identify the intrinsic values of the simple EI with regard to in and out classroom/school learning and importantly, their overlap. Since the F-model is often associated with the out of classroom activities (such as CCAs activities), it is imperative to intentionally reconceive CCAs in association with the classroom learning, at the least for a start, rather than classifying them (which is the current practice) to the values (e.g., resilience, electronic knowledge) that it may afford in silo. For example, what does it mean to be resilient, both in addressing repeated failures to prove a physics concept and the feeling of desperateness to find that next pivot point in a rock climbing. Attempts such as this can be more intentionally designed for in the interplay between the formal and CCA (informal) curriculum. The essence is to use CCAs in gaining the ability to think critically and independently and to engage in authentic activities such as to write, reason, and communicate clearly—the foundation for many professions—in the pursuit of accomplishing goals. The capitalization of the interplay between the formal and informal curriculum is an opportunity to challenge the underlying philosophy assumptions of the conventional paths and trajectories undertaken by schools and teachers.

We acknowledge that not all CCAs can be mapped to the classroom activities because of the central curriculum requirement stipulated by the Ministry, limited time and resources, large number of students in any particular school, and different degrees of perceived values and efficacies in doing these activities. We suggest to test or validate this policy by adopting the incremental approach of the C-model, that is, to experiment it with the strong pedagogy affinity of the teachers, driven by the vision to design for integration of the out of classroom CCA activities into the formal classroom.

15.5.2 D-Model

We realize the deep learning experiences that the D-Model can offer and also acknowledge the difficulty in operationalizing this model because not many typical schools have the capacity to initiate and sustain the model on its own. Lately, however, we have noted the mushrooming of schools in Singapore which adapt this model (i.e., there are more specialized schools) as a clear signal that this model has its merit. They have strong instructional leaders and teachers who play crucial role integrating multiplicity of pedagogy approaches to arrive to the desired learning outcome. The leaders' competencies in negotiation and managing uncertainties are important. Firstly, the role of the leaders' in defining and articulating a curriculum vision that is simple and powerful is highly important to generate innovative practices. Secondly, leaders who are interested in developing innovative teaching and learning such as an arts-anchored curriculum or even legitimizing the arts in curriculum should be mindful to foster links between the human and non-human elements that allow the school to function as an "ecosystem".

Like any maturing system, these schools are highly focused in the area that they are specializing in. This approach is valid. They are careful about experimenting with too many specializations, increasing the chances for their success to deliver as mandated. For instance, although an ideal will be for the specialized schools to partner with the mainstream schools at every level of the system, the logistics and readiness of the schools might not be there yet. If such is the intentional goal for the model, policy to assist these schools integrate and collaborate should be put in place or enhance further. For instance, a policy to formulate learning from these specialized schools to develop socio-technological infrastructure for schools whom do not have the same resources as specialized schools is imperative. The basic tenet of this policy is to balance the area of specialization with the core academic subjects for the general student and teacher population to benefit.

We recommend the specialized schools to share key success factors of their area of specialization. There are some obvious mechanisms that drive success factors to include funding, strict selection criteria, passionate practitioners as partners, strong social capital with the like-minded organization (local and international), and shrewd prioritization of area of specialization. We are more interested in the less obvious and tacit success factors. For that to happen, a strategic policy to document the specialized school trajectory is necessary. Meanwhile, an interim policy to encourage schools in developing long time partnerships with the community agencies should be in place. Specialized schools can begin to invite interested schools to network, participate, and collaborate joint event where innovations can be made visible and facilitation for interaction for the leaders, teachers, and students of the schools can happen.

In sum, policy makers need to be alert to the linkages that occur between different elements and appropriate the diverse networks in the organization. These networks create order and disorder and therefore sustain a micro-climate across system. Policy makers and leaders should exploit the interactions in the different systems of the ecology in the school to enable social and cultural capacity building among the staff and its students. Capitalizing on the interactions in the ecosystem may give rise to a sense of belonging, a greater regard for higher cognitive knowledge and processes and therefore a more rooted, knowledge-centric society.

15.5.3 C-Model

In the C-Model, despite the strong steering committee roles and its tight management, the teachers are the foci of scaling. The teachers are driven by the vision to scale the EI from onset in its formation. A high level management and tight control of the partnerships is necessary to coordinate the schools. A rigorous vetting process on the EI potential contributions, its offspring relevancy, and the proposed methodology are critical processes that need to be undertaken at the start of every new EI. A core group of individuals that subscribe to the vision is key to the success of this model, and the production of the EI and its wide dispersion is emphasized. Equally important, and if not more, are the teachers that form the domain teams; their significant contributions are foregrounded for adaptation of the EI to their respective contexts. The teachers form the driving force for executing the steering committee convictions to spread the EI and the needed behaviors. They instill and sustain the mindset to scale at their respective local levels to peer-teachers. The teachers are encouraged to learn incrementally which is characterized by the higher chance of scaling the EI by forming different versions and adaptations that suit their needs. The affinity of the EI effort to existing pedagogical knowledge is strong, increasing the predictability of adaptations and chances of acceptance by the schools management.

C-Model is a scalable model for teacher learning and should be adopted elsewhere as a teacher professionalism strategy. The model has successfully scaled EIs by addressing the local needs of the teachers. We note that the model success is partly due to an unobtrusive intervention policy from the Ministry of Education. The partners have the autonomous power to enable this model to function, and it has been efficiently managed for several years to produce results. On that regard, despite its success, we recommend some form of policy recognition (if not none) for this model, other than encouragement, recognition, and offering platforms to broadcast its success for others to emulate. This model can be structured for other zones and clusters across the school system.

Our suggestion of a minimal policy for such a system follow Professor Toby Greany's (2015) synthesis on the UK Government Department White Paper titled "The Importance of Teaching" (Department for Education, 2010):

1. Teachers and schools are responsible for their own improvement;
2. Teachers and schools learn from each other and from research so that effective practice spreads;
3. The best schools and leaders extend their reach across other schools so that all schools improve; and (by implication); and
4. Government intervention and support is minimized.

15.6 Conclusion

This chapter discusses three models, namely, the F-model, D- model, and C-Model, of partnerships that are practiced in Singapore schools for spreading educational innovations. These models do not exhaustively represent all the partnership models in the Singapore education system. Rather the chapter broadly represents three models to showcase diverse collaborations within, across, and beyond levels of the education system as well as with external agencies. Each model has different affordances and constraints for teacher professional development, school capacity building, and student learning. System brokers (either students, teachers, or school leaders) contribute in varying ways in each model to shape educational innovations for school change and improvement. The models also illustrate how partnerships are integral to the social and relational underpinnings of scaling. System brokers need to leverage leadership and policies to create the socio-technological infrastructure for spreading educational innovations.

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Chapter 16
Learning Networks in Supporting Innovation Diffusion

Ching Leen Chiam

Abstract This chapter will comment on the value of the learning networks in supporting innovation diffusion. Learning networks refer to any group of connected educators who collaborate to leverage this connectivity to improve practices in and across schools. Through the explication of learning network practices demonstrated by two exemplar schools that have successfully leveled up their school-based innovation, we argue that a ubiquitous collaborative network infrastructure is most important and that pro-innovation diffusion schools should work toward building stronger learning networks efforts. Apart from this, the challenges in building learning networks are discussed and various other mechanisms, particularly the larger cultural, resource, and leadership forces that shape the learning networks need to be considered.

16.1 Introduction

Much has been written about the changes in the cultures of work and learning brought about by the emergence of information and communication technologies, technological innovations, and social tools that reduced temporal and spatial constraints (Trust et al., 2016). For instance, tools such as blogs, Twitter, social bookmarks, and many, many more-extend our reach into global conversations via text, audio, and video and allow us to build global learning networks to pursue our intellectual or creative passions or needs with others who share them. We can turn to all sorts of professionals and collaborators from anywhere in the world to help us with problem-solving, connect us to relevant content and resources, or just share their own experiences with us. Tasks that were previously the domain of teachers are now under the control of learners: searching for information, creating space of interaction, forming learning networks, and so on (Siemens & Weller, 2011). Through blogs, wikis, online video, podcasts, and open educational resources, learners are able to

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access content from leading lecturers and researchers around the world (Siemens & Weller, 2011).

There is a clear recognition that with the rapid growth, and the old order is no longer functioning as well as they had done. To remain viable in such an uncertain and changing environment, organizations and individuals alike rely on an ability to learn (Edmondson & Moingeon, 1998; Senge, 1990). Learning has become increasingly important. The growing awareness of the need for learning has also yielded a wide variety of alternatives to formal training arrangements that can contribute to individual and team learning. Different lines of research found themselves committed to addressing different learning issues including looking at platforms for establishing collegial relationships that help people to share and improving organizational culture and organizational spaces to create a "culture of development" (Hannan & Silver, 2000).

In the education sector, much as elsewhere, there is much talk about the rapid and profound changes in our educational practices brought by the rapid changes in work, the way work is organized and the changes in organizational ethos (McNay, 1995). Commentators have noted that there exists an inherent pressure for schools, educators, and researchers to *transform* and implement technology-transformed learning mediated by pedagogical innovations that bring about improvements to overall teaching and learning (Toh et al., 2015). As Senge, Schneider, and Wallace (2014) aptly reminds us, while "business is the most powerful institution today, education (institution) is the most important. How we go about educating children shapes the next 50 to 70 years of our society. It is the only institution in modern society that has that long a time horizon" (Senge et al., 2014, p. 12). That means schools will need to embrace a form of learning that is fundamentally different from the one they have known.

Although there is this awakening, what is not talked about is the role of learning networks in supporting learning, innovation diffusion of schools, and education. And this is a gap that this book chapter will try to demonstrate as part of the practical finding that came from working on a meta-study project involving 11 Singapore's eduLab innovation projects, where we saw that it was the communities characteristic or what we prefer to call as learning networks of people that enabled innovation to diffuse and this has practical implications to efforts for innovation diffusion.

