Teachers' prefection in early stages of diffusion of an innovation

Longkai Wu · Xiaoxuan Ye · Chee-Kit Looi

Received: 6 August 2014 / Revised: 19 November 2014 / Accepted: 26 November 2014 /
Published online: 10 December 2014
© Beijing Normal University 2014

Abstract Teachers play an important role in the process of diffusion of an innovation. In our endeavour to achieve the diffusion of a curricular innovation from one seeding school to five other schools, we have investigated the learning of a group of teachers through an across-schools collaborative seeding journey. A pre-reflective learning model for teachers is proposed with the aim to prepare seeded teachers in reflection-for-action and to build their capacities in designing and enacting the curriculum. In this paper, we describe this model and explore its effectiveness, especially with regards to teachers' perception towards the innovation and their buy-in. We found that the seeded teachers from the five schools, regardless of their own teaching profiles and school contexts, have obtained high degrees of buy-in of the innovation and developed their readiness towards implementation for the next phase. It is envisioned that such a learning model will inform the design for teacher professional development and achieve innovation diffusion to create a wider community of teacher practice.

Keywords Preflective learning · Buy-in · Perception · Mobile seamless learning · Diffusion of innovation

Introduction

The essential role of teachers in implementing innovative pedagogical practices, particularly those adopting inquiry-based learning has been widely recognized by researchers and educators (Krajcik et al. 2008; Urhahne et al. 2010). At the same time, the characteristics of teachers, together with the characteristics of the

L. Wu (✉) · X. Ye · C.-K. Looi
Office of Educational Research, National Institute of Education, Nanyang Technological University,
1 Nanyang Walk, Singapore 637616, Singapore
e-mail: longkai.wu@nie.edu.sg

innovation and features of environmental context, account for the outcome of diffusion of an innovation (Rogers 2003).

The innovation to be spread in this study is mobile seamless learning (MSL) which refers to the synergistic integration of the learning experiences across various dimensions such as formal and informal learning contexts, individual and social learning, and physical world and cyberspace (Chan et al. 2006). This kind of learning leverages the affordances of mobile technologies, and involves the transformation of the existing primary science curriculum into an inquiry-based one (Chan et al. 2006; Wong and Looi 2011). The experimentation of the innovation has been into its sixth year since it was first introduced to one primary school (school N, hereafter) in Singapore in 2009. Because of the positive outcomes of the innovation, the school intended to collaborate with five other schools in its school cluster to scale it up to the different contexts of another five schools. The MSL was “seeded” in the five schools, and probably spread to even more schools. In this regard, we perceive the N school as the seeding school, and the five schools as the seeded schools.

Teachers need to understand an innovation and “reduce uncertainty about the advantages and disadvantages of an innovation.” This pertains to an innovation–decision process which involves five steps: (1) knowledge, (2) persuasion, (3) decision, (4) implementation, and (5) confirmation (Rogers 2003). In the context of diffusing MSL to more schools, teachers in the five schools need to learn about the existence of MSL and seek information about the innovation in the “knowledge” stage, shape their attitudes in the “persuasion stage”, and choose to adopt or reject the innovation at the “decision stage”. If they choose to adopt the innovation, they put the innovation into practice in the “implementation” stage and look for support for their decisions in the “confirmation” stage. 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 2012).

Teachers, undeniably, play a critical role in the process. In these different steps of the innovation–decision process, teachers would have different experiences and evolve their own understanding of the innovation. Our project aims to study the process of how the ideas of MSL are spread to the five schools, focusing teachers’ learning at a micro-level, and especially from the perspective of professional development. In 2013, we worked with a teacher in N school, who is regarded as an early adopter teacher (EAT) of the innovation, to provide teachers from other five schools, which we call seeded teachers (STs), with learning opportunities to gain knowledge of MSL and to develop their capacity for future implementation. We interpret what we did in 2013 as the first three stages in the innovation–decision process: knowledge–persuasion–decision. The innovation was implemented in the five schools in the subsequent year (that is, 2014), and we observed whether and how these STs translate their learning experiences in N school back to their own schools thereby diffusing the innovation, which is the process of implementation–confirmation.

In this paper, we focus to report the early stages of the process wherein the seeded teachers acquired knowledge about the MSL and formed their perceptions. We first introduce the context of the innovation diffusion, and then propose a model of teacher's prereflective learning where different stages and types of activities were designed for the STs' comprehensive understanding of the innovation. Different parties, including the school leaders of school N, the EAT, school leaders and teachers from the five schools, and researchers, as well as officers from Ministry of Education (MOE) were engaged in the learning journey. By examining the learning process and STs' perceptions and buy-in of the innovation, we want to explore the effectiveness and mechanism of such a model.

