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PROJECT CLOSURE REPORT

Infusion, Dissemination and Evolution: Seeding an Innovation from one school to a few schools

By

Looi Chee-Kit, Wu Longkai, Ye Xiaoxuan

National Institute of Education
Singapore

Executive Summary (No more than 5 pages)

INTRODUCTION/BACKGROUND
Description of prior research in this area and/or the context in which this project was conducted

STATEMENT OF PROBLEMS
Justification for the study

PURPOSE OF STUDY
Description of the aims of this research project, including research questions and/or objectives

PARTICIPANTS
Description of the sample used in the study, e.g., sample size and characteristics

METHODOLOGY / DESIGN
Description of the methods and design used, including data collection and analysis

FINDINGS / RESULTS
Description and discussion of the main findings

IMPLICATION TO POLICY MAKERS
Description of how the project is of value and worth to policy makers

IMPACT TO SCHOOLS
Highlight the possible impact on the professional development of teachers and the education system. Also, highlight who and/or which subject/sector do you think the results of your research would make the biggest impact.

CONCLUSION
Discussion of conclusions based on the findings, and recommendations, if any

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KEYWORDS
Keyword 1; keyword 2; keyword 3; keyword 4; keyword 5; keyword 6

INFUSION, DISSEMINATION AND EVOLUTION: SEEDING AN INNOVATION FROM ONE SCHOOL TO A FEW SCHOOLS

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National Institute of Education

INTRODUCTION

The challenge of how to diffuse and scale-up effective educational innovations has received increasing attention in recent years. Researchers spent efforts developing educational innovation and proving its efficacy and effectiveness in pilot studies in small scale, but when the innovation is put into practice and especially when the context of use is broadened, the designed principles of the innovation need to be refined iteratively to work well through a process of design-based implementation research. Scaling up successful educational innovation not only draws interests from the researchers, but also education policy makers and practitioners, as they all aim to create deep and sustainable changes in the processes of teaching and learning. One of the most cited literature on scaling is that of Coburn (Coburn, 2003) who defined scale as encompassing four interrelated dimensions: depth, sustainability, spread and shift in reform ownership, and Clarke and Dede (Clarke & Dede, 2009) added in a fifth dimension of evolution of an innovation in this framework to understand and analyse the process of scaling-up.

The innovation that we are trying to scale up is Inquiry-Based Seamless Learning (IBSL), and has been developed by working with a class of primary school students over a period of two school years (a P3 class in 2009 and P4 in 2010) in school N. Because the research findings demonstrated increased student achievement, the school N has decided to scale-up the roll-out of the innovation to all P3 and P4 classes in 2013. Furthermore, the school (in its role as a Centre of Excellence for IT in Education in the North Zone cluster of schools) has intended to collaborate with other five schools in the cluster to scale up its successful innovation, and in particular, the enactment of mobile curriculum from the context of one school to a cluster of schools. In this regards, we see the innovation has achieved some successes in dimensions of scale by Coburn (2003) and Clarke and Dede (2009):

- Depth: The intervention has created positive learning gains for the students of the two classes (Looi et al., 2011) and positive changes in attitudes and knowledge of teachers (Looi et al., 2011) as well as one teacher's transformation in pedagogical orientation from a teacher-cantered, traditional-transmission view to a more constructivist model that focused on learning processes rather than stressing the results (Looi, Sun, Seow, & Chia, 2014).
- Sustainability: The innovation was sustainably used and refined in the school for five years, and clearly changes have occurred in the school with evidences from research analysis (Looi et al., 2010; Zhang et al., 2010).
- Spread: The innovation has been and is experiencing the following levels of spreading: pilot class in P3 level in one school (2009) — two classes in P4 level in the school (2010)—whole P3 classes in the school (2012)—whole P3 and P4 classes in the school and one pilot class in P3 in five other schools in the same cluster (2013 and 2014). The innovation has scaled up in the grade level, school level and now in cluster level.
- Shift in ownership: The school has taken over ownership by driving the spread of the IBSL innovation within school and across schools.
- Evolution: The innovation developer is learning conditions of implementing the innovation in diverse school contexts and refining the design principles to be more feasible for practitioners.

School N has been through grade level scaling and is currently at school-level and even cluster-level scaling-up. It is looking forward to sharing the model with other schools to achieve success in cluster-level scaling-up through across-schools network. A question that arises from the perspective of other schools: What is the innovation about? What can we learn from the innovation going on in school N? If we start our own innovation, do we need to go through all the phases that school N has been through? There is much room for exploration in this nascent field of scale-up research across schools. This study aims to shed light on the in-situ influences that may affect the diffusion process across varying contexts; in particular, whether insights from the pilot school can shorten the learning curves and eschew the need for prototyping at new experimental schools. There is much complexity in understanding the issues in scaling at across-school level, and there is no universal model for the operationalization of scaling in the educational research community. In our study, we proposed a model of scaling that revolves around the concept of "seeding" effect (Figure 1), with the three phases of infusion, dissemination and evolution.

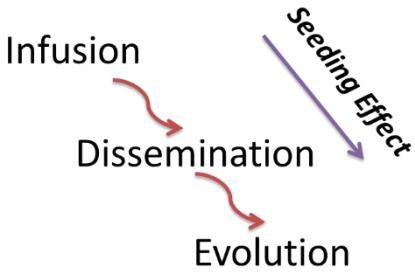

Figure 1. A Model of Scaling with Seeding Effect

By infusion, we refer to the intentional design for training of seeding practitioners, including teachers and school administrators etc., to take an active part in the actual social participation of the instantiations of research projects and develop an embodied understanding that may or may not be explicit. Subsequently, such programmes proceeds to dissemination, by which is meant the need for participants, when back to respective institutions, to constantly interflow around and disseminate the reifications. Through the process of dissemination, misconceptions can be elucidated and understandings evolved. Participants newer to the process can also be gradually enculturated through interflow with different members of community of practice, such as researchers and practitioners. As a whole, outcomes of the seeding effect, consisting of infusion, dissemination and evolution, to echo the points of Barab and Luehmann (2003), must be important and feasible to practitioners of multiple contexts, and addressing issues of local circumstances.

Specially in the school N case, whether/what/how do participating teachers (seeded teachers) from other schools learn from school N's experiences and translate these insights back to their own schools to disseminate innovation. The study is situated in a programme of research as a start to specially study both of the spread and evolution dimensions of scaling, leading to a better understanding of how the outcomes arising from researcher-driven interventions may be scaled across schools into wider practitioner-driven enactments, in context of the education system in Singapore. It studies closely the process of how a school's experiences in designing and practising an innovation can be spread to and then evolved in a few other schools. Our objective is to propose a model of scaling that can be operationalized and validated to understand how innovations can be spread and evolved across schools which are generally not well understood.

RESEARCH BACKGROUND

The innovation has been developed and implemented in the school context for several years, and the transforming process was proved a challenging one. In the efforts of spreading the innovation from one school context to more schools with diverse background, more issues emerged since the scaling up process involved more actors and contextual variables than that was in one

school. In this section, we will first introduce briefly about the innovation, and then review the perspectives to understand the scale-up process and challenges in the scaling up process in other reform system or diffusion of innovations.

The Innovation to Be Spread

The seamless learning notion views learning as distributed across different learning processes (emergent or planned) as well as across different spaces (in or out of class). Mobile devices are as mediating tools to facilitate the seamless integration of different types of learning processes. Students are assigned a mobile device with 24x7 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 experiments involving parents, online information search and peer discussions, and digital student artefact creation, among others. To facilitate the IBSL, MyDesk mobile learning environment that runs on a Microsoft Windows Mobile operating system was developed (Looi et al., 2010) for teachers to create curriculum-based lessons which embed multiple media (i.e., text, graphical, animations)and applications (KWL for students' reflection, NotePad for data collection, Sketchbook for drawing, MapIT for constructing concept map). Students' assignments and artefacts can be easily accessed and evaluated by the teacher for immediate feedback and comments. The innovative curriculum also incorporates the 5E (Engagement-Exploration-Explanation-Elaboration-Evaluation) instructional model (Bybee, 2006), which has been pervasively employed in the instruction of science in Singapore schools. Teachers are encouraged to apply constructivist teaching approaches to ask questions, conduct mobile and non-mobile activities, interact with students and scaffold the students' learning (Zhang et al., 2010). Equipped with mobile devices, individual students may carry out the learning activities in their own pace and pursue their preferred learning paths. The innovative curriculum was proved to be effective in engaging students to learn science in personal, deep and engaging ways as well as developing students' positive attitudes towards mobile learning (Looi et al., 2011).