16.2 Theoretical Framework

Four concepts derived from the literature on social networks are particularly relevant as the theoretical framework for understanding the creation and performance of learning networks in supporting learning and diffusion of innovations, namely, networks concept, learning networks, benefits, and challenges of learning networks.

16.2.1 Networks Concept

In its basic definition, the network has been defined as *connections* between entities (Siemens, 2005).

Networks function on the simple principle that people, groups, systems, nodes, and entities can be connected to create an integrated whole (ibid.). Ogden (2018) for instance has defined it as *nodes of links of elements* of different kinds (individual people, groups, schools, other kinds of organizations) that are tied together (consciously or unconsciously; experienced in person or virtually) in some larger patterns by one or more types of connectedness—the passion to learn, values, views, interest, ideas, friends and acquaintances, likes, exchange, communication channels (Richardson & Mancabelli, 2011; Siemens & Weller, 2011).

The power of networks resides in the connections and how connection and flow contribute to life, liveliness, and learning. Nodes that acquire greater social qualifications profile such as reliability will be more successful at acquiring additional connections (Ritter & Gemünden, 2003; Siemens, 2005).

In this regard, the placing of a value on certain nodes over others is a reality. The social network literature for instance notes that identifying the relevance in the learning interactions is important with some nodes becoming more important than others.

The diversity of the network's membership is a core consideration for the reasons for communication and that diversity has considerable innovative potential. It has been explicated that as humans have a herd mentality, and it is easy for learners to gather with others who share their passion to learn, views, and interest, thus causing networks to have a "birds of a feather" effect (Siemens & Weller, 2011). Iterations of interaction between a group of actors also lead to a convergence of norms, values, beliefs, and behaviors (Steward & Conway, 2000). This process of convergence or "isomorphism" leads to the formation of densely connected groups of learners, terms "cluster" or "cliques". And the "homophily (the similarity of learners) and effective communication breed each other" (E. Rogers & Bhowmik, 1971) that can also lead to the pooling of ignorance. Interactions that lead to innovation are often those that are between "heterophilous" learners that meet less frequently (Steward & Conway, 2000). It has been argued that ideas and information that pass between "sociometrically distant" or "heterophilous" (dissimilar) actors are more likely to be 'new' and 'fresh' (Granovetter, 1973; Rogers & Kincaid, 1981). This would suggest that to some extent, quality in networks requires us to seek those who respectfully disagree and make them part of our network. This also suggests that we should aim to improve understanding and tolerance within the network, without reducing the innovative potential of diversity, as the innovation diffusion literature has shown us that innovation diffusion is best facilitated by "open" networks, providing bridges to other cliques (Conway, 1997; Granovetter, 1973; E. Rogers & Bhowmik, 1971).

Networks in the education context are seen as models of organizing education. The networks' movement is part of a larger "general shift, beginning in the second half of the twentieth century, away from individualist, essentialist and atomistic explanations to more relational, contextual, and systemic understandings" (Borgatti & Foster, 2003). The idea of networks as structural models for education and learning is not new. Ivan Illich has suggested in 1971 that school was not the sole avenue for learning and showed that learning webs "can provide the learner with new links to the world instead of continuing to funnel all educational programs through the teacher" (Illich, 1971, p. 73).

Networks are generally not under the control of an individual organization but are more of self-organizing systems that permit learners to explore and define their own learning space in which order emerges from the local interactions taking place (Wilkinson & Young, 2002). Networks can thus take various shapes depending on both learners' dynamics and work characteristics. Networks are defined by attributes of autonomy, reduced resistance to information flow, ease of connectivity, organic growth, and self-directed strategies that include discussions and reflections, testing of new strategies, rapid iteration and improvement of ideas and concepts as well as ease of scalability (Siemens & Weller, 2011). These attributes are antithetical to the traditional model of education, where the structure is defined by the centrality of the educator and the structured, and generally the one-way flow of content from the teacher. Others have also noted that collaboration in networks can be challenging as it does not involve the use of legitimate authority and order in the network emerges from the local interactions taking place (Wilkinson & Young, 2002; Yström et al., 2019).

In this regard, commentators have noted that there is much to be said about the "strength of weak ties" (Granovetter, 1973) upon which most of our network interactions will be built. Weak ties are links or bridges that allow short connections between information, and this has great merit in the notion of serendipity, innovation, and creativity (Siemens, 2005). Connections between disparate ideas and fields can create creative outcomes for innovation problems and create innovations (Yström et al., 2019). These alterations within the network have ripple effects on the whole (Barabási, 2002; Richardson & Mancabelli, 2011).

16.2.2 Learning Networks

Richardson and Mancabelli (2011) have defined learning networks as "the rich set of connections each of us can make to people in both our online and offline worlds who can help us with our learning pursuits" (p. 21). Actors in the learning network can each have their theories and strategies in organizing work-related learning. Hence, learning networks can take various shapes depending on both actor dynamics and work characteristics. The literature notes that the Internet pushes the potential scope and scale of learning networks to unprecedented heights. Others have noted that *learning networks* are often used interchangeably with a few other common terms such as *communities of practice (COPs)*, *professional learning communities (PLCs)*, *collaborative learning communities*, *professional learning groups*, *critical friends groups* (although terms such as *professional learning groups*, *critical friends groups* are typically applied to smaller teams of teacher—usually between four and eight, although group sizes vary) (Great School Partnerships, 2014; Reinelt, 2007), research or data use teams, multisite lesson study teams, teacher design teams, whole-child support teams, and so on (Poortman & Brown, 2018). It is also trite to note that learning networks can also vary in composition, nature, and focus: they may consist of teachers and/or school leaders from different schools, teachers with local or national policymakers, teachers and other stakeholders, teachers in a partnership or involve joint work with academic researchers and many other potential combinations. Indeed, the loose usage of the terms and subtle distinction between the terms use is potentially confusing.

While these terms are often used interchangeably in a very loose way, others have made a distinction between the terms. For instance, Wheatley and Frieze (2006) described that *communities of practice* evolve from networks. Richardson and Mancabelli (2011) meanwhile explicate that while connections in learning networks are social, they go beyond the popular "social networks" moniker that has been applied to Facebook, MySpace, and others. "Social networks" are personal spaces where people connect to people they already know and love, friends, or friends of friends where they share their hobbies, likes, and dislikes through their profile. As Richardson and Mancabelli (2011) explained, learning networks are very different both in form and purpose in that in learning networks, people connect to people they do not necessarily already know, and these can be strangers who share their passion for a particular topic. The connection made on learning networks is not just to keep in touch, but rather *to help one to learn.*

Learning in learning networks has been touted as a big departure from the conventional learning spaces that require a shift in teachers/tutors and learner's perspective. The role of teachers shifts from control to subtle influence and/or initial shaping (Siemens, 2010). Instead of the legacy of the one-way information flow model of teacher-centric pedagogy, learning in networks requires peer-management, collaborative sharing, autonomy, and for learners to have a well-developed sense of *self-direction* and *self-responsibility* as networked learning is not linear. For instance, in the case of web learning networks, the conversations and content that learners immerse in are distributed all over the web, glued together with the judicious use of links by the people the learner is connected with (Richardson & Mancabelli, 2011).

Learning in networks begins with the learner's *passion to learn* and those connections start with *sharing*, which is the lifeblood of the learning network (Richardson & Mancabelli, 2011). The literature notes that once the learners in the network start connecting, it is all about the *quality of the connections the learner makes and not the quantity*. This idea pertains to choosing connections carefully as well as choosing diverse connections. The knowledge resides in these networks (as even though one may not be connected at a given time, invariably others in the network are, and they are reading, filtering, and thinking) and that an integral part of the learning process is to be able to find and synthesize the most current information and recognize connections between ideas that may be found in many different places from any different people (Cross, 2007). To this end, good listening, collaboration skills and not getting too attached to the idea that everything is going to work fine have been suggested as beneficial for the lifelong learning journey (Senge et al., 2014). Members of the network thus become a part of an *ongoing flow of learning*. As they participate in these spaces, they become one node, one actor/learner of many in the network that in aggregate is constantly learning (Richardson & Mancabelli, 2011).

In these learning spaces, people may share links using participative tools like Twitter or Edmodo, offer one's thoughts on one another's blogs, act as critical friends, push one another's thinking, and collaboratively create new knowledge to share with the world. These are primarily intellectual exercises, not social ones. The interactions are often engaging and in many cases can be friendly, but it is not uncommon for members of learning networks to keep these learning and social spaces very separate (Richardson & Mancabelli, 2011). *Regular reflection* is needed to prevent getting lost in the sea of information and conversations and to improve the "signal to noise" ratio to shift practice and allowing learners to grow and deepen in their learning, increase overall efficiency, offer increased participation, increased information flow, and ease the generation and sharing of content. This helps the learners to build their problem-solving capacity, be better prepared for life, and work in the twenty-first century (Richardson & Mancabelli, 2011).

In a learning sense, the likelihood that a concept of learning will be linked depends on how well it is currently linked (Siemens, 2005). Nodes that have gain recognition for their expertise have greater chances of recognition, thus resulting in the cross-pollination of learning communities. Here in this paper, we define learning networks as *any group of connected educators who collaborate to leverage this connectivity to learn more than the current state of knowledge and improve practices in and across schools that may potentially result in higher levels of student learning*. This capability to connect and learn from the knowledge shared by the different parties within the network to achieve "collaborative advantage" (Huxham, 1996) becomes critical when facing rising and multifaceted demands (Chesbrough & Teece, 2002; Inkpen & Li, 1999). They learn actionable knowledge for them to change—that is "the alteration of one state to another, to make different, to exchange, to replace, to transfer, to transform" (Goodman & Kurke, 1982, p. 2).

16.2.3 Benefits and Challenges of Learning Networks

Research evidence has suggested that the use of learning networks can be effective in supporting school improvement. The idea is that the shared competence manifest in the dynamic functioning of learning networks and the cognitive socialization which would enable the learners to productively participate in their knowledge work.