Theoretical background

From the growing body of research studying the process of adoption of educational technology innovation, we know that teachers play a pivotal role in making the decision of adoption or rejection, and in the implementation of curriculum (Akker 2003; Chee and Mehrotra 2012). Rogers (2003) outlined five attributes, which were the perceived characteristics of an innovation: relative advantage, compatibility, complexity, trialability and observability. It was suggested that the first three account for considerable variance in explaining the adoption decision. A lot of studies examined teacher's adoption of an innovation by relating to their perceptions on these five attributes. For example, Mustafa and Al-Mothana (2013) explored the teachers' perceptions of the five attributes after their use of the interactive white board, and they found that the teachers all held positive attitudes towards the innovation, and their perceptions of the five attributes accounted for their decision of adoption. Freeman (2012) also examined the five attributes and found that besides the attribute of relative advantage, a crucial factor affecting adoption of team-based learning (TBL) was its compatibility with the would-be adopter's teaching approach and with the dominant organizational culture. This finding aligns well with Dearing's notion of guided adaptation (Dearing 2009; Dearing et al. 2013) which highlights the advice provided to implementers so that their changes to a program or practice can demonstrate positive rather than negative outcomes. In a quantitative study conducted by Vanderlinde and van Braak (2011) to measure teachers' perceptions of an ICT-related curriculum innovation, it was found that teachers' ICT competency and schools' ICT vision and policy were important predictors of their perceptions of innovation. The study also implied the importance of providing teachers with ICT professional development training on not only how to use the tools but also how to incorporate those tools for enhanced learning outcomes. Thus, it is important to provide teachers with experiences to know more about those attributes of an innovation and thereafter to make the decision on whether or not to adopt the innovation. Another group of researchers proposed and refined the Concern Based Adoption Model (CBAM) to study the adoption of an educational innovation (Hall et al. 1975; Hord et al. 1987; Newhouse 2001). The CBAM model comprises three dimensions, namely, stages of concern, levels of use, and innovation configuration. The stage of concern describes how teachers perceive

an innovation and their feelings about it, while the levels of use describe the implementers' usage, and innovation configuration focuses on the characteristics of the innovation itself. The model was mostly used to structure instruments to measure teachers' adoption and implementation of an innovation.

Professional learning opportunities for teachers at the early stages of innovation diffusion serve the purpose of helping teachers obtain knowledge about the innovation, form attitudes toward the innovation, and make the decision of adoption. Rogers (2003) summarized three types of knowledge that needed to be conveyed to individuals who wanted to adopt an innovation: awareness–knowledge, how-to knowledge, and principles knowledge. Awareness–knowledge represents the knowledge of the innovation's existence; how-to-knowledge contains information on how to use an innovation correctly; and principles knowledge includes the functioning principles describing how and why an innovation works. 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 et al. 1999). In much of the literature, teachers' learning community and network building were highlighted (Scribner et al. 1999; Sun et al. 2013). In the context of diffusion of innovation, Dearing et al. (2011) proposed the idea of an "implementation registry" in the domain of healthcare, which was an online resource for practitioners within or across different institutions for sharing knowledge about solutions to challenges during dissemination, diffusion and implementation of an innovation. The idea of sharing success and challenges from practices would also benefit teachers when they are about to adopt an innovation. Through the sharing platform, they could learn from pioneers or colleagues who are also implementing the innovation and exchange their thoughts.

Teachers are encouraged to be more reflective when participating in professional development. In the early stages of innovation diffusion, teachers gain knowledge of the innovation and synthesize information that helps them make decision and plan for possible adaption. At these stages, the reflections are for their later implementation/actions, which is called *preflection* as defined by Jones and Bjelland (2004). *Preflection* is reflection-for-action as contrasted with reflection-in-action and reflection-on-action (Makinster et al. 2006) that guides future action based on past thoughts and actions. Learners who are involved in facilitated *preflection* will be able to utilize the process of reflection upon concrete learning experiences in a greater degree than those who are not involved in *preflection*. The *preflection* would increase the readiness capacity of the learners to learn from the concrete experiences, hence increase their capacity to reflect upon the experiences and the overall learning. Jones and Bjelland (2004) took the internship in agriculture as an example and proposed a model of *preflection*, where the learners achieved enhanced learning through the iterative process of reflective observation, concrete experience, active experimentation and abstract conceptualization.

Prompts are essential instructional methods for guiding key processes of self-regulated learning (Bannert 2009). Prompts, in the form of static questions,

incomplete sentences, execution instructions, or pictures, graphics and other forms of multimedia, can be used as scaffolding to guide the learning process offering both cognitive and metacognitive support to students (Bannert 2009; Ifenthaler and Lehmann 2012). From an instructional perspective, prompts for reflection could be appropriated before, during and after the learning process. The prompts before the learning task facilitates the planning of required learning procedures, whereas prompting during and after the learning process helps the learner to monitor and evaluate complex learning events. Preflection prompts have been a strategy designed as a tool to enhance and enrich the reflection process (Falk 1995), which involves posing questions to learners before a learning experience to help them develop a frame of reference through which they will be engaged. Looi and Wu (2015) suggested three types of reflection and preflection prompts in the context of intelligent learning environment and further incorporated these prompts into a learning-through-teaching process. Four stages of the reflective learning process were identified: familiarization, production, evaluation and post-task reflection. In the first stage, prompt like “can you read the learning objectives to identify the important parts?” was used for learner’s understanding and planning. This kind of prompt could also be designed in teacher’s learning activities to promote their reflection and consequently promote their teaching practices.