Perspectives to Scaling of Innovation

We have previously mentioned the most cited literature of Coburn's dimensions of scaling. Another set of concepts were articulated by Roger (Rogers, 2003) as Diffusion of Innovation theory. In Roger's theory, there are several key components included (Dearing, 2008; Rogers, 2003; SAHIN, 2006):

- The *innovation*, including its *characteristics* such as relative advantage (effectiveness and cost-efficiency relative to alternatives), complexity (how simple it is to understand), compatibility (the fit of the innovation to the norms, beliefs, and past practices that characterize the potential adopter), observability (the extent to which outcomes can be seen), and trialability (the extent to which the adopter must commit to full adoption).
- The *Innovation-Decision process*, which is a stage-ordered model of knowledge, persuasion, decision, implementation, and confirmation.
- The *social system*, especially in terms of the *structure* of the system. The members of the social system are categorized based on their innovativeness: innovators, early adopters, early majority, late majority, and laggards.
- The *diffusion system*, especially an external change agency and its change agents who, if well trained, correctly seek out and intervene with the client system's opinion leaders, paraprofessional aides, and innovation champions.

The two sets of concepts derive from different streams of research, so the concepts about scale and diffusion are not mutually exclusive. In our study, we are especially interested to know what are the social relations, resources and expertise to achieve dissemination, so the diffusion of innovation theory provides us with a good lens to look at the process.

Spreading and expanding educational innovations were proved to be challenging task by many literature, and early research about it documented the importance of time and interpersonal networks to diffusion (Coburn & Russell, 2008). A group of researchers proposed and refined the

Concern Based Adoption Model (CBAM) to study the adoption of an educational innovation (Gene E Hall & Loucks, 1978; G. E. Hall, Loucks, Rutherford, & Newlove, 1975; Newhouse, 2001). The CBAM model comprises three dimensions, namely, stages of concern, levels of use, and innovation configuration. The levels of use describe the stages of implementers' usage of an innovation, and include levels like orientation, preparation, mechanical use, routine or refinement, integration, and renewal. One strategy proposed by Hargreaves and Fink (2000) is to use model successes to reculture as well as to restructure schools – adopt the philosophy and intentions into the existing culture of adventurous volunteer schools before enacting the structures for change. In this regards, adopting an innovation could be a long process. Mort (Mort, 1953) proved that it took 25 years for educational innovations to be adopted by schools.

Considering the complexity and interplay of multiple dimensions of education reforms, we view the spread of the innovation from a systemic change perspective that includes the micro, meso, and macro levels of educational systems. The policy imperatives governing Singapore's educational landscape constitute the macro-level factors, and the contextualized classroom-based work and interactions as micro-level factors. The socio-cultural factors of the school's learning ecology constitute the meso-level environment and we as researchers from the university can be interpreted as an example of meso-level actors who work in that environment to recontextualise pedagogic discourse. The orchestration of efforts from all actors will contribute explanatory power to the sustainability of an intervention. By analyzing this pedagogy-driven reform at the macro, meso and micro levels, it is contended that the alignment of systemic forces at work will provide a buttress for sustainability.

Lessons learned from prior technology-based educational improvement research clearly indicates the importance of empowering teachers and building capacity to effect deeper changes in teachers' beliefs, knowledge, and practices (Fishman, 2005). How teachers perceive an innovation will influence their actions in implementation (Freeman, 2012; Mustafa & Al-Mothana, 2013), and their perceptions were determined by multiple factors, such as teachers' ICT competency and schools' ICT vision and policy (Vanderlinde & van Braak, 2011). Professional development workshops were often provided for teachers who would like to adopt an innovative pedagogical practice, but normally the workshops were short-term and teachers playing the role as passive recipients. In fact they benefited more when they participated in professional learning in a collaborative form (Cloonan, 2009; Kopcha, 2012) and when their school contexts and needs had to be considered (Stein, Smith, & Silver, 1999). In much of the literature, teachers' learning community and network building were highlighted (Coburn & Russell, 2008; Sun, Penuel, Frank, Gallagher, & Youngs, 2013). Especially in Coburn and Russell (2008) work, they defined teachers' social capital which largely determined the quality of teacher's social network. Four dimensions constitute teacher's social capital, including structure of ties, trust, access to expertise and content of interaction. Specifically, they found that more opportunities (i.e., routines of interactions) for teachers communications may impact if there's little other priorities competing for teachers' time and attention; the design of coaching/mentoring (selection of mentor, specification of mentor's supporting roles and the focus of PD) influence teacher's social capital in both dimensions of access to expertise and depth of interaction.

PURPOSE OF STUDY

The theoretical framework views scaling as a diffusion model in which the infusion of seeding teachers into a practicing community of teachers leads to dissemination of knowledge about the innovation, how it is practiced, the pitfalls and challenges, as well as the benefits if it is implemented efficaciously. A weaker sense of living the innovation (by observing classes, by doing some mock teaching, and by being part of the conversations) leads to dissemination to the seeding teachers. The key driving research question is: *how does this model of spreading an innovation from one school to other schools work?* Unpacking this further, what are the social relations, resources and expertise to achieve dissemination and spread? What are the processes and mechanisms that can help disseminate practices related to designing and implementing a new innovation – from one

school where the innovation is being enacted to a few other schools with different contextual conditions?

Hence we will elaborate the diffusion framework with evidence (first from a social network that grows – from practitioner community to a social community and then to a wider social community). Answering this driving research question would entail exploring three research sub-questions:

- [Factors that affect what they share and Outcomes] How do the context variables, as well as interactions, among teachers as "early adopters" at NCPS, teachers as "followers" from other schools, "followers" as teacher activists in their own school and researchers as meso-level agents affect the scaling of innovation across schools?
- [Perceptions of feasibility] How do the agents of the learning, i.e. teachers from other schools (seeding teachers) who participated in the sharing and in classroom observations perceive of the feasibility of customizing/adapting the innovation for their own schools or of utilizing/adapting the innovation processes for creating their own innovation?
- [What and how do teachers share?] What and how do these agents share with in their own schools about the innovation of NCPS? i.e. how does the diffusion process start in these other schools? How do the teachers and administrators of these schools perceive of the innovation?

Through answering the research questions, we aim to propose a model of scaling that can be operationalized and validated to understand how innovations can be spread and evolved across schools which are generally not well understood. Thus, this research will:

- Study how the design principles and theories which informed the original research projects can be subsequently shared and spread;
- Assess whether there is sufficient preparedness in the participating schools in terms of school-readiness for adopting and adapting innovations which are developed to some degree to enable scaling to occur next;
- Assess how different schools with different contextual conditions (e.g. academic ability levels of their students, etc), will respond, uptake and adapt an innovation for evolution, leading to an understanding of what scaling entails for schools with such different conditions.

This study will enable NIE, schools and MOE to derive a deeper understanding of the factors that influence the spread and evolution of innovations:

- School-readiness with accompanying school leadership support, availability of resources, current capacity, etc.;
- Specifications or guidelines for spreading an innovation – in order to inform policy makers on how different types of research projects could be scaled.
- Dynamics, whether internal or external, leading to possible consequences or outcomes of spreading and evolving an innovation in contexts of different schools.
- Classification of schools (if any or if applicable) for which different scaling models might be applicable, and different resources, support, and strategies might be relevant.

METHODOLOGY

The study was conducted in the form of design-based research (DBR) (Brown, 1992), as the research objectives stated above imply the central theme of the methodology to result in greater understanding of a learning ecology by designing its elements and by anticipating how these elements function together to support learning (Cobb, Confrey, diSessa, Lehrer, & Schauble, 2003). We aim to explore the dynamics of the scale-up process and study the interactions among multiple context variables that influence the result of the scale-up, so the DBR method allows us to identify the issues emerged in the implementation-dissemination process and figure out better solutions to those issues through research.

Research Design

Generally, the study comprises three continuous phases: infusion in 2012, implementation in 2013 and 2014, dissemination and evolution in 2014.

In the infusion phase, some design principles for the seeding process were proposed for teachers' capacity building: There are several design principles we put forward for the professional development sessions across the learning journey:

1) Sharing of the Early Adopter teacher (EAT) to the Seeded Teachers (STs) from other schools should be participatory;

2) STs will also have a chance to have an lived in or embodied experience of what it means to teach such lessons during implementation stage;

3) STs have the flexibility to personalize the curricular innovation considering the local needs of their own schools;

4) EATs also benefit from a reflective practitioner stance of re-looking and adapting their own innovation and innovation approaches through their active participation and sharing with STs;

5) Communities of practice for EATs, STs and non-seeded teachers to share experiences, challenges, tips and constraints of how to enact a classroom innovation (with researchers as meso-level catalysts but to eventually fade away).