Studies have suggested that effective learning networks are those that meet the necessary criteria for successful professional development (Stoll, Bolam, Wallace, & Thomas, 2006). Teachers' collaboration in learning networks can lead to improved teaching practice and increased student learning (Borko, 2004; Vescio et al., 2008). Analyses of three case studies by Panckhurst and Marsh (2011) have demonstrated that learning networks allow learners a sense of freedom, encouraging learners to be more independent, and take more responsibility for their learning. The learning network works for a couple of reasons.

Part of the equation is the act of making a public commitment, as Ian Ayres, author of Carrots and Sticks, says about motivation: “Other people matter. Mindfulness matters and participation matter” (Ayers, 2010). Ayers, an economist and professor at the Yale Law School, was quick to point out how public commitments are a terrific way to sustain changes that would otherwise be forgotten. Commenting on the post in the learning networks, sharing a plan with a group of peers, or posting ideas raises the level of commitment people have to this kind of learning.

The other half of the equation is that these learning networks can also provide an opportunity to participate in the reflective dialogue that allows learners to scaffold on each other’s learning (Vygotsky, 1978), leverage on experts power, knowledge, support, and experiences and helps learners to develop new approaches to teaching and learning and relate to the innovation ideas and concepts and to see the success of innovation being repeated allows one to re-frame and see a new future or way forward, which are the elements of successful change recommended by journalist Alan Deutschman (2009) in Change or Die. Being part of the network provides an ideal structure for individual ownership (rather than being told to do so) to support the changes in mindsets as relationships in the network helps one to learn new ways of thinking about the situation, practice, and master the new habits and skills that one will need and ultimately makes one amenable to look at the world differently.

However, it is noted by Poortman and Brown (2018) that participation in learning networks does not automatically improve practice and that the effects can sometimes be small and results have been mixed (Chapman & Muijs, 2014; Lomos, 2011).

The literature has noted that harnessing the benefits of learning networks is not without challenge (Hubers, Poortman, Schildkamp, & Pieters, 2019). An earlier paper by Hubers et al. (2017) has shown that it can never be assumed that knowledge will automatically flow through the team, network, or organization. This indicated that dissemination of knowledge is something that will require *explicit attention*, focus, and considerable effort. In that research, it noted that learning network teams who increased their knowledge sharing had quality managers on their team who were willing and able to share their knowledge, who were actively involved in their team’s progress, and regularly discussed their ideas and beliefs about the educational problem. In contrast learning networks that decreased in their knowledge brokerage relied exclusively on written communication or did not undertake any activities at all. It takes a lot of repetition over time before new patterns of behavior become automatic and seem natural and until one accepts the innovation without even thinking about it (Richardson & Mancabelli, 2011).

16.3 Research Methods

As alluded at the outset, this chapter will try to demonstrate as part of the practical finding that came from working on a larger project involving 11 Singapore's eduLab innovation projects. In this regards, the 11 eduLab innovation projects were part of Singapore's ambitious eduLab programs, a key program for Singapore teachers, researchers and Ministry of Education Head Quarters officers to develop Information Communication Technologies (ICT) innovations for learning that can potentially be adopted and adapted by different schools across the system (Ministry of Education of Singapore, 2017; National Institute of Education, 2019). It was launched as an initiative of Singapore's Ministry of Education (MOE) with its sole teacher training institute, the National Institute of Education (NIE) which was supported by the National Research Foundation (NRF) in 2011 to facilitate the diffusion of technological innovations. From 2016 to 2018, it was funded by MOE and administered by NIE (ibid.). The eduLab program has since ended but provided a good frame of reference, as it reflected an important move away from traditional change policy instruments based on the 'linear model' of innovation, to those based on the 'interactive model', where diffusion is no longer considered a distinct last phase of the innovation process, but integrated into the education process as a whole. Through the explication of learning network practices demonstrated by two exemplar schools that have successfully leveled up their school-based innovation, this chapter argues that a ubiquitous collaborative network infrastructure is most important and that pro-innovation diffusion schools should work toward building stronger learning networks efforts.

The next section tries to unpack what has been discovered about learning networks in supporting innovation diffusion, as demonstrated by the case of an innovation that started at two schools that have successfully spread to five schools. Data were collected through purposeful interviews to identify key stakeholders that could provide significant insights into supporting the innovation diffusion efforts. Additional conversations with research participants were often serendipitously arranged with the voluntary assistance of, and invitation by, prior interviewees.

16.4 Case Study the Innovative Knowledge Building (KB) Pedagogy

At the inception of the innovation project, the innovation facilitator of the innovation project was very cognizant about the kind of operational infrastructure and resources that must be put in before the two schools join her project. Her experience in following a teacher learning network of a lab school overseas had helped her to see what might be involved in designing a KB classroom. Her requirements were minimally two teachers (of which must include the Head of Department) to join the team of innovation implementers, and that the teachers to be committed and be involved in the project to understand what the KB principles look like and be fully involved in the innovative technology to see the benefits of the innovation. This came from her previous experience as a classroom teacher who had previously enacted KB principles in her previous secondary school. Hence, when she approached the two schools Principals for participation in the innovation project, she simplified the model, just telling them the theory behind the pedagogical innovation, the possible value that could be gained from the pedagogical innovation, what she planned to do, the operational requirements and the kind of commitment needed from the teachers, what possibly a classroom practice with the innovation pedagogy will look like, the weekly meeting that will be involved and the kind of analysis that could be derived from participating in this project and gave the school leaders the authority to choose the teachers who will implement the innovation in the school.

While it was a new concept that might perceivably have resistance in getting buy-in, the co-principal investigator of the innovation project's association as the Lead Specialist of the Learning Partnership in Educational Technology Branch that provides the strategic direction on information communications technologies in education in Singapore and the fit in pedagogical innovation the school was trying to aim for had contributed to her success in getting the buy-in from the two schools Principals to participate in the project and each of the schools managed to provide her with two teachers (one HOD and one teacher).

So, it was always the three of them involved. At the inception, the HODs of both schools did not have professional learning teams (PLTs) as the schools only started the principle-based community approach of PLTs to support these teachers' professional development much later. However, the investigator of the innovation project knew very well that PLTs needs to have more than a pair of participants and cannot be just one person as they needed to scaffold on one another's idea when things did not work out. At that point, the three of them worked quite closely and met on weekly basis. They allocated an hour each week to design the lesson in such a way that they could study the notes that students post on the innovative technology platform. The investigator shared the theoretical concepts and the examples from overseas and so forth as she was very cognizant on the need for the teacher to be open of the innovative technology platform and to talk about it or other means of archiving students' ideas and understanding what it means to work with students' ideas. They were very clear it was a very ideas-centered approach. She also went in to observe one lesson a week and this usually took place on the days she was in for the discussions with the team. The HOD and teacher in each school need not write any lesson plan, they will scribble things and the investigator will collect those and then record the conversation and all that. Hence, activities in the PLTs may involve sharing the first viewpoints, systematically analyze and discuss students' ideas, examine KB principles and research, discuss issues and challenges, identifying promising ideas based on the broader curriculum or real scientific ideas, share practices or strategies used in the classroom. This was the same for the two schools that participated, with the investigator being the constant denominator. Half a year into the intervention, she will write knowledge stories out of the PLTs conversations as trigger activities for the teachers to reflect on. Every teacher at the PLTs will get their own knowledge reading story, and they will reflect and the research team will pose a few questions for the members of the learning network to reflect on at the end of the term. The investigator also shared that part of the reporting process, she kept the Principals updated at least every half a year of the progress of the innovation project as the Principals do not come into the class at all. She shared she updated the Principals every half a year and analyze whatever learning insights gained till that point in time.

Time was highlighted as a major barrier to adopting the innovative pedagogy in schools and mismatches with norms and established practices to improve education, especially in a climate of accountability and high-stakes testing, as evidenced in data from our interviews:

> Sometimes [the teachers] see the benefits [of innovative pedagogy], but they're just scared to go on full board, especially the upper secondary teachers. They're still worried about *time, they are practical*, so we're still trying to convince them that, if you do all these practical skills, actually all these skills can be integrated…So some of them give suggestions like, can we go down to lower secondary? Play around with lower secondary?
>
> (Interview with Teacher S)

> Because of the curriculum, …because of the education in Singapore, we felt that we need to also fulfill the curriculum content. So, the time is a constraint for them… so it's important to teach it in the fastest possible way, so [teaching] content … is the fastest possible way to deliver the content.
>
> (Interview with learning designer)

The investigator and teachers we interviewed also shared the importance of the role played by school leaders such as the senior leaders (i.e., Principals and Vice-Principals) and middle managers (i.e., HOD). The senior leader's willingness to allocate teachers time to partake in this innovative pedagogy was cited as an enabling factor in the implementation of this innovative pedagogy. As one of the teachers put it "I think before anything first, the support from management is crucial. That's the first step" (Interview with Lead Teacher M). Another teacher similarly puts it:

> I think you need the Principals and Vice-Principals to be supportive in this whole thing. They have to believe in this, in that they must be able to give the teachers the *time* and *space* to plan lessons. Very important…At least there must be a *time-tabled time given to the teachers*. To sit down and talk about how they want to carry out the KB lessons in the classrooms. That at least plan lessons. That's the first step.
>
> (Interview with Lead Teacher P)

It was revealed that after one of the Principals of one of the schools left the project; the project faced some problems.

> …to tell you the truth that not all the principals will be very receptive, because in my, ah, stay in the school, we have two principals and the first Principal is very supportive …But the second Principal, ah, is a bit resistant because she felt that it may be spending too much time for the teacher's part and maybe also taking too much time of the student's part...
>
> (Interview with Teacher K)

In this regard, it again highlights that Principals have a crucial role to play in stimulating focus and providing support for the innovation diffusion within the school and learning network. This challenge for learning networks, therefore, is how participants might engage effectively with and maximize the benefits of having access to the range of knowledge, experience, and expertise present within the learning network. For instance, we saw how the departure of an innovation supportive Principal to an innovation resistant Principal initially brought some problem in diffusing the innovation in one of the schools. Nevertheless, we saw how the strong learning networks was able to keep itself going and slowly the "knowledge broker" who has a structural position in the network (as Educational Technology Officer, ETO) was able to influence the new Principal in operating strategically and accept the innovation, albeit it takes time. An implication from this is the need to have a middle man as a "knowledge broker" between our central MOE and schools to reconcile any tensions:

> I have to be the middle man, ah, between HQ and school, trying to bring in KB, bit by bit during [second Principal's] leadership in the school. So let her see, knowledge building has true usefulness and is in line with a 21st-century education, how it helps students to learn and develop collaborative skills and IT skills. And so I convince her also because during my stay there I conducted a few talks when visitors visited our school. People from Australia, professors from Australia as well as Hong Kong. And also, during the school open house, I conducted it for primary school teachers who came to my school with their students. So, in a way, I help spread the culture, not within the school but also out of the school. So, she sees that this one has been intensive and deliberative and she buys in this slowly and um, ask me to conduct such talks when the visitors who are coming into the schools.
>
> (Interview with Teacher K)

Throughout the project, sharing events across schools were also conducted quarterly to allow the inter-school KB community to exchange ideas and build knowledge about the KB practice. There was evidence of the positive impact of KB learning networks as teachers and students were sharing on the impact of the KB community on teachers' professional development and students found effects on deepening of their inquiry process, respectively.

It was worth noting that in School P, and it was the structural facilities along with students' bottom-up initiative that helped spread the innovation. Of interest is that the students acted as innovation drivers as they took an active role in organizing their learning and acted as champions to spread the innovation from Science subject and suggested that all subjects should to it.

> Okay. In School P's case, right, so the Science 1, I mean the school has all this structure, right. In June, they'll have their learning festival, December, whatever right? Then they get the students and teachers to share. So, in School P, *the students went to share and say that all subjects should do it.* So then, it's their internal effort, lah. So, which means that they share there, the humanities, hey pick this up and then came on.
>
> (Interview with the innovation facilitator)

The core PLT Science KB group was critical in sustaining teachers' KB practice. From the initial PLT Science KB membership of three teachers, it spread to six teachers and gained momentum and traction. Soon the whole Science department participated. Through these activities, the teachers found it deepened their inquiry process. A second PLT was formed for the Humanities, and a third was later formed for English. Out of the three PLTs, only the Science and Humanities sustained.

In School E, the PLT started with three Science teachers and then spread to five teachers in 2011 as at primary school the Science teachers were usually also teaching English, so this helped it to scale to English subject and by 2012 it spread to 8 teachers.

In this regard, the interview revealed that it is vital that there be a set of ubiquitous infrastructures that have been determined to be the commitment level necessary for something to work to be in place or an avenue for achieving collaborative professional development. This needs to be engineered to ensure those good ideas are brought out to the next stage and to ensure the things that will make the KB momentum happen in the community grows.

> Teachers are the driver. The Professional Development part must come in, to keep the momentum going. Have *structures to facilitate* and make it happen. Information Technology people also come in to help with technical issues.
>
> (Interview with one of the Principals)

In 2016, this emerging cross-school learning networks became an official structure known as KB Network Learning Communities (NLCs). What started as an innovation initiative in two schools seeded the innovation conversations and helped spread it out to five schools. Although getting buy-in from the school leaders for innovation diffusion was important, we think that learning networks have the highest leverage point in supporting innovation diffusion as the initial innovation adopter school acted as champions to help spread the diffusion of the innovation through its learning network relationship, as gleaned from our interview:

> School P's teachers were in some sharing. And they knew each other so they decided that this is the thing to adopt. So of course, then the teacher from School P went to talk to School M teachers first. Then after that, we say that they are interested in coming in then I went down to talk to them and started the PLT. School M was because every school has PLTs and this is not like you know, we are going to do something very different. But explaining to them what the principle is about, what the practice is about. By the time when School P is more established in that kind of classroom, I would, I mean it's kind of KB classroom in Singapore. That school that listens to it, the 4 schools that listen to it is so easy already. Because they know what it looks like and what it feels like. It's only the initial 2 years that it was so hard to get new people in. so it was more internal.
>
> (Interview with the innovation facilitator)

In this regards, we also recognize that there is a need to *deliberate*ly demonstrate or highlight innovation success that can be observed in the actions of experienced individuals, teams, and schools in facilitating the innovation diffusion, such as in the case of the enactment process of the pedagogical innovations in School P and School E which has taken roots quite deeply so that those teachers from schools at the infancy stages of the innovation can learn from them and then "personalized" (Leadbeater, 2004) it in their own department/schools.

> …the schools are doing a lot more to explain the practice to other schools. ..We get School P and E teachers to open up their classroom and open up their PLTs where other schools will go and visit. So we have been doing this since this year. So like January to now, we have at least 3 classroom visits and PLC visits. So, for example, the new, the other three new schools…they have actually gone into School P's PLTs, sat down and listen to what

> have they discussed, going to the classroom to see what happened and then go back and then tweak such things.
>
> (Interview with the innovation facilitator)

> Yeah. [I've opened up my classroom for the science teacher to see KB enactment]. As and when he wants… I will work with him first… the first step we need to do is sit down together, look at the syllabus first, he needs to know the entire syllabus in terms of the content, the concepts, all that is needed. I believe that's very important…. Once you're able to see the big picture, then we're able to tell him, how do you plan to carry out a lesson that way? So, the different steps and possibilities. Then he will try it out, and we will have debriefed accordingly. Once he gets used to the idea of KB, maybe just [using] *one KB principle*, then maybe we ask him to just share with his department
>
> (Interview with Lead Teacher M)

This demonstration process of showing what a KB classroom enactment looks like by the teacher who has had experienced using the innovative pedagogy to new team members is akin to an apprenticeship process that helps establish a risk-free environment for the new members to observe the principles of KB and how it is possible for them to weave the innovative pedagogy. As the new team members continue to plan, practice co-teach, learning in context and receiving feedback, reflect, and collaborate with the teacher who has experienced in the innovation, new teaching habits will become routine and beliefs on the innovative principles will solidify. Immersion by those new to the innovative pedagogy in the apprenticeship activity focuses on the new learning and helps builds social trust among those involved. They will in turn take the initial knowledge and demonstrations back to their classrooms and reproduce them with their students.

We found from our interviews that adopters of the innovation journey appreciated the sharing and demonstration by those who are more experienced in the learning networks. Receiving encouragement and positive feedback that builds the expectations of success also appeared to be helpful.

> Actually, throughout these 2 years *M, HOD, and subject head [school leaders]* …when I carried out lessons, there were lesson observations. About 3 times, M pops in as and when he likes. They do encourage me, especially when they see students questioning more. So that gives me confidence. *The support is very important*. Because while I don't have full control of my classes, because I give the ownership to the students, that's when *their support that I"m on the right track is very [important]…*the school support is very strong.
>
> (Interview with one of the teachers)

In this regard, the literature noted that in implementing innovation, people often experience a social-psychological fear of change as well as the reality of any lack of skills to make the change successful. Also, people often desire to retreat to previous practices during this time because it seems as if no progress is being made. To offset any potential innovation implementation dip, school leaders may need to remember that "change or improvement efforts are a process, not an event" (Fullan, 2001). For instance, in peer coaching of the PLTs, positive change often requires time and acceptance of potential setbacks. In this regard, the innovation facilitator who acts as an instructional partner helps encourage support and guide the teachers toward sustained change as they attempt to use the best instructional practices for their students' learning (Gassenheimer, 2013).

In our case study, these efforts may also not be limited to just local efforts in Singapore but may include extended efforts done by others enacting the same innovation overseas to learn from them.

> …we have like *study trip* to Hong Kong then we have *video conferencing* with [overseas experts]. You know they came in and presented their classroom. Yeah. So, all these are important points where they come together as an inter-school.
>
> (Interview with the innovation facilitator)

These cross-network learning are beneficial in providing opportunities for generating and sharing knowledge and enabling teachers to direct their development, as one of the teachers puts it:

> We've shared at different platforms, heard from different schools. Like Bali International Conference, I went there to present as well. So, I managed to learn, come back, lead the team.
>
> (Interview with Teacher P)

Our findings from the two schools have also consistently shown that school leadership support is a vital supporting condition required for learning networks. Once the school leaders are committed to the innovation, it is usually natural that the rest of the members of the school will comply and accept the innovation, as exemplified from the following interview snippets:

> Culture has to start somewhere, from the *senior leaders* to the SMCs.
>
> (Interview with one of the Principals)
>
> *First level of change must come from key personnel*. Once they are bought in and know what the school stands for, teachers will come in. It's only sustainable when there's a critical mass of people who do this and impact other people through this community of sharing.
>
> (Interview with one of the Principals)

Our findings also revealed that in supporting innovation diffusion, it is also instructive to examine the cultural-historical perspective of participating schools. For real and deeper transformation toward innovation, the capacity and capabilities of the learning networks are also influenced by the cultural-historical perspective of the school, which means we should also be cognizant of the innovation being introduced is "right" for the participating schools, given their particular context, history, and needs. In this regard, schools that had school leaders (Principals) who were already sensitized to Knowledge Building classroom through their learning journeys visits and workshops, were the initiators of the innovations and had proved to be the change agent within the learning architecture of the innovation diffusion.

> And then the other structure that other new schools that we are working on now are because *they have been using knowledge building classrooms as a learning journey for the school leaders* and all that right. *So when the Principal sees it and they assign someone to come and talk to us, so we have all these new schools coming in.*
>
> (Interview with the innovation facilitator)

For instance, in School E the carryover effects of having to move toward transformative assessment have helped the school leader in legitimizing the assessment change process and making the status quo more difficult to protect, which helps the KB innovation to flourish.