Based on the design principles, a model for teachers' preflective learning is proposed as shown in Figure 2. It consists of four types of activities, as well as the preflection prompts to scaffold teachers' reflection-for-implementation. In the first activity which we call "infusion", or the kick-off meeting, different parties in the project, including all the teachers and school administrators from the seeded schools, as well as the MOE officers, gather for initial understanding of the innovation about "what it is" and "whether it works" from perspectives of both researchers and pioneer practitioners. In the meeting, the effectiveness of MSL on students learning was presented to teachers, especially students' improvement on semester assessments in answering multiple choice questions (MCQ), open-ended (OE) questions and the total scores. The objective of the project was made clear to all the parties, as well as the responsibility and key performance indicators.

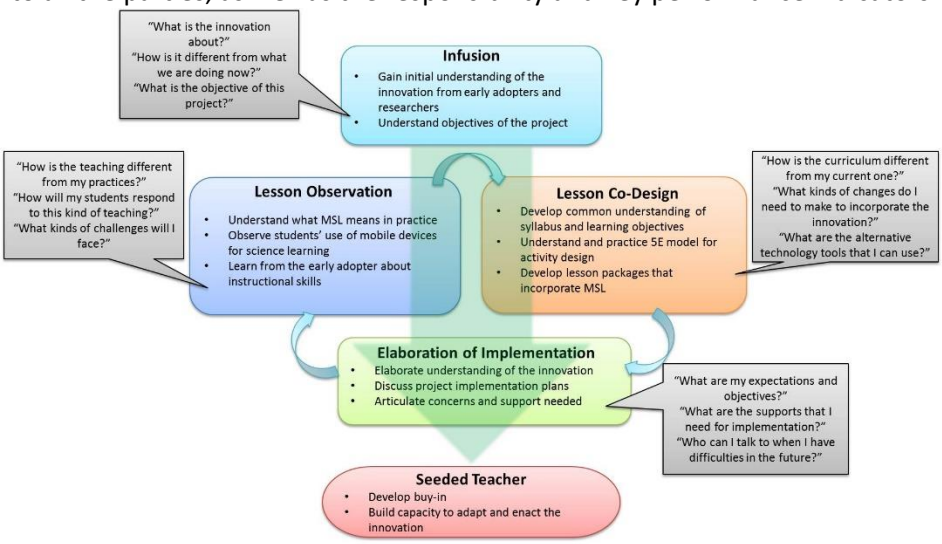

Figure 2. Model of Teacher's Preflective Learning with Preflection Prompts in the Infusion Phase

In the implementation phase, teachers implemented the co-designed lessons with certain degree of adaptation. The co-design session continued during the stage, and at the same time lesson observation in the five schools and the post-observation discussions formed another type of teacher PD. The observation team was comprised of the EAT, the MOE officers, and the researchers, and went for observation fortnightly. After every lesson, the observation team would feedback on teacher's teaching and students' responses in classroom, with special focus on the aspects like teacher's strategies of inquiry teaching, the lesson design, and areas for improvement.

In the dissemination phase, we hope to see the five schools to take more ownership of spreading the innovation within their own schools. However, due to the readiness of the software (i.e., MyDesk learning platform), there were little lessons involving the use of the learning platform. What's more, three out of five schools remained use of the mobile devices within school due to parents' concerns, so we couldn't see the full effectiveness of the IBSL so far. But as we have foreseen in the beginning of the project, there would be varied trajectory and pace of different school's uptake of the innovation. In the findings, we will delineate various progress and specify the influences of the context variables on the uptake process.

Participants

The five schools were selected by the cluster superintendent based on a few criteria. Some of these criteria are: whether there is some basic level of commitment by the school leaders towards using ICT in teaching and learning, how ready are they to embark on such an ICT project, and the support and buy-in by the principals especially whether they will stay in their school long enough to see through the project. The teachers involved in this project were chosen by the principals. There were 12 STs from 5 seeded schools and 9 out of 12 teachers have relatively low level experiences in teaching (equal to or less than 6 years). The general information for the teachers can be found in Table 1. All names are pseudonyms. The last column of the table presented the teachers' previous pedagogical practices which were provided by them in a survey.

We also have the EAT Jane from school N, who has been working on the project of IBSL since the year of 2009. She has about eight years of teaching experiences and now is the champion of the innovation within school N. She had mentored teachers in her own school, and then started to perform as a mentor for the five schools STs.

There were two officers form Educational Technology Division (ETD), MOE actively following up the project, with a focus on students' improvement through inquiry-based learning, as well as teacher's inquiry-based teaching. Together with Jane, STs from the five schools and the NIE researchers, we formed a community of practice (COP) with a common goal of benefiting more students through the use of technology-afforded inquiry learning.

Table 1. *General information for the implementing teachers from four seeded schools*

Teacher Name	Information		
	School	Years of Teaching Experience[a]	Other Administration role
Ian	A	5	Level head, Science
Ying	B	1.5	
Cherry	B	1.5	
Wilson	C	5	
Joanna	C	13	
Yaw Ming (YM)	C	15	
Anna	D	2	Assistant Year Head
Kabir	D	6	Subject Head, ICT
Amber	E	6	Head of Department, Science
Rohana	E	10	
Ida	E	<1	
Wanda	E	<1	

a. The years of experiences refer to the total years of teaching experiences as of 2013

There were ten classes engaged in the study, one experimental and one control class from each school. Selection criteria of classes were given to schools, but the final decisions were made by

the school. School A, B, and C chose to enact the curriculum in class with higher ability students, while the others chose middle ability students. Ian, Cherry, Joanna, Anna, Amber and Rohana were the teachers teaching the experimental classes.

Data Collection and Analysis

The purpose of the study was to examine the process of different schools customize/adapt the innovation in their own schools, with a special focus on teachers: what they have learnt and observed from school N, what they took back, how they shared with the school leaders and teachers in their own school, how they planned to start their own innovation back in their own school, their reflections, etc. The study was not intended to demonstrate the effectiveness of the IBSL intervention on students' learning as compared with other interventions or traditional teaching methods. Therefore, the primary data sources for the study were teachers' surveys and interviews, as well as observations of their teaching practices. Students' data of content test and inquiry helped the school to monitor the process and helped us better understand the overall picture. The following descriptions illustrate the data sources and how we analysed them to answer the research questions.

Teacher's pre-survey and post-survey. The post-survey is attached in the appendix A. The 12 teachers filled up surveys on their perceptions toward the innovation, while pre-survey was distributed online at the end of the infusion stage in October 2013, and post-survey was distributed at the end of first round of implementation in Nov 2014. The questions in the two surveys were not identical, but some questions remained similar, such as their understanding of the innovation, their current pedagogical orientation, their plan of implementation etc. In the post-survey, there were more questions added in on their reflection about the feasibility of adapting the innovation in their own school, their perception of supports from different levels, and the challenges they faced in the process. The purpose of the survey was to understand teachers' perceptions, help STs reflect on their learning experiences both in school N and their own schools.

Teacher interview. The post-interview is attached in Appendix B. After the survey, researchers went to each school to have interview with teachers. The interviews were conducted twice, one before the actual implementation and another after first round of implementation. The interviews were semi-structured and focused on teachers' perceptions and their articulations on teaching practices, especially those involving inquiry-based teaching, challenges and successes, evaluation of students' performance, and description of support systems. In the schools with more than one teacher involving, we conducted the interview in the form of group discussion. On average the interviews lasted one hour. The researcher audio-taped the interviews and took notes, after which selective parts were transcribed for more detailed analysis.

Classroom observation and field notes. The actual classroom implementation started from April 2014. One teacher from each school conducted lessons, with an exception of two teacher co-teaching in school E. The observation team observed lessons fortnightly with a focus on assisting teacher's implementation, understanding the challenges faced by the STs and supports utilized by the teachers. During classroom observation, the video recordings and field notes were taken by the researcher. The field notes were taken with the following dimensions according to the research focus: the adaptations that teachers have made comparing to the co-designed lesson plan (activity design, resources used etc.), the technical tools that teachers have used, the questions that teachers asked in the lesson, the dialogue in the classroom/interactions between teacher and students (especially teacher's follow-up to students' responses). As we explained before, most schools weren't able to allow students to bring tablets home, so the examination of activities were all in classroom.

Student content and inquiry test. Students in all the ten classes were given pre- and post-assessment on content and inquiry. The content assessment instrument was designed collaboratively by the EAT and researchers and contained five multiple-choice and three open-ended items, and the inquiry instrument was designed by the ETD officers with seven multiple-choice and five open-ended items. The content assessment covered the content of primary three

and the inquiry assessment tested students' ability in inquiry such as keeping just one variable for fair test. The content pre- and post-assessment were identical so that repeated-measure analysis of variances could be used to illustrated students changes in content understanding.