> Teachers get support from HOD for transformative assessment (integrating a 30% KF component in students' final year assessment). I must say, before that our HOD is fairly aligned to what we mentioned because we were moving towards a formative assessment. So, this [innovation] obviously aligns very nicely with formative assessment. So, our HOD allows us to evaluate this aspect.
>
> (Interview with a Middle Leader)

16.5 Discussions and Concluding Remarks

This chapter has narrated on actual process and practices of how the principled KB pedagogy innovation has spread from individual schools subject to cross-subjects and to cross the boundary to other schools through learning networks. Although we recognize that marrying interview data with the impact data provided by the innovation facilitator, teachers, and school leaders does not necessarily enable us to establish a definitive "cause and effect" relationship of the impact of the learning network in supporting innovation diffusion, it does provide a compelling case that learning networks can be a high leverage focus and can have a significant impact on not only supporting innovation diffusion but sustaining it. These findings support the literature that has indicated that learning networks can support school improvement efforts (Chapman & Muijs, 2014).

We thus argue that pro-innovation diffusion schools should work toward building stronger learning network efforts that allow education stakeholders to speak to one another. Learning networks offer a pragmatic, low-overhead approach to making time and space for organizational learning habits to grow. Having seen how learning networks help diffuse innovation case, so what would our schools look like if every school implementing innovation embraced in learning networks? Well frankly, each school would probably look exciting but unique. In this evolutionary process of building a stronger learning network, we are cognizant that learning networks are not a one-size-fits-all solution that works for the diffusion of innovations for each school in the same way. We have seen how innovation implementers have to work with existing structures of the participating schools, adjust, and adapt in the innovation journey. The case study illustrated how schools do not simply adopt the innovation but negotiate a response to the systems of relationships in which they reside rather than at a discrete level.

We can see from our case study how systems of relationships and negotiated meanings take place between individual, team, community, cultural norms, values, resources, and power of the actors (students and leaders). For instance, it was clear to us that the influence of the innovation facilitator as Lead Specialist might have influenced the uptake of the innovation at the initiation stage and we also saw that the students' bottom-up suggestion to spread the innovation across other subjects had a consequence in spreading the innovation. Besides, even though both schools were trying to roll out the same innovation and had the same innovation facilitator/ coordinator, the diffusion of innovations was never a linear, orderly, or easily co-ordinated process. It also raises several immediate questions. Hence, one might ask, might it be more fruitful efforts that learning networks to be enforced from top–bottom or from bottom-up? Is there a case that we may need both a top-down and bottom-up approach in building a learning network?

A variety of factors need to be in place before the learning networks can be successful. In this regard, the elements of the affordance of ubiquitous collaborative network infrastructure are most important to allow the teachers to function well. The ubiquitous collaborative network infrastructure we are referring to refers to boundary objects, tools, mechanisms, platforms, and resources to enable others to take on an innovative practice that promotes people to share their knowledge such as through availing professional development courses/workshops, resources for video-conferencing, study trips, learning journeys visits, and learning festivals. Innovation adopters should communicate their ideas freely as they never know who might hear them and be influenced. As we have seen in the case study, we saw that the principals who went on learning journeys to the classroom enacting the innovation could understand how to meaningfully support the participation within their school. Hence the original context, intentions, and activities undertaken by individual schools before the innovation being introduced and the extent of the learning impact achieved from participating in learning networks should be examined in future studies.

In this regard, a pro-innovation mediator/facilitator (such as the role played by the innovation facilitator who is passionate and intimately experienced in KB) in monitoring, guiding the collaborative inquiry, facilitating the exploratory learning by ensuring some structures are put in place in the KF view and coordinating the student learning is also critical in supporting the innovation diffusion. It was also evident to us that her dual experience of having worked as a teacher and later as Lead Specialist of the Learning Partnership Division of the Educational Technology Division at the central headquarter of MOE which has central control of schools had created favorable conditions that helped her to spread and diffuse the KB innovation. In our interview, we were cognizant that because of her background and experience, she understood the system and leveraged her power to make decisions on what were the necessary commitments, get the Principals' support, and create conditions necessary for the innovation to work such as ensuring that teachers have time to do what they needed to do.

It becomes clear to us while reading the narratives of our case study the political nature of supporting innovation diffusion would require the *school leadership support* (such as in the case of adapting the assessment structure component from formative to transformative assessment with the inclusion of 30% for KF that helps legitimize the innovation). Leadership was instrumental in ensuring support to make such changes in practice were provided. As noted from our case study, the school leader's support for the innovation was also influenced by school-level goals of moving toward transformative assessment. Our case study has also suggested that it is easier to build support for innovation diffusion the more that the benefits of an innovation map onto the interests, values, and power of the actors in the adopting schools. For instance, we saw that the decision of the school leaders to adopt the pedagogical innovation somehow relates to the school's interest and values in moving toward transformative assessment) and it could be inferred from the evidence that their previous learning journey experience that exposed the Principals to the innovative KB pedagogy had provided an impetus for them to consider the innovation. Hence, profound changes are needed in the current culture and practice of education; also, a great deal of support is necessary for innovation adopters' attempts to surpass challenges that may arise from the innovation adoption learning journey.

In closing, we are cognizant that there can be a variety of reasons for schools to decide to participate in the innovation project and for the participating schools' members to participate in the learning network. Practical implications associated with this notion are the need to encompass individual learning, group learning, organizational learning, and system contexts within which learning networks operate to support the effective development and use of the learning network for diffusing innovation. We also note that the best plan in the world will falter if the people implementing it do not have a passion for the plan. We hope that we have succeeded in our aim of highlighting the possibility of learning networks being 'productive'—a term deployed here knowingly—and giving rise, potentially, to more meaningful professional collaboration and dialogue between local educators, policymakers, and communities. We hope that this paper will contribute to a richer debate on learning networks in supporting innovation diffusion that moves away from thinking about learning networks in supporting innovation diffusion generically and toward greater specificity and conceptual clarity.

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Chapter 17
Learning Initiatives for the Future of Education (LIFE)

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Abstract This chapter describes the past, present, and future research trajectory of CRPP and the Office of Education Research at NIE Singapore. It includes the aims and initiatives in supporting the education-research-practice nexus, providing for high quality learning/classroom/school environments and for teachers-as-designers and teachers-as-facilitators of high quality interactions, and, in the process, heightening learner's capacity to learn and to deliver high quality education. In order to stay relevant, progressive, and futuristic, we juxtapose the Science of Learning, the Science of Systems, and Learning Sciences to highlight ways that we can address the gaps in our education system in a systematic fashion. Besides creating the space and context for better understanding of factors, designs, physiological, and behavioral mechanisms to enable all learners to succeed, we hope to scale up, spread, and sustain these learning Initiatives as a whole living laboratory for the future of education.

17.1 Introduction

In 2016, the then Deputy Prime Minister gave the National Institute of Education (NIE) 48 million dollars over five years to set up the Center for Research in Pedagogy and Practice (CRPP). Over the next 15 years, the Ministry of Education (MOE) has been providing NIE with generous funding of approximately 100 million for education research every five years. Since the advent of CRPP, the future of education has always been the recurring theme and focus of research. EduLab started in 2011 as a MOE-NIE initiative supported by the National Research Foundation (NRF). The previous chapters in this book documents the innovations conducted across and

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throughout the ecological layers in the Singapore education system as part of MOE's efforts in changing the school system.

This chapter concludes with a discussion on the past, present, and future research trajectory of CRPP and the Office of Education Research at the NIE. It aggregates the initiatives under the umbrella of Learning Initiatives for the Future of Education, which is coined, LIFE. LIFE will be elaborated in the later sections of this chapter. This chapter also documents directions relating to the science of learning and artificial intelligence in education which we hope that post-eduLab efforts might have a view toward.

We believe in pedagogical-driven technology-enabled learning. Our focus is not so much on technology or what learning can be driven by technology. Instead, our concern is meaningful learning and the pedagogies that foster and promote such learning. Technologies are enablers of the pedagogies and learning that we seek to develop.

As envisaged by many reports attempting to foresee the future, manual routine skills are going to be taken over by technology. This is a certainty. Changing demands of skills inevitably see a greater need for non-routine communicative expertise (Levy & Murnane, 2004). Notions of students needing to develop higher level metacognitive ability leveraging upon a strong content base is also foreseen. In the problematisation of our current gaps in our education system, our students ostensibly lack the drive and hunger for innovation (Ong, 2012). Research needs to attend to user inspired practice problems as defined by the Pasteur's quadrant (Stokes, 1997), i.e., use inspired basic research. How do we take problems of practice and not reinvent the wheel? The outliers that cannot fit the one size fits all approach of our education system may suffer. Today the national discourse is that every child matters. Increasingly, more students have more problems conforming to predominant models of pedagogy. We see use-inspired problems in our classrooms such as school policies that create greater social isolation, thus requiring the need to foster greater social mixing in our schools. The lack of questioning in our classrooms is another practice use-inspired problem; disadvantaged families have kids that are not developed in their pre-academic numeracy/literacy is another; while the fear of failure also is an issue weighing on our children's minds according to a 2018 PISA study (MOE, 2019). Thus there is a need to develop students to be twenty-first century prepared, while teachers need to be better lesson designers.

In our past research efforts, we situated many interventions but we quickly realized that they were rather episodic. We subsequently delved into trying to understand how to sustain these (episodic) innovations. We realized that school culture is non-secondary but primary, in creating the enabling conditions that would cultivate teachers to be good designers of learning, including the care that they would continuously show to their students. Teachers' belief change is probably the most important leverage point through which we can enable sustainable change to take place (Koh et al., 2018). We feel that because belief change is something so difficult to do, thus we studied teacher apprenticing work which occurred both within and across schools to be central to the change (in innovation) process. This change enabled students to engage in more creative and critical thinking which is absolutely necessary for future learning and education.

With LIFE@NIE, Artificial Intelligence (AI) in education is proposed as one of the initiatives, and we refer to it as AI-LIFE or AI Learning Initiative for the Future of Education. In the second half of this chapter, AI-LIFE is discussed, and articulates how AI plays a critical role in the context of past, present, and future goals in the fulfillment of NIE's vision. Past learning initiatives which have already been underway include: V^3SK (NIE, 2017), which focuses on Values-LIFE and similarly 21st CC-LIFE. Values and 21st CC underpin education as the bedrock of past and future initiatives. Recent initiatives in the Science of Learning in Education or SoLE are poised to play this national role of coordinating learner data across the lifespan and for enabling the building blocks for vision 2030 on behalf of Singapore, coordinating NIEC, NIE (k to 12 goals), and the Institute of Adult Learning (IAL). These building blocks include the data infrastructure that enables learning and learner data to be mined for policy thinking and decisions (Merceron, Blikstein & Siemens, 2016).

The use of "LIFE" here also points to the four Lives framework below—Life-long, Life-deep, Life-wide, and Life-wise (see Fig. 17.1)—for the future of education at NIE. Technologically supported networked learning is an inevitable part of the learning process (Siemens, 2009) and journey of which AI is an integral part. Moreover life-wise is also an inevitable part of the AI discourse as humanity and other existential implications are being grappled with in the advent of AI, especially in education.

Looking at the four lives framework—our system is very good with life-deep learning, however, we do not place enough emphasis on seeding metacognitive regulatory lifelong learning dispositions and seeding inquiry and interest cum learner agency. There is a need to move toward more adaptively across different disciplinary

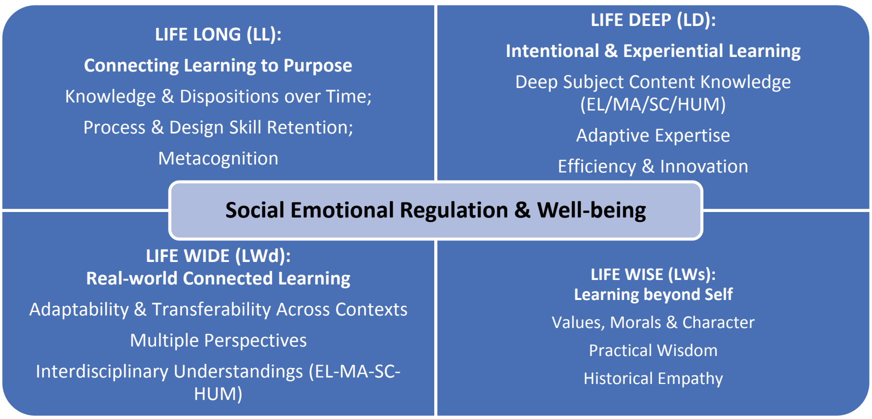

Fig. 17.1 The four lives framework developed by the Office of Education Research (Koh et al., 2018)

domains. Life wise learning is about being values driven, morally ethical, and identifying with self-constructs which propel learners to do what they do and why they do. In the middle of the notion of four lives framework is the notion of socioemotional well-being and characterization. There is a need to develop not just conscious knowledge but intuitive knowledge that makes and characterizes what experts perform in their enactments.

Consistent with NIE's focus for 2030 and with its vision for excellence and the future of learning and education, AI-LIFE would have a strong research-practice nexus with both industry and K-12 schools. It should also serve to advance evidence-based learning (across the lifespan) working closely with NTU and support the national Skills Future initiative to enable learners/teachers to successfully apply their learnings in a constantly changing and complex environment. AI in education also affords opportunities to synergize with the fields of the *science of learning* (SoL) and *assessment*, in the form of learning analytics. AI techniques are now able to make explicit learners' data and 'make visible' systemic data of many students engaged in an instructional activity, from which teachers can make further design/pedagogical decisions to optimize learning. AI systems can also now better track teachers (as learners) as they undertake trajectories of (modularized) courses in their learning agendas and programs and make more nuanced recommendations for their professional development. More broadly, this chapter attempts to propose a working model which can be operationalized toward Vision 2020 for NIE in relation to AI-LIFE. The working model proposes:

(a) How NIE can have a systematic process with process quality indicators to achieve its goals and vision,

(b) Areas of foci and growth which can be concerted, rationalized and strategically positioned in order to be futuristic, and

(c) The mechanisms at policy, socio-technical, and teaching and learning levels which can achieve this vision.

17.2 Addressing the Gaps

For NIE to be progressive and futuristic, she has to stay relevant to the education system which has emphasized 'joy of learning', 'entrepreneurial dare', and other dimensions of twenty-first century learning and character and citizenship education. With the advent of big data and MOOCs, technological advances promise that we can have levels of systems' data and individual precisions (or customizations) that traditional forms of education cannot deliver, albeit with its constraints, e.g., large bandings of students.

With the establishment of AI-LIFE, a working and visible model which combines a local cum systemic perspective enables a point-at-able policy to practice translational construct (i.e., system use case) that can show what education 2030 can envision and to better facilitate decisions on policies through big data that is longitudinally collected. The promises of technology also enable new modes and modalities in assessment that formative tracking at the individual level (vis a vis larger normative cohort(s) data) becomes a foreseeable reality in the coming decade. More intractable to improvement change as a system are the institutional structures and norms which 'hold' cultures to what they presently are; however, the NIE has acquired understandings on how change occurs within the multiple levels of the education system. As such, investment in educational R&D in the last 15 years is now enabling us to leverage on the wave of technological advances in charting out a roadmap that would position NIE for the future.

Advances in neuroscience and special needs are also promising techniques that can revolutionize learning in the next two decades. In order to identify where we are framing 'needs' from disadvantaged profiles of learners may be a useful start and which can potentially generalize to more mainstream cohorts. Concomitantly, with the recent national discourse on the socially disadvantaged, we can characterize disadvantages into three categories:

- Biological, neurological, or individual factors, e.g., low working memory, emotional disorders;
- Interactional factors, e.g., poor instruction or parent–child interactional quality; and
  - or environmental factors, e.g., low social economic status (SES), detachments due to family (mis) situations.

From the literature on 'risks' especially on special needs domains, biological, and environmental risks are well documented. However, it is the field of the learning sciences (not science of learning or neuroscience) that has in the last decade or more adopted design-based research to exploit on the conditions and interactional factors and mechanisms that enable higher quality interactions between individuals (students) and the environment. Hence, the design of learning environments that can enable good quality interactions is held within the fields of the learning sciences and instructional science. In other words, interaction is the 'and' of the individual-and-environment dialectics. Often, this interaction is not generalizable and can only be distilled in the form of design principles. As such, if we can professionally develop teachers (and parents, including educators across the lifespan) to enable and facilitate high quality interactions based on good evidenced based design principles derived from sustainable inquiry based interventions, NIE would impact society at large.

In other words, if we can provide for high quality learning/classroom/school environments and for teachers-as-designers and teachers-as-facilitators of high quality interactions, and in the process heighten the learner's capacity to learn, we are bringing high quality education. As such, there is a belief that all learners can learn, even the 'individual'-ly disadvantaged, and to *developmentally* enable these learners to be educated. Science of Learning (SoL) delves at the biological dimensions and to find solutions to increase the biological capacity of learners such as through nutrition and other neutrally-informed interventions.

NIE plays a crucial national role to professionally develop good teachers who can facilitate good interactions, albeit with the skills to design for, and to facilitate good conversations and learning experiences in the different domain and subject disciplines. As such, for NIE to be future oriented, the *design principles* for developing teachers for high quality interactions are as follows:

a. To develop a repertoire of skills that can appropriate pedagogical toolkits for differentiated instruction;
b. To be sensitive to learners needs and to care for their well-being;
c. To have the continuous learning dispositions and competencies to embrace new methods and sciences of learning, and to be literate on advances in technologies such as AI in order to appropriate these understandings to different learners;
d. To instill in their learners/students the same life-long learning dispositions and competencies which they themselves possess and role-model; and
e. To work with other stakeholders e.g., parents and other education providers with a focus on the individual child or learner with a view to the learner's well-being and continuous improvement. This includes working with researchers from other IHLs on the 'individual' and 'sociological' factors with a view to improvement process and outcomes for the learner(s) at the 'interactional' factors layer.

In other words, the LIFE initiatives which are recommended in this chapter would address the five points (a to e) above. The SoL in Education (or SoLE) initiative addresses points a, b, and e above. Similarly, the AI in Education initiative or AI-LIFE is to provide data to teachers on students' formative learning process and outcomes (both cognitively and emotional-regulation wise), including the intelligent learning systems for both teachers' adoptions and for learners' use. All points (a–e) are attended to for AI in Education. *As such, the titling of AI-LIFE.* AI techniques, tools, and methodologies span stakeholders from teachers and students to providers from industry and other system-level decision makers as AI aggregates system data for large cohorts of students through its machine learning algorithms (Gasevic et al., 2014).

The other areas of NIE's initiatives that would attend to her strategic futures are in the areas of (a) assessments, in particular Assessment for Learning (AfL), (b) Differentiated Instruction (or DI) and also for specialized populations (i.e., special needs and gifted needs), (c) policy work which has overlaps with leadership, school improvements, and system perspectives for sustaining innovations. As such, from

- Macro Perspectives (environmental or sociological)
    - o *Science of systems*—Policy R&D work for sustainability
    - o **AI-LIFE**
- Meso Perspective (interactional)
    - o Learning Sciences (design)
    - o **Assessment,** including AfL and multi-modal literacies
    - o *Differentiated Instruction*
- Micro Perspective (individual)

- o Science of Learning and **SoLE**
- o *Special and Gifted needs*

17.3 Translational Pathway to be Sought Through the Synergies of the Science of Learning, Learning Sciences, and the Science of Systems

Science of Learning (SoL) projects draw upon *science-based* understandings—typically experimental designs—from interdisciplinary fields (such as cognitive neuroscience, physiological science) to biologically ground analysis of behaviors, cognition, and learning. Building on classroom evidence, key SoL and Learning Sciences (LS) projects are targeted to solve practice based "problems". These include projects which i) level up the base and bridge gaps from early childhood to schooling years, ii) target early primary struggling learners to develop strong foundations for subsequent development, and iii) aim to foster joy of learning from adolescence to early adulthood to develop positive propensities and interest toward lifelong learning. In adopting a multi-level and multi-disciplinary framing to translate research findings to classroom implications, a Science of Systems (SoS) perspective is critical where SoL provides the *science,* LS informs *pedagogical redesign and implementations*, and SoS addresses *scale* and *sustainability* issues in education.