Other data sources were used to triangulate the abovementioned data, such as meeting notes of the co-designed sessions, notes of leadership meeting, field notes of post-observation discussions between teacher who implemented the lesson and the observation team.

Data Analysis. For answering the research questions on the context variables, we adapted the qualitative analysis protocol of Chi (Chi, 1997) to analyse data of teacher interview and classroom field notes. First a preliminary category was developed, and then each school was coded for the factors, and then checked and rechecked data sources for consistency. Patterns that emerged were checked for consistency with interview data, and confirmed with other researchers until consensus was reached. To answer the questions of how the agents disseminate the innovation in their own schools, we took a closer look at teacher implementation, and used the data from classroom videos and field notes. The data of curriculum implementation was collected for the period of one term (about three months) covering the content of "Exploring Materials" under the theme of "Diversity", and "Plant system" and ""Body system" under the theme of "Systems". The dimensions of examination of teaching practices were decided according to the research focus. The dimensions were confirmed to be: activity theme and sequence, the classroom interaction pattern, and the ICT-integrated activity design. There were limited sources of lessons (six lessons from each classroom, except for school B of only 2 lessons) so we decided to code for all the lessons. The lessons in school B were all conducted in traditional way without use of devices and was more teacher dominant, so we didn't analyse the data from school B. For the other lessons, we first divided into episodes, with each episode focusing on a specific topic and activity. For example, in the first lesson of Material, Ian's lesson was divided into: Cinderella storytelling, students' searching on Google about types of materials, Socrative activity on options of material for making shoes. This helps us to compare with the co-designed lesson design to see how teachers adapt the curriculum. Then, the episodes were examined following Chin's (Chin, 2006) framework to see the classroom interaction pattern. This helps us to determine teachers' pedagogical orientation and their facilitation skills through examining the questions they asked and the feedback they provided to the students. In this process, we especially looked at the activities that involved the use of ICT tools, with focus on how the activity was designed and conducted. Teacher's perceptions were asked in the survey and interviews, and the results were examined using content analysis method.

FINDINGS

In this session, we organize our findings in two categories: the contextual conditions entailed in the process of the diffusion of an innovation to more schools, and teacher's perception of the innovation. In the first part, we aimed to answer the first and third research question in our study by proposing a framework for examining the readiness of a school to adopt and adapt technology-related innovation and exemplifying the framework through cases of the five schools in our study. The framework is composed of the facilitating or limiting factors within a school system that may influence the process of the infusion, dissemination, and evolution of an innovation. In the second part, we take closer look at the teacher, who is undoubtedly the critical factor in the scaling-up process. We not only examined their perceptions of the innovation, but also explained how the perceptions were formed through learning in the seeding school and their actual implementation. What's more, we expanded our learning at teachers by examining their real teaching practices in their own schools. By detailed examination of the implementation, and making connection between their response to the innovation and the contextual conditions in his/her school, we further verified that scaling up an innovation in diverse context is a complex process and that multiple factors in a systemic relationship interacted to determine the success of implementation.

Contextual Conditions that Affect the Diffusion of IBSL in Schools

School reform is a complicated work that all the pieces from leadership, to professional learning and curriculum development are interconnected, so as the process of adoption and adaptation of an innovative pedagogy. Some schools developed their own innovative approach from within while others collaborate with external organizations that have developed coherent, research-based approaches. In our case, one pilot school took the leading role in disseminating IBSL in five more schools, with supports from the innovation developer. The adoption of an innovation is determined by the interplay of factors from multiple levels of the school system such as macro-level ones like the national educational policies and socio-cultural factors of the school's learning ecology, meso-level ones like school-researcher partnerships, and micro-level ones like classroom-based work and interactions (Looi, 2011). As we described before, the unit of analysis in our study is school, so we summarize the critical factors within school's boundary. The factors were proposed based on our field observation in the five schools till the end of first round implementation, and that is end of 2014. The scaling work is still ongoing and there might be additions as the observation goes on to the next phase.

Table 2. *Contextual Conditions that Affect Diffusion of Innovation in School*

A. Organizational Characteristics

A1. School culture in learning (e.g., characteristics of the existing curriculum, normal pedagogy and assessment practices)

A2. Technology-related characteristics: ICT infrastructure, usual learning platform etc.

A3. Culture in professional development and professional learning community (PLC) structure (e.g., teachers' PD opportunities, within school PLC themes, across schools PLC)

A4. School demographic (e.g., students' population, percentage of students under FAS)

B. Actors in School

B1. Administrative leaders (e.g., Principal, Science/ICT Head of Department)

- Perception of the innovation (effectiveness, compatibility, simplicity, cost, trialability, observability)
- Level of commitment
- Recognition of staff work
- Ability in prevision, planning and problem solving
- Obtaining resources (e.g. for research funding, equipment, training)

B2. Teachers

- Perception of the innovation

- Belief in technology in teaching and learning
- Teaching experiences, especially experiences in inquiry-based teaching
- Teaching competencies (i.e., CK, PCK, TPCK)
- Social capital (social network structure, access to expertise, trust to early adopter teacher of innovation, participating in COP and interaction depth) (Coburn & Russell, 2008)

B3. Early Adopter, Innovation developer and/or researcher's supports

- Supports in social network building
- Provision of PD sessions
- Onsite support and feedback (e.g., trouble shooting for technical issue, activity design, students' responses)
- Suggestions on strategies for adoption and adaptation
- Mediating between levels of actors within school or across schools to address emerging issues

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B4. Students (e.g. attitudes towards learning, and technology for learning, media literacy)

The scaling-up work has gone to its third year, and the five schools are at different stages of use of IBSL. During the diffusion of IBSL, we formed a seeding-seeded relationship between school N and the five schools, as shown in Figure 3. The school N played a pivotal role in leading the spread of IBSL, through sharing the experiences of adopting an innovative pedagogy, success and challenges in the process, suggestions on making adaptions for school's context. The ties between the seeding school and the seeded schools are not only through the leadership, but more importantly through the establishment of teacher's learning community, which will be discussed in the second part. The five schools also formed a community where sharing of resources, communicating success and failure, and reflecting practices could take place.

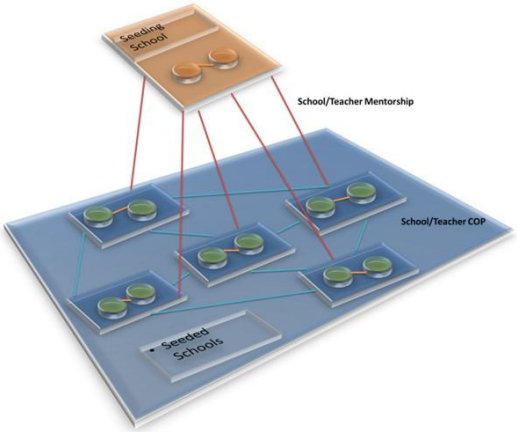

Figure 3. The Seeding-Seeded Relationship in Diffusion of IBSL

We categorized the stages of the five schools in the process of adopting of the innovation according the framework of Hall et al. (1975), and explained how the interactions between the contextual conditions within the school affect the school's process.