We know that the science of learning, in particular, neuroscience has gained significant traction recently, and there is world-wide interest in the promise it brings. In Singapore, we have a school system that is exemplar and the envy of many other systems. Thus, it would be interesting to ask how the science of learning can find translational pathways to practice and wide-spread adoptions. Singapore's centralized system might perhaps have a greater propensity for a translation since we have concrete understandings on how innovations travel from the science of systems' end of the pathway. We hypothesize that the study of the learning sciences is the link between the science of learning and the science of systems. The learning sciences delves into learning designs, bridging between theory and practice. The learning sciences concerns itself in how learning occurs, the design mechanisms that supports learning, and also the structural affordances that enable learning to occur in authentic contexts. As such, the learning sciences believes in ecological contextually rich, embodied, and situated learning, while the science of learning has most studies in experimental conditions which may not be generalizable in messy classrooms. However, there are tenets in neuroscience which may potentially inform the learning sciences and the science of systems. Very few studies, in my opinion, would dare attempt to go into juxtaposition of these three theories—the science of learning, the learning sciences, and the science of systems.

To reiterate, the aim of our pursuit is to discover better ways in which we could identify students' difficulties early on and then situate effective interventions so that we have the early attending to their problems. What we want to know is when and how to intervene. What are the appropriate measures and markers that we need to capture in order to understand whether we are on track and whether or not we can measure the positive outcomes through which we make our interventions. We create and design meaningful interactions through these interventions between the learner and the environment. Once these effective interventions are better evidenced and understood, we can create equitable policies that enable this to be done across all schools in Singapore and not just in a limited number of schools (which is currently the limitation of research). How do we actually create equitable access? And how are we going to level up professional development, with situated practice, for all teachers and educators throughout the system? This is the realm of the science of systems.

The notion of the future of education cannot be divorced from equitable access for every student. In order that NIE can play this role to help schools and to help teacher education become a kind of high quality profession with high quality design interactions that will enable all learners to be future ready, there is a need for interventions that can be situated in varied conditions in order to succeed.

We are a long way from this goal but now that we have some notion of the Science of Systems (SoS) and Leadership from the Middle (LftM) that enables the 'scaling' up of these interventions, we can systematically chart the direction that leads to this future that NIE can play a crucial role. We might stand a chance at being more systematic in situating these interventions through early identification of the problems and through spreading out these practices across school-to-school networks and multiplying these school-to-school networks across the system and also to monitor the kinds of improvement outcomes that will come. Teacher leaders at the middle of every layer in the system can be change-improvement-for-learning agents/facilitators of student learning and of all kinds of learners.

As the mission of the National Institute of Education (NIE) is practice-oriented, and being a teacher education institution, our research contributes to the top performing education system, where teachers' roles in schools is prominent. In this regard, the practice inclination brings to the foreground the need for teachers to take the findings derived from neuroscience (including genetics) into translatable skills for teachers in the design and understandings underpinning learning. Hence learning is translated into pedagogical transformatory understandings, and this in turn leads us into how such efforts are sustained in the context of schools and school improvements where school leaders and middle leaders play their functions and roles. We advance research in the context of understanding how learning and teaching is situated. And so, in this way, we hopefully become a future-ready institution for Singapore and the world. Thus, at the NIE, we are not just [providing] a teacher preparation at the pre-service, we also have higher degree programs, working with teachers.

From the perspective of the Office of Education Research (OER), the vision is to be an international leader in education research-practice nexus. In other words, we are saying that there is much research out there in the world, but there is an insufficient translation of the research studies into actual classroom practices, school systems, and education systems as a whole. The mission of OER is to make a translational pathway or process a reality at the multiple levels of a system and hopefully through the whole process inform the very important piece of policy thinking, which is an inevitable mechanism for system improvement and school change. In addition, we try to exploit our knowledge and understandings and use it to benefit other educational systems, and that is potentially done through in educational research around the juxtaposition of the three theories at hand.

17.4 Macro, Meso, and Micro Levels of an Education System

In this chapter, we would not be delving too much into the science of systems. The Singapore school system is discussed in many previous studies with the impact and significance of its leadership summarized in the book *Leadership for Change: The Singapore School's Experience*, and within these, reference is made to a system characterized as three levels. Appropriating from Bronfenbrenner's ecological systems theory (Bronfenbrenner, 1979), the micro layer or level of the system can be seen as the micro-level enactments of classrooms where teachers' work with students for learning—both as a process and outcome. Such micro enactments can be further unpacked into the micro genetic enactments of moment to moment episodes or into the individual (behavioral, cognitive, and emotional) aspects of learning. We refer to the meso-level as the structures, routines, and norms that support the classrooms in schools, that is, the school leadership enabling socio-technical infrastructures, and the middle leaders (such as the heads of departments) that facilitate instructional and curriculum enactments for the teacher and students in (classroom) learning. We expand such a space of learning to informal learning contexts too. At the macro-level, we refer to the policies and the networks that facilitate school-to-school enablements. These are the school-to-school networks, and the system policies that enable schools to function and improve. Our earlier studies suggest that schools need the support of these networks to be resourced with expertise and other forms of carry-overs, to make transitions in the school improvement journey. As such, we focus on the science of learning and the learning sciences and how the translational pathway can be forged in the context of our science of systems' understandings.

We know that learning occurs with a ratio of about 50% individual factors, and 50%, from the environment. Genes from an individual person are inherited from parents and grandparents. And it turns out that our individual propensities for behavior, and thus of learning abilities, that is accounted for by genes, is thus 50%. In other words, if we have a very gifted child situated in a very impoverished environment, the learning can still plausibly be good. If we have an impoverished individual propensity but a highly flourishing social environment, then learning can also occur. But, if you have an impoverished individual genetics for growth and for learning, and also an impoverished environment, then we are in a downward spiral as far as opportunities that afford the learning process is concerned.

However, since we can neither control our genes or our social environment through which we are born, we can however be good at designing for the interaction between the individual and the environment (schools and equivalent). Teachers play a crucial role in facilitating this dialectics between individuals and the environment. We are interested in how teachers interact with students, or how interactions occur with the school community as a whole, and how social-cultural settings are designed through which learning occurs for different kinds of learners.

OECD reports that an individual child's ability to learn has much to go with the mother's educational level (Shuey & Kankaraš, 2018). This is nothing surprising. That could only mean that a highly educated mother, with the assumption that the mother has the time to interact with the child, can enable a greater or higher quality of interaction between the mother and the child. Vygotskian theories (Vygotsky, 1978) have explicitly alluded to this many years back that the social mental level mediated through language is how higher order thinking becomes internalized by the individual learner. Now, if a highly educated mother has no time to spend with her child, then it does not account very sensibly for why a mother's educational level has a higher interactional effect on the child's learning.

From a learning sciences perspective, understanding how this interaction occurs with a view to designing the process/interaction of which learning is in the change process (because it is a transformation process) is key. The unit of analysis can be individual and/or across individuals-and-environment as reciprocally interwoven in order to achieve the best learning outcomes. Thus, the learning sciences aims to understand learning as a process of alignment between the individual, the environment, and the in-between of the interactions that creates the best (optimal) learning outcomes to occur.

This juxtaposition of the three theories apply across the lifespan. At the NIE, we are concerned with learning at the stages from early childhood, and all the way to adult development (because our teachers are adults) and to consider the mechanisms and leverages that enable good learning to occur. For example, we know from early childhood literature that if a child is exposed to multiple languages in an earlier age, they can probably adapt to multiple languages more easily, and this could be explained as sensitive periods in neuroscience literature (Knudsen, 2004). Now, of course, the brain is malleable, and therefore the brain can learn throughout the lifespan. We need to figure out at which points of a person's journey are more sensitive for learning particular skills and dispositions with curriculum designed in ways that create the best opportunities for learning. For example, teenagers. Teenagers are known to have identity crisis: "faces" of their lives. In other words, they are "face-conscious" during this period and hence are probably more reluctant to be embarrassed. Thus learning multiple languages and using them in social contexts to the degree that they have to experiment with these new languages becomes more challenging compared to earlier age periods, possibly. But, this theory is still in flux, and we can find cases of learning opportunities affording for different individual considerations according to different patterns of interactions. Making learners learn a language with technology might then overcome the "face" issue. While everyone learns throughout the lifespan, we are asking ourselves whether there are opportunities from a curriculum design point of view, that learners in general are more apt or should learn certain things earlier vis-à-vis later as there is only a finite amount of time and space that can be afforded to learners and learners of different individual propensities within the k-12 curriculum.

17.5 Juxtaposition of the Three Theories—Science of Learning, Learning Sciences, and Science of Systems

The science of learning would characterize individuals' learning into cognition, emotions, and beliefs. If we are to understand the nature of beliefs, we would know that education as a whole, including its socialness would fall in the realm of values and beliefs. On this end of the continuum, we typically discuss the cognitive mechanisms to enable the brain to work. In the last decade, we have the field of the learning sciences adopting design-based research in actual classrooms, and through ecologically valid descriptions, characterize what is happening. To a large extent, the Learning Sciences had it right for learning because much of research that was done in the Science of Learning in lab-based experimental situations could not be translated into classrooms. And, many of the constraining conditions through which learning is tested in laboratories could not be so easily generalized and translated to classrooms, because of the messiness of the multiple variables that gets enacted in both environmental and individual factors. Thus design-based research disbanded with lab-based experimentations and went straight to the classrooms and described the nuances and the complexities of what took place in classrooms, in order to derive design principles 'bottom-up' from the classroom context. But the learning sciences also could not take its inventions to scale from a system perspective. Hence, figuring out the juxtaposition of the three fields/theories is the aim of this chapter.