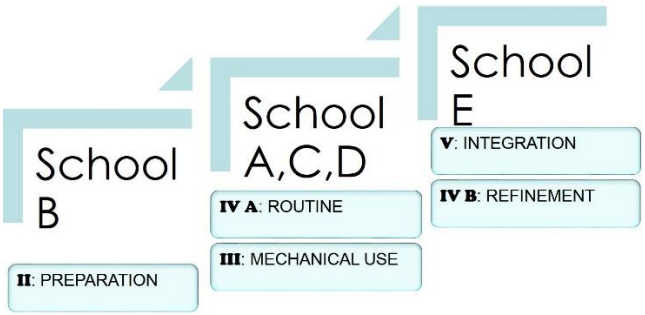

Figure 4. The Five Schools' Level of Use of IBSL

School E is now scaling up the IBSL to one more pilot class in primary 3. The project only afforded the devices for one class, so the Principal applied funds from other resources and succeeded. As we observed, the level of use of IBSL has reached refinement and integration, which was a result of the interactions of the contextual factors within the school. The school has a culture of using ICT to facilitate deeper learning, and before participating the project they occasionally conducted science lessons in computer lab or in gardens with assistance of iPad (factor A1 and A2). The teacher professional learning community was well established in school E: the science teachers in the P3 level joined the project as a team, they observed every lesson and had weekly reflection and planning session besides the post-observation discussion with the impetus team. One of the four teachers was HoD Science in the school, and she leaded the team in lesson observation, reflection and planning. Rohana was an experienced teacher, and the other two teachers were beginning teachers with less teaching experiences. Besides the across schools teachers community, the four teachers also participated the school-wide science teacher PLC to share with others about the progress, and align the direction of project with school focus on teacher development (factor A3). From our observation, we found that the students in the pilot class in 2014 were very active in classroom and were willing to express themselves (factor A4 and B4). The school leaders provided strong supports as observed from the following dimensions (factor B1): level of commitment from both science HOD and ICT HOD, Principal's support in searching for funding to scale up, recognition of teachers' work. The science HOD engaged in every activity of diffusion of IBSL in the school, and the ICT HOD went to observe lessons frequently. Senior science teachers from other levels were invited to observe lessons occasionally and they provided professional feedback to teachers. In the first year of implementation (2014), Amber and Rohana co-taught the pilot class and the four teachers worked closely and formed a routine use of IBSL. In 2015, Amber moved to another level, and decided to let Rohana and Wanda implement the refined curriculum. Although Wanda was less experienced, she was guided and supported by Rohana and Amber. From our observation, we found the teachers in school E appreciated the idea that learning as inquiry, and conveyed this idea to their students (factor B2). The school indeed faced challenges when getting buy-in from the parents, but the school leaders and teachers endeavoured to constantly explain to parents and convince them of the benefits to students' learning.

School A, C and D is in the stage of mechanical use and forming routine use of IBSL. In school A, only one teacher, who was the level head, mainly drove the project conduction in the school. There was no formal PLC on science in the school, so the teacher didn't get much opportunity to communicate with others on the project and discuss on the adaptation of the curriculum. The teacher was interested to use ICT in classroom, and he was willing to try the learning platform, but he did not feel confident about his content knowledge, at the same time he felt less competent to teach in an inquiry-based way. He reflected that he gained a lot on the pedagogy and resources from the across schools teachers community. In school C, two teachers joined the project, with the more experienced teacher implementing the curriculum. The teacher's teaching was constructivism oriented, and from the lesson observation, we found her very competent in guiding students and

pacing class activities. However, she decided not to use the devices until the learning platform's ready, while she could have tried other available tools to get students used to the learning environment. Although the school has teacher lesson study sessions, the focus of it was on another subject instead of science, so the teachers could not be able to share and disseminate the practice. Besides discussion in school N, the two teachers also didn't have platform or opportunity to have discussion on how to customize the package for school's use. The supports from school leaders in school A and C were less observable as compared to school E. In school D, two teachers were involved but mainly one teacher drove the project conduction in the school. The school has tradition in using storytelling to engage students in learning, and the school Principal was open to any good innovative practice. The teacher has only two years' teaching experience, but she was good at communicating with students and disciplining the students. Due to the class learning ability, the teacher conducted activities with a mix of inquiry-based one and drilling oriented one. Her work in the project got recognized by the leaders and she was promoted to year head at the end of 2014.

School B is now making decision of whether they would stay in the project, because of several conditions. First of all, there was leadership change in 2014, resulting in a vague position of the project in the school development. The previous Principal did not hand over the issues on the project well to the new Principal, and there was also lack of involvement of middle level leadership, such as science HOD in the project conduction. Secondly, the teachers in school B were not ready to adopt IBSL, especially from pedagogical aspect. School B sent two teachers with teaching experiences of less than two years to school N for lesson observation and project coordination in the beginning of the project. They were less active in the teachers' community, and according to our interaction with the teacher, she was struggling in the classroom management and getting teaching resources from other colleagues. There were no other teaching assistant or technician in the classroom to support her.

As we can see, the conditions in every school differed. The result in the level of use of IBSL was a consequence of interactions among the factors. We positioned the support from meso-level in school context as the supports contributed to the following dimensions: firstly, we formed a platform where teachers with similar experiences could interact and reflect. Secondly, we identified the difficulties in teaching and provided professional development in both theory and practice. Thirdly, during implementation, we provided feedback on teacher's practices, at the same time encouraged them to take ownership in spreading the innovation. Lastly, we observed the process with a systemic lens, detected the problems in project conduction and connected relative personnel to solve the problems.

Teachers' Perception of IBSL and Their Implementation in Schools

Empowering teachers and building teacher's capacity in innovation implementation would undoubtedly result in a deeper and lasting change of teacher's teaching practices, thus lead to a sustainable use of the innovation. It is important to foster professional community for diffusion of innovation so as to develop quality of teacher's social capital. In our teacher's learning community, teacher's social capital was fostered guided by the following principles:

1) *establishing the mentorship (selecting the mentor and specifying her role) and norms within the community*. Jane as an early adopter teacher was experienced in integrating IBSL in curriculum design and enactment, and she also had experiences of mentoring teachers in her own school. So she was selected as the "change agent" to influence the thoughts and actions of the "followers". Jane played a leading role in driving the spread of IBSL, with supports from researcher and MOE officers, and together the three agents formed a team of impetus for the scaling up work. Researchers used to provide extensive supports when school N adopted and adapted the innovation, but we aimed to shift the ownership to the schools for a sustainable and scalable change in schools. The impetus team sought professional development opportunities for teachers, provided resources and stimulated interactions among the STs, provide onsite supports in classroom with descending frequency as the stages of diffusion advanced, and collecting teachers' concerns regarding implementation and mediating. The seeded teachers were not just following whatever

Jane said or did, but were active participant in the process and encouraged to provide constructive feedback and take ownership.

2) *Multiple professional development opportunities for deeper interactions within the community*. Various types of activities were designed for the teacher's preflection learning in the first stage, as we discussed previously and demonstrated in Figure 2. During the lesson co-design sessions, conversations covered the subject content knowledge, pedagogical content knowledge, as well as how to leverage the use of technology for classroom (technological pedagogical content knowledge). In the second stage of implementation, lesson co-design continued and the impetus team went to observe the STs' lessons. After each lesson observation, a post-observation discussion would be conducted for specific feedback to teacher's lesson enactment. At the same time, the impetus team proposed some PD topics according to teachers' needs and observation. For example, teachers all felt a need to know more about how to better apply questioning strategies to probe deeper thinking, so the researchers and the ETD officers collaborated to offer a PD on questioning and made it authentic through summarizing some good examples from participating teachers. We also observed teachers ambiguous about the use of the learning platform, so we invited the researchers who have been working closely with Jane in school N and shared the tips and pitfalls from their observations. In summary, the model for teacher capacity building for implementation and dissemination of IBSL was concluded in Figure 5.

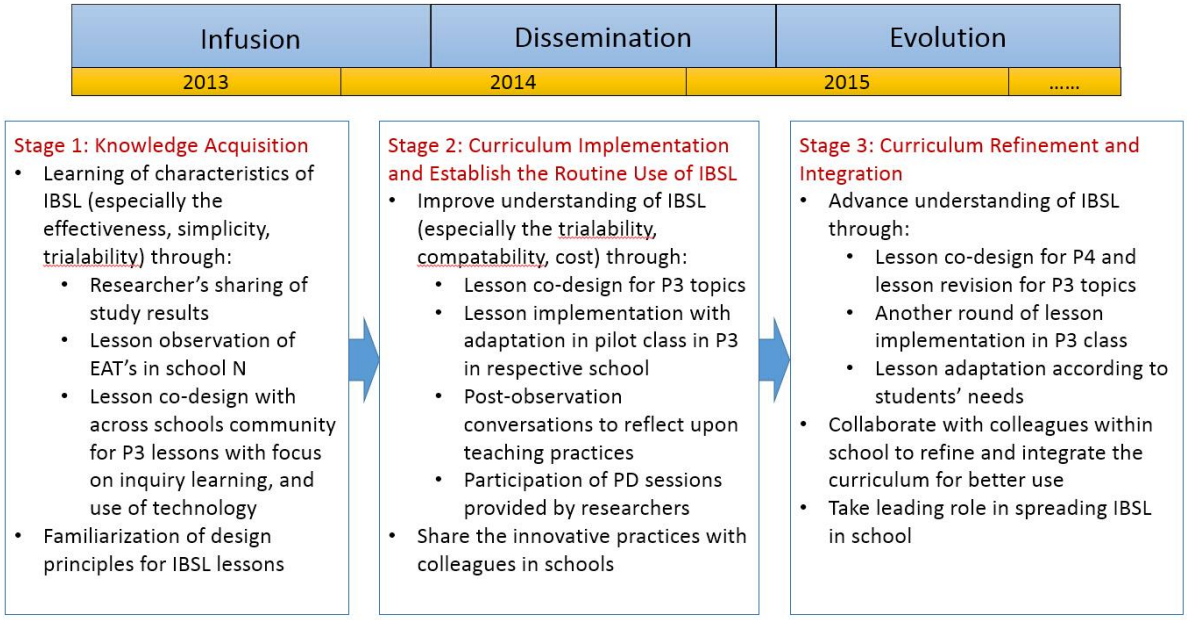

Figure 5. Trajectory of Teacher Professional Development in Diffusion of IBSL

Teachers' Perception of IBSL

Teachers' perception of IBSL developed along the process. In the first phase, teachers developed high degree of buy-in through observation and researchers' introduction. In the second phase, they implemented the curriculum in their own context and gained more practical experiences, hence advanced their understanding.

- Effectiveness and Observability

Students' improvement in answering open-ended questions was most impressive effectiveness to the teachers because for teachers it is the part they always want to achieve, as Wilson stated in the interview (direct quotation was edited to be easier understood):

> I mean the exciting part of [the innovation] is that you know when you talk about open-ended questions. Because even up to Primary 6, that's the key issue which students not being able to do science questions [in] science exams. I mean I'm not harping on exams all the time but you know it's a reality of Singapore's education.

> So when you first came up and gave us the number. Wow, impressive! You know. The figures were very impressive and very exciting. That is where we want to improve. Seriously right now, even the better students in our school do not know how to answer in a certain way.

Besides the academic achievement, the formation of a learning culture was also viewed as a desired outcome of participating the innovation diffusion. From the lesson observations, the STs were impressed with the learning culture in the classroom: students were doing inquiries, they were not afraid to ask questions, tended to find evidence to support their scientific claims, explained well to the teacher and their peers about what they were thinking, and collaborated somewhat orderly with good division of labor. As Wilson expressed in the interview, he was very impressed that the students behaved naturally like scientists, which could not be trained and achieved in the traditional way of teaching:

> The way I see Jane's student answers [to the questions that Jane asked in the classroom] right, it's very encouraging because that is how a scientist, a researcher, a person who is into doing science [does]. That's how you ask questions and how you answer questions. And that's how she does with her class. She expects them to be (a) [budding] scientist.

STs also saw that students were also very skillful at using the mobile devices for learning, whether individually or collaboratively. Thus, from the lesson observation, the STs were able to see that the benefits of MSL not only included the exam performance, but also promoting a cultural change for learning in which students were doing self-directed learning.

- Simplicity

Simplicity is the extent to which an innovation is easy to understand and use. We surveyed the STs about the essence of IBSL, and they described it using the following keywords (with descending frequencies): use of technology, student-centered and teacher as facilitator, fostering self-directed learner, beyond classroom, or in and out of classroom, life-long learning, 21st century skills and enhance students' interests in science learning. In the post-survey, fostering students' critical thinking and facilitate collaborative learning were added by half of the teachers.

In the interview, teachers' ideas were further clarified. Most of the STs especially acknowledged the "seamless" element in the package and viewed it as a linkage between formal learning and informal learning. Wilson stated in the interview that the unique part of MSL was that the mobile devices served as a means to make learning a really 24/7 thing:

> I think [the unique part of MSL] is that the students who are embarking on this programme have a means to an end. They have the means to do [inquiry], [and] they have been given a means to explore, research and to be able to do their research easily…. Using the mobile device, and like what the programme's name suggest, it is really seamless because they don't just do it in school. Right now here in school I [only] have 3 periods to teach. And after that they have other subjects to do and after they go home I also don't know [what they do at home]. But with MSL, they have their mobile device, [so] whatever that they upload from home I also know.

STs also mentioned "self-directed learning" a lot, which is advocated by MOE as one of the desired student outcomes in 21st competencies. Anna gave an example of what she envisioned for her students, and elaborated her understanding of self-directed learning:

> I mean you see it's like, we can give them a topic, and off we go, whether at home, along the road, even when they are in canteen with their friends, they may discover certain things, and then there they post. We can have the discussion forum. They may even notice something during holidays, even post and we have discussion. So that's what we mean by self-directed learning. It's no longer always teachers asking

you must do this you must learn this, maybe the child can even post pictures of a creature that looks like an insect but doesn't have the full characteristics of the insect, but we can all discuss this.

- Compatibility and Feasibility

The five schools have different backgrounds from the school N, hence, they faced different challenges. For example, for some of the schools, parents' buy-in of the use of tablet is a critical issue since most of the students of the schools are under the national financial assistance scheme. Parents would concern about the compensation in case that students lose the device, at the same time they concern that pupils would use tablet for game playing. In the teachers' survey, we asked teachers to put their perception of compatibility and feasibility of adapting IBSL in their own school on a scale from 1 to 10, and the results showed that teachers held positive attitudes of customizing the innovation in their school. We also summarized the concerns from the teachers, and the following factors were found affecting the sustainable or scalable use of IBSL: technical issues or technical support from the vendor, parents' buy in, teacher's capacity of conducting inquiry-based teaching.

Teachers' Implementation of IBSL

There were many factors influencing how teachers enacting the curriculum innovation. Morris and Hiebert (Morris & Hiebert, 2011) attribute the variation to differences in the expertise or differences in the local context (teachers' teaching resources, training opportunities, teacher and student mobility, administration support etc.) that prompt teachers to change the plans. Researchers also found that teachers' adaptations to innovations were influenced by their knowledge and beliefs about the subject they were teaching, their beliefs about their own identity and about teaching and learning, and the degree that the innovation was supported within their local contexts (Pintó, 2005). Although the curriculum package was co-designed by the COP, teachers in our study adapted it in different ways to better fit in their school context that was related to but not limited to students' learning abilities. In this section, we attempted to identify some commonalities and differences in the following dimensions: the way they structure the activities and they adapt the curriculum, how they facilitate the inquiry, and how they integrate technology in learning activities.

- 5E to Structure the Activities with Differing Details

The teachers are familiar with the 5E framework for lesson design but only some teachers used it for their lesson plan before the IBSL curriculum. From our analysis, we found that teachers mostly followed the structures and sequences of the activities. Taking "Exploring Materials" for example, the teachers all started with a story to engage students and to introduce different types of materials. To further investigate the topic, the teachers designed experiments for students to explore the properties of different materials, after which, students' acquired knowledge was applied to solve a design activity of boat making, and explained their choices of different materials for each part of a boat. Despite the similarities on the structure and flow, there were differences in the details of substantiation of each stage. For instance, in the "engage" stage, Amber created a story that a mouse family had to build a raft to escape from an island because of a volcano eruption, and she asked students to think about the materials that the daddy mouse needed to build the raft, and the material that the mummy mouse needed to pack the food in and so on. According to Amber, the Cinderella story (the original story telling designed for engagement) would "bored the students since they were very familiar with it", so she needed to "think very hard to draft a story that make them excited" (quotations from Amber in the post-observation discussion). We also observed the differences in students' autonomy in learning that was resulted from the teachers' activity design, especially in the experiment. In the experiment of investigating a specific property of different materials, Joanna distributed worksheets to students where steps of the experiment and the structures of reporting observations and findings were stated clearly; whereas Rohana gave more freedom to students with regards to the design and execution after she elaborated the purposes and objectives of the experiments, and she walked around the classroom to ask scaffolding

questions and guided students' thinking. The difference in the level of students' autonomy might result from teachers' perceptions on students' ability, since the students were in the P3 level and just started to learn science, so some teachers took more control during lessons because they were afraid students would not know what to do if they were given too much freedom.

In summary, we differentiate the levels in terms of the ways that teachers adapt the co-designed curriculum package as seen in Table 3. We matched teacher's current way of curriculum adaption with the level of use as described in the literature. The teachers in our case did not reach the higher level due to limited exposure to the innovation but we believe they would move to the higher level when they have more experiences.

Table 3. *Different levels of adaptations to the co-designed curriculum package*

Level	Ways of Adaptation to the Curriculum Package
High-Integration and Evolution	Take more ownership in curriculum development and evolve the curriculum package by integrating other available innovative resources available.
Medium-Refinement	Customize the curriculum package according to students' learning ability, and schools' resources.
Low-Mechanical Use	Follow the original lesson plan without pondering the rationale of the design and internalizing the curriculum package for own use.

- Varied Pedagogical Orientation and Facilitation Skills

It is the teacher's pedagogy that substantiates the curriculum design or structure of the innovation. The curriculum was arranged as inquiry-oriented, but teachers might implement it not in a constructivist-oriented way. From our lesson observations, we tentatively categorized the teachers in different types. However, we believe that the pedagogical orientation could be changed through the process when more student-centered activities were experienced.