17.6 Multilevel Intervention Approach

Our task at the OER is to come up with the mechanisms that would make the whole system change, that is, the policy mechanisms, the socio-technical mechanisms, and the design mechanisms at all levels. Early identification, the interventions that will make it work, equitable access, and the monitoring of these improvement outcomes all contribute to this goal. From the Science of Learning (SoL), we endeavor to figure out what the individualized neurologically informed interventions could be. Learning Sciences (LS) informs us about school-based practices and pedagogical principles for which student learner-environment becomes heightened in terms of its quality. And we create community based interventions through school-to-school networks through LftM in our science of systems (SoS) understandings. Through SoS understandings, we hope to influence policy makers with policy leverages (referring to point at base—"policy recommendations and advocacy").

In other words, Science of Learning becomes the neurological aspects of individualized customization. Learning Sciences becomes the socio-cultural environment as it interacts with the individual. And policy work becomes the socio-technical infrastructure that enable it to work; not just at the classroom levels, school levels, school-to-school network levels, but the system as a whole. The complex relationships between the Science of Learning, Learning Sciences, and System Science is to really get at more precise interventions, good designs that enable the interaction to take place and good socio-technical policies that sustain them.

To frame things from the science of learning point of view or neuroscience point of view, it is to take the complex research papers from neuroscience, take it to designs, which we have done and then sustaining the interventions that take place. But the field of education has already progressed beyond many of the current neuroscience implications on learning such as on retrieval or spaced instruction. From a bio-ecological framing, we are now moving forward toward studies that not just identify the dominant school-based practices from an external viewpoint, but we are trying to figure out the kinds of intrinsically motivating practices for our students. And we are also looking at the kinds of stresses that our children and youths go through and to look at the bio-ecological markers through which they interact and affect each other. We are also considering social factors that foster or otherwise social mixing through the analysis of social networks, through which we then see how these factors affect the learning situations and interactions that these learners might have and to find remediation across them.

In particular, as informed by recent developments in the learning sciences, we are moving into areas of analytics for formative assessments. Learning analytics data can be sought not just individually at micro level but also at broader levels of the system. Similarly AI affords not just intelligent tutoring systems (ITS) but data from the systems perspectives that will enable us to not just understand individual profiles but a whole collective group of learning profiles that might inform us how to customize more accurately at the sub-profile groupings that we intend to create individualized or sub-profile customization for our learners. Assessment should go beyond assessing for content knowledge, but cognitive markers, emotive markers, and other creative indicators for individual performance and also system performance over time.

In a nutshell, Science of Learning delves into cognitive and emotional mechanisms in laboratory based settings, Learning Sciences is about interactional mechanisms, and the Science of Systems discuss social and cultural mechanisms. All three are needed in order to enact systemic change in the whole system. At the societal level, we begin to see schools as not just classrooms; we view schools as communities. The hypothesis is that the individual interacts with the environment, and the environment cannot be just classroom environments, and so we must begin to see schools as communities.

The juxtaposition is important as use-inspired research attempts to 'solve' problems of practice. For example, the Ministry of Education (MOE) wants to disband the Normal Stream by 2024 and therefore begins to group students up by disciplinary subjects. Subject-based banding still makes the assumptions that we organize the students not by streams, but by ability in the subjects, and place them all into a class that teachers can teach according to their same pace of learning as assessed by summative assessments. We wish to argue that subject-based banding is insufficient. We should begin to think of, not just grouping students by subject, but we want to group them beyond subjects to other factors like emotional affective environments, well-being, or other factors. We could consider non-academic factors and also create groupings of students where the unit of analysis of the school as a community through which learning occurs, and not just classrooms. Community gives the sense of both academic and non-academic factors in learning. Schools as communities enable the complementarity to subject-based banding. As the African saying goes, “It takes a village to raise the child”. Children, parents, and tribal forefathers, sit around telling stories. Because embedded stories and traditions are also values oriented, communities take a village metaphor to raise a child. The science of systems can be reoriented as community as a unit of analysis. We re-emphasize the successful ways of the traditional past in apprenticeship learning and communities. In traditional schooling, we started segmenting kids up into fixed curricular activities and programs, so much so that the integration of these curricular activities and programs is missing. When we talk about context-rich learning through apprenticeship and through story-telling, which is a powerful way through which the brain evokes both its cognitive and emotional mechanisms, learning is contextualized, where emotions play an integral part with cognition.

17.7 Authentic, Context-Rich Learning

Learning is demand-driven, a social act, and identity formation process (Brown & Duguid, 2017). These three principles of learning concur with the notion that learning requires cognition, emotion, and belief. This ultimately springs to what purpose is, to why we do what we do, and as a result of goal setting, we begin to go through iterative cycles of how we change our world views, our beliefs, and our emotional cognitive response to what ultimate purpose we derive at any particular stage of our journey in life. For example, if we want to learn to be a Mathematician, our interest in Mathematics will grow. Therefore, what are we saying is that learning is not just regurgitating words you can find on the Internet because that is not learning. Learning is having lived experiences. Learning is not articulating or regurgitating a body of represented knowledge. Having a lived experience is more than representations. “The map is not the territory”.

Schools and curricular are all about the map and not sufficiently about the territory. The territory is our lived experience. The whole notion of the Science of Learning must juxtapose the issue of maps and territories, and that is why more recently experiential learning has become very popular. Experiential learning is actually lived experience. More recently, schools here in Singapore emphasize on maker spaces. In such spaces, students tinker. But what is tinkering? Tinkering is simply saying, “Don’t go too fast into the representational forms of what’s in the textbooks”; Try to live the phenomena out, deconstructing a phenomena and re-constructing it again.

Thus tinkering, again, is not new. Tinkering is a very old-aged theory which worked. But because the way we have done schooling is such an extreme today that on maps that we want to do territories, tinkering is simply a revisiting back to what we are asking students to do, which is to live out the territories in experiential ways.

The problem we have now is that there are so many maps to learn in schools, and so little time for experiences that we cannot find time to learn both the maps and the territories. Experiences are more important than the maps. We can learn how to construct the maps, as a process methodology for every experience we live, rather than memorizing the maps. Basically, if you can go through any experience, and construct, from first principles, the maps for ourselves. Thus, if learning becomes a life-long journey, we do not need to learn 'everything' in early childhood as the recent movements appear to suggest. You can always construct the map from our live opportunities. Therefore, a good education system provides students with live opportunities and enables frameworks and structures, including metacognition, for students to construct those representations and maps for themselves.

Therefore, in the Science of Learning, we are basically trying to understand that in every learning phenomena, based on individual and environmental factors, how genetics, psychological, psycho-physiological, neuro-biological, and social-cultural factors interact, in order to understand the best learning optimal outcomes through which we maximize learning opportunities for every child. That is what we are trying to figure out as a large goal for the Science of Learning from our perspective.

In the same vein, we are also enabling in our schools, teachers to go through lived experiences of inquiry-based pedagogies, in order to enable them to work out the representational design through which they interact with students. This is to enable that kind of lived experiences from their student-centered learning to occur in classrooms, which is traditionally different from what they have been practicing. The issue of concern then for discussion is whether AI in education can enable learning to be lived experiences (cognition, emotion, and social-beliefs embedded) while concomitantly affording representational forms that would augment the learning process with heightened interactional quality.

In the same vein, the basic premise of 'scaling' in education is not the replication of products but the capacity of people through lived experiences at every locality where the enactments of innovations are situated. In Chaps. 1 and 2, we discussed "eco-localization" to characterize that at every locality where lived experiences occur high quality interactions can happen if we have the people and environment/cultures to enable them. As a by-product of these interactions, knowledge in the form of representations and artifacts are produced. Each locality is also a local community that is inter-connected to other communities.

Each school is a local ecology-community. The students who have lived experiences grow up in local schools through established instructional practices, including co-curricular activities (CCAs), etc. The teachers and students, if they are well equipped to develop student capacities, establish clear learning processes and outcomes. The locality of each school prepares the child in that learning process. The interactions within that local school fosters and cultivates the learning for students attending to the disadvantages mentioned earlier, and teachers' repertoire also grow as they enact their instructional practices via professional learning communities.

Eco-localization occurs when teachers from each school share knowledge with teachers from other schools and brokered by individuals such as lead teachers who rove across the school cluster or network of schools. These could also take the form of networked learning communities. The principles around "eco" are forged into practice by cluster superintendents and school leaders, where the principle of adoption is 'cluster for schools and not school for clusters', as so well-articulated by one of the school principals in our school system. This principle speaks to the supporting mechanisms of the cluster (i.e., eco) in support of local schools (i.e., localization) in fostering and sustaining the learning innovations that occur in local schools.

In order for each school to be a good school, every locality (of a school) must have the key tenets (or characteristics) that make for a good school with the capacity to deliver on the learning outcomes defined. Each school has the intra-ecosystem that enables the school to be a good school. Inter-ecosystem is when school-to-school networks are formed.

Concomitantly, AI techniques, methods, and applications can facilitate and enable the eco-localization principles but cannot replace fundamental notions of high quality interactions between individuals and the environment and the social life of information (Brown & Duguid, 2017).

In conclusion, the Singapore education system with its past, present, and future orientations creates a 'living lab' with schools and the NIE as a fertile place where the AI potentials can be experimented on and visualized. We hope the establishment of AI-LIFE makes reality a conceptual idea and contributes to the levelling up of all schools and all learners across the system. It also hopes to contribute to new knowledge and to the international community.

NIE becomes a place where we can 'solve' the most difficult problems of remediating the disadvantages that students have encountered. Through good pedagogy and in multimodal fashions, we hope to better understand the biological (which is intuitive), environmental and sociological factors, through which we create this space and context for which we not just delve into designs, but even physiological and behavioral mechanisms to enable all learners to succeed. Another one of the aims is to scale up, spread, and sustain as a whole living laboratory through which Singapore can actualize a system where excellent education is enabled and fostered.

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