Amber, Joanna and Rohana had comparatively more teaching experiences, and we did find that they were inclined to apply more constructivist oriented pedagogical approaches. For example, we identified a similar characteristic in Ambar and Joanna in that when getting wrong answers from their students they probed their thinking through clarifying questions like "Why do you think so?" or "It's interesting. Tell me why you say so" rather than ignoring or directly correcting them. We also observed another valuable pedagogical strategy that Joanna applied to foster students thinking: generating arguments. She questioned students a lot when getting into a concept and if she found there were two contrasting or different opinions got from students, she rephrased the contrasting viewpoints and asked the class to vote and argued about it. Rohana highly emphasized the spirit and skills of inquiry, so she intended to explicitly address the inquiry thinking skills. It is also worth mentioning that Rohana highlighted the ideas of fair test and inquiry spirit to students for every experiment, either by demonstrations done by the teacher or the students.

Ian and Anna had fewer years of teaching experiences, and we found that they were inclined to apply goal-driven oriented pedagogical approaches. In the first few lessons, we found that Ian tended to ask factual knowledge questions and "polling questions". For example, he asked a lot of questions on the use of scientific terms, such as "long-lasting means what? What is the term for this property?" The "polling question" refers to the questions where he asked the class to vote for the two different answers obtained from two students, and if more students voted for the correct one, he proceeded to the next activity. At the same time, we found he seldom responded to the wrong answers from Socrative (©2014 Socrative.com), which is a tool embedding the use of real time questioning, instant result aggregation and visualization for students' ideas sharing. Anna has a class with mixed ability, so in her class, she spent quite an amount of time to let students spell the term and correct their spelling. At the same time, she also saved time to "drill" students about the

answering skills for open ended questions, which were required by the exam papers. In her lesson, she tended to give much more guidance and provided varied thinking routines to students considering their learning ability. So from the observation, we identified her as applying more goal-oriented pedagogical approaches.

- Use of Technology for Different Purposes at Different Levels

Use of the mobile devises with 24/7 access to internet is another critical feature of the IBSL. The teachers haven't used MyDesk platform by the time we analysed the data, so in this report we only discussed use of other applications supported by the mobile device and internet access. From analysis of the lessons, we found that the most frequently used technology-afforded activities included: students using Google to search information; Socrative for teachers posing questions and the class responded; teachers running videos for demonstration and explaining concepts. When integrating technology into lesson designs, it is not the frequency of using certain tools, but how the activity was designed (i.e., what is the task, how teachers feedback to students' artifact, what is the follow-up activity) that really matters. We proposed different levels of ways of teachers' integration of technology in lessons (see Table 4), and identified the instances of using technology for the four classes into different levels, as seen in Figure 6. As long as the activity involved the use of the mobile devices, we considered it as one instance.

Table 3. *Different levels of integration of technology in lessons enactment*

Level	**Google for information searching**	**Socrative as formative assessment**	**Video playing for demonstration**
Level 1	The task involves students in lower cognitive level activities like retrieving information; teacher checks up the search result but not follow up.	The questions require only factual knowledge; the teacher only selects right answers without identifying and addressing misconceptions.	The video serves purposes of information delivery, but the teacher doesn't cautiously choose the video (i.e. misconceptions maybe caused by the video).
Level 2	The task involves students in activities like interpreting, comparing, and summarizing; teacher follow-up and foster meaningful discussion on the search result.	The question requires students explaining, or applying knowledge and the teacher synthesizes students' responses and correcting students' wrong answers.	The video was engaging and informative, and the teacher uses it to reinforce students' understanding.
Level 3	The task involves critiquing and creating. The teacher facilitates students to collaborate and argument in the search activity	The question requires students explaining, or applying knowledge and the teacher synthesizes students' responses and identified valuable teaching points from students' misconceptions for class discussion.	The video was engaging and informative, and the teacher develops a lesson from the content covered in the video.

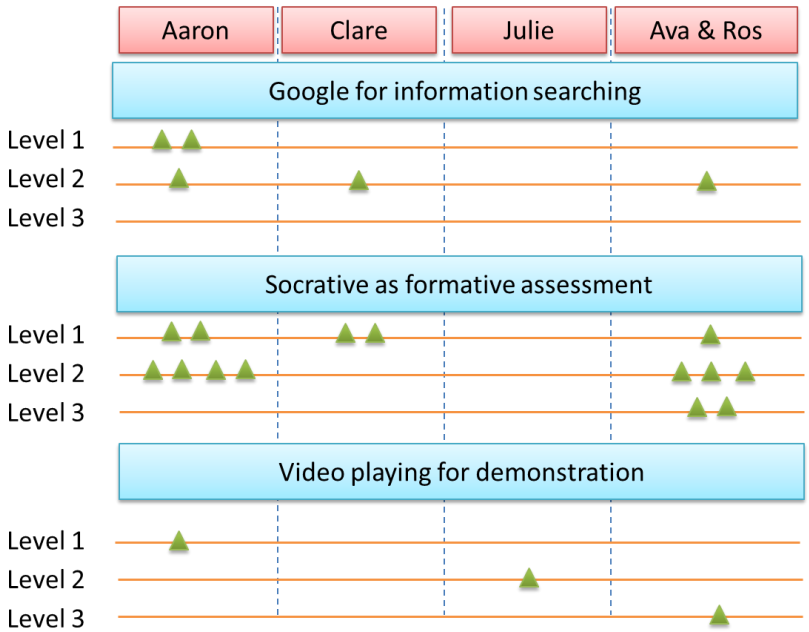

Figure 6. Teachers' differentiation in integration of technology in teaching

As we can observe from Figure 6, Ian, Amber and Rohana used technology more frequently. Anna paced the syllabus much faster than the other three schools, so the lessons we were able to observe were mostly the review of content knowledge, and it explained the quantity of the technology integration in lessons. According to our conversations with Anna, we found that besides the three ways analysed, she also used Edmodo (https://www.edmodo.com/) for students to work in groups to discuss and collaborate. For Joanna, she was not willing to start to use the mobile devices until the MyDesk was ready, so there was little use of technology observed. Besides the three ways, Amber and Rohana also asked students to use their mobile devices to collect data (picture taking or video recording). The data collected was usually shared within the class for further discussion. They also explored to use Lionit (http://en.linoit.com/) for simultaneous collaboration and ideas sharing.

We observed improvements in Ian's use of technology as lessons moved on. In the first few lessons, the design of technology use was not targeted and illy organized or followed-up. But we observed better designs, i.e., more meaningful questions set in Socrative, and more feedback was given to students' answers. Same patterns were evidenced in Amber and Rohana's class. Not only the frequency, but also the quality and variety of use of technology was observed.

As a summary, we found that teachers enacted the innovation in differing ways. We found that while following the main structure and flow of the curriculum package, they adapted and detailed the curriculum in different ways. In instantiating the lesson package, teachers applied pedagogical approaches, and we identified teachers having different pedagogical orientations. Some teachers were more skilful on questioning and facilitating, while others were learning to improve their strategies to probe students' deeper conceptual understanding. When integrating the technology into lessons, teachers designed tasks and conducted differently. Despite of the differences, we witnessed the progress in some teachers, and understood their challenges.

From ongoing conversations with teachers and our observations of their lessons, we identified some factors that influenced their practices and determined the differences: teachers' content knowledge or their confidence in their content knowledge; teachers' beliefs in teaching and learning, as well as their beliefs in technology for learning; teachers' perceptions in students' learning ability; systematic supports from the school leadership. For example, Ian was very dedicated and held positive attitudes towards the innovation, however, he was not very confident about his science knowledge, so in the lesson he might choose not to probe deeper for

understanding of certain concepts. Initially his teaching was quite goal-driven, and he would only acknowledged the correct answers, but later we found he also appreciated some wrong answers from students and tried to probe their thinking by asking why, so we thought he might change on belief in learning. We also found teacher's beliefs in use of technology in learning made a difference in their implementations. Joanna had 13 years of teaching experiences and most of the classes she taught were higher level, so she was quite conscious about the learning objectives she must achieve, so she paced the class to achieve the goals smoothly. When teaching the class, we found she was quite willing to interacting with students and probe students' thinking, so we deemed her strategies as more constructivist oriented. However, she was not willing to use the mobile devices till MyDesk was ready because according to her experiences the technology would introduce too many technical problems, which was similar to most of the teachers in Singapore.

Nevertheless, we had compelling examples from the other school of Amber and Rohana. Initially the use of mobile device did introduce some technical issues, but as the lessons went on, we found students were quite comfortable using the mobile devices and could trouble-shoot the problems skillfully. The teachers were also very skilful and confident using the technology. The difference between Joanna, Amber and Rohana was not only due to their personal beliefs in use of technology, but also to the systemic supports from their schools. In Amber and Rohana's school, the principal was very supportive and sent the whole level science teachers to the deeding school for learning of the IBSL and the teachers went back school forming a within-school community for implementation reflection and lesson design. Each lesson was peer observed and supported, at the same time they had a teaching assistant attending to the technical issues faced up in the classroom. Contrast to the strong supports in Amber and Rohana's school, some teachers in our study received quite limited supports from the leadership and within-school peers, for example Cherry from school B. Besides these factors, we also found teachers' perceptions of students' learning ability played a role in explaining teachers' pedagogical approaches. In Anna's class, she saw students as middle ability so she "controlled" the openness of the lessons and provided a lot of guidance comparing to other teachers.

IMPLICATION TO POLICY MAKERS

To scale up a researcher-driven intervention in Singapore education system, this study proposed a model of scaling with seeding effect, including the process of infusion, dissemination and evolution. In this model, an early adopter school took the leadership in spreading the innovation to more schools, with intensive efforts spent on seeded teachers' capacity building and establishment of systematic supporting structure. The model is a combination of ground-up and top-down strategies, aiming to produce sustainable and scalable change in school contexts.

IMPACT TO SCHOOLS

We found that a successful diffusion of the innovation in school was influenced by multiple factors. The schools may assess their level of use of an innovation and examine the attributes from the factors we proposed. It is suggested to the schools that the following dimensions should be attained when deciding to adopt an innovation: 1) Understanding the innovation thoroughly, and making sure the school learning culture is aligned with the one that the innovation designers advocate; 2) Understanding that the school leaders need to establish systemic supporting structure for diffusion of an innovation; 3) Establishing an effective teacher professional learning community for sustainable and scalable use of the innovation; and 4)selecting the teachers with more teaching experiences and who are more competent in inquiry-based teaching to lead the project.

CONCLUSION

Generally, the study has achieved the research objectives of the project. First, through comparison and synthesis, we summarized the facilitating or limiting factors within a school system that may influence the process of the infusion, dissemination, and evolution of an innovation. These

contextual factors include, but not limited to, school's characteristics in curriculum and assessment, school culture in learning and teaching, demographic, school leaders' perception of the innovation (its effectiveness, feasibility, compatibility, trialability in the school context), their level of commitment, their ability in prevision and problem solving, school's PLC organizational structure and culture in PLC, teachers' perceptions, their teaching experiences and competency in inquiry-based teaching, their belief in technology in learning, and their social capital, supports from meso-level etc. We assessed the readiness of the five participating schools through examining them using the framework.

Secondly, from classroom observations and interviews with teachers, we examined the process of how the innovation got infused, implemented and disseminated in schools. Specifically, we reported the commonalities and differences in the three dimensions: their adaptations of the co-designed curriculum, their pedagogical practices, and the use of technology. We found that while following the main structure and flow of the curriculum package, they adapted and detailed the curriculum in different ways. In instantiating the lesson package, teachers applied pedagogical approaches, and we identified teachers having different pedagogical orientations. Some teachers were more skillful on questioning and facilitating, while others were learning to improve their strategies to probe students' deeper conceptual understanding. When integrating the technology into lessons, teachers designed tasks and conducted differently.

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APPENDIX A

Pre-Survey for Teachers

Dear teachers:

You have been participating in the IBSL project for almost two years, starting from observation of Jenny's lessons and continuous lesson co- design sessions, to bringing it to practices in your own school. This survey is to help us understand your current understanding of the mobile seamless learning (MSL), your degree of buy-in of MSL after the implementation, as well as your reflection upon the curriculum and instruction, and your future plan.

Your survey responses will be kept confidential, and when reporting, only fictitious names will be used. Thank you very much for your cooperation.

1. Teacher name:
2. How do you perceive the innovation that you have implemented for this year? Describe in your own words the essence of the MSL innovation.
3. How would you put your degree of buy-in of the MSL now, on a scale from 1 to 10?
4. Researchers defined compatibility as the extent to which an innovation fits with the norms, beliefs, and past practices that characterize those persons who adopt it. If there's a scale of 1 to 10, how would you put the degree of the compatibility of MSL with you? Why?
5. How do you perceive of the feasibility of customizing/adapting the MSL for your school? How would you put it on a scale from 1 to 10? Why?
6. What are the conditions that you think can help your school to sustain and scale up the MSL innovation even when the extensive supports from the project were withdrawn? Rank the conditions with "1" indicating the most important one.
    a. My principal/Vice principal has to agree to extend the innovation to other cohort/classes
    b. Parents of students request for adopting the MSL approach.
    c. My HoD IT/Science has to agree to use MSL for other cohorts/classes.
    d. I am willing to use the innovative pedagogy as my routine teaching practice.
    e. I am confident myself so that I can help other colleagues in my school.
    f. The school principal/VP have to give us good appraisal even student grade does not go higher.
    g. I can seek advice from the across-schools teachers' community of MSL.
    h. The vendor has to provide continual technical supports.
7. How do you characterize your current pedagogical approaches?
    a. Teacher-centered
    b. Somewhat teacher-centered
    c. Somewhat student-centered
    d. Student-centered
8. What was the biggest challenge to you for implementing the MSL in your classroom?
9. What do you think are the most valuable learning experiences for your implementation? Choose 3 that you think are more valuable from the following options.

a. Observation of Jane's lessons
b. Lesson co-design sessions
c. Post-observation discussions
d. PD sessions conducted in 2014 (on questioning and ICT-integration)
e. Others (Please specify)

10. What do you want to achieve at the end of the next round of implementation?
11. Does your school have specific plans with regards to adopting or adapting the innovation? Please elaborate.

APPENDIX B

Post-Interview for Teachers

Part 1 Curriculum and teaching (learning from NCPS and adaptions plan)

Expectation and objective	What are some of your goals in terms of students' improvement (e.g. attitudes, conceptual understanding of content)? • Do you think you have achieved your goals in terms of students' improvement? Why/ why not? (refer to their pre-survey) • How do you communicate and reinforce your expectations for your pupils regarding the learning of science? • Are any of these expectations related to thinking like scientists?
Curriculum adaptation	How do you adapt the co-designed lesson materials for implementation? • What are some of your concerns/ considerations when adapting the lesson plans and resources? • What are some resources you refer to when refining/ adapting the co-designed lesson plans? • Did you use anything you learnt from the post-observation discussions or lesson co-design sessions in adapting the lesson materials, as well as in teaching?
Scientific inquiry	Can you give an example of how you engaged pupils in scientific inquiry? • How regularly do you plan structured inquiry activities for your pupils? • What are some things that you consider when planning a structured inquiry activity?
Collaboration	Can you give an example of how you designed for collaboration in the classroom? • Do you define roles for group members? What sort of roles do you use? • How do you teach pupils to negotiate differences? • Do you teach your pupils strategies/ routines to facilitate reflection, group discussions etc.?

Part 2 Perception of the innovation, buy-in and future plans

Change in perception	What is your most significant change from participating in this project? [Comparison with previous, elaboration for current,] • How about your own professional development? • E.g. perception, belief in technology in teaching, pedagogy (activities in class, questioning etc.) • What is your current understanding of inquiry-based (mobile) seamless learning? • What was it like before the change?

	• How did the change come about? What made the change happen? • What difference does the change make? • What are the lessons learnt? What was successful/ unsuccessful? • What suggestions/ recommendations can you make?
Compatibility	Researchers define compatibility as the extent to which an innovation fits with the norms, beliefs, and past practices that characterize those persons who adopt it. If there's a scale of 1 to 10, how would you put the degree of the compatibility of MSL with you? [Probe using the survey answers, and follow up on interesting responses]
Feasibility	How feasible is it for you to customize/adapt inquiry-based seamless learning for your school?
Contextual factor, refer to the survey question	Follow up for elaboration in FGD if necessary. In the survey, you identified the most important conditions that affect scaling an innovation as _____. Why do you think these are the most important factors?
Buy-in Scale	How would you put your degree of buy-in now, on a scale from 1 to 10? Why?
Innovation adoption	Previous studies have described different level of use for an innovation as level 0 to VI (present the chart to the interviewee, as seen from the annex) (G. E. Hall et al., 1975) . Which level do you think you are at for the time being? Why do you say so? [Probe using the survey answers, and follow up on interesting responses]. In the survey, you rated yourself as being at level ___ for use of an innovation. Why do you rate yourself at this level?
Future plans	What do you want to achieve at the end of the next round of implementation? Does your school have specific plans regarding adopting or adapting the innovation?