In summary, we highlighted the importance of teacher’s perceptions of an innovation and the need for professional learning for teachers who want to adopt the innovation. Teachers were encouraged to form a community of practices, especially amongst members with different attitudes to innovations, and to be participative, collaborative and especially reflective in their professional learning experiences. In diffusion of innovation, it is especially important for teachers to be preflective in the “knowledge” stage. When the learning before the implementation is more targeted, more appropriate expectations and planning would be established.

Context

The MSL regards learning as being distributed across different learning processes (emergent or planned) as well as across different spaces (in or out of class). Students are assigned a mobile device with internet 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 neighborhood, home-based experiments involving parents, online information search and peer discussions, and digital student artifact creation, among others. To facilitate MSL, the 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 (e.g. KWL for students’ reflection, Sketchbook for drawing, MapIT for constructing concept map). Students’ assignments and artifacts can be easily accessed and evaluated by the teacher for immediate feedback and comments.

Fig. 1 Overview of the activities that incorporate 5E model for “Fungi and bacteria”

To design such lessons, the 5E instructional model (Bybee 2009) was used to involve students in a learning cycle of engagement, exploration, explanation, elaboration and evaluation. In Engagement, teachers access the learners' prior knowledge and help them become engaged in a new concept through the use of short activities, and in exploration, students are provided with a common base of activities within which current concepts (i.e. misconceptions), processes, and skills are identified and conceptual change is facilitated. The explanation phase focuses students' attention on a particular aspect of their engagement and exploration experiences and provides opportunities to demonstrate their conceptual understanding, process skills, or behaviors. Teachers then challenge and extend students' conceptual understanding and skills in elaboration stage, and evaluate student progress toward achieving the educational objectives in evaluation stage.

Figure 1 demonstrates a topic of "Fungi and bacteria". With the technology, students are able to collect multimodal data, i.e. text format afforded by the "Notepad" application for students to write observation notes, graphical format afforded by the camera function for students to take photos of the fungi growing on the bread, audio format supported by the recorder function to record their questions and exciting moments, and animation format enabled by the "Sketchbook" application for students to compile the research data through days of the investigation and show the progress of the growth of bread mold. The multiple modalities of data would help students to make sense of the topic through diverse angles, and teachers are also able to monitor, assess and provide feedback to their learning timely. The innovative curriculum also features the connection between learning in and out of classroom which is afforded by the mobile technology. For example, due to the time constraints, the experiment that investigates the growth of bread mold could not be done during school time, so teachers could instruct the students to conduct experiment and collect at home using their mobile devices. Hence, more meaningful discussions could be done during the class time.

MSL was first introduced to school N in 2008. It was implemented in 2009 by one teacher involving a class of grade level 3 (P3) students. In 2010, one more teacher joined the intervention, and two classes in P4 were involved. Because MSL demonstrated increased student achievement, the school scaled-up the rolled-out of the innovative curriculum to all the eight P3 classes within the school in 2012, and all P3 and P4 classes in 2013. In the year of 2013, the school (in its role as a Centre of Excellence for IT in Education in the North Zone cluster of schools) decided to collaborate with other schools in the cluster to explore the scale-up of the innovation, and in particular, the enactment of innovative curriculum from the context of one school to a group of five schools. N school teachers and researchers designed activities for the five schools teachers in 2013. The innovation package will be implemented in 2014 starting from February, when the mobile devices are supplied to the schools. Each school will choose one experimental class, and provide its own technical support. N school will provide training sessions for teaching assistants and technicians from the five schools, and researchers also plan to share ideas of innovation diffusion and curriculum development with the school leaders and teachers.

Model of teachers' preflexive learning

Building on the lessons learned from prior technology-based educational improvement research, we clearly recognize the importance of empowering teachers and building capacity to effect deeper changes in teachers' beliefs, knowledge, and practices (Fishman 2005). We expect teachers to be reflective in the learning experiences we provided for them, associate the learning experiences with and prepare for their future actions, which is preflexion (Jones and Bjelland 2004) in the context of diffusion of innovation.

There are several design principles we put forward for the professional development sessions across the learning journey: (1) Sharing of the EATs to the 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' preflexive learning is proposed as shown in Fig. 2. It consists of four types of activities, as well as the preflexion 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.

The impact of MSL was not only demonstrated on students' improvement in examinations, but also in teachers' pedagogical practices and students' classroom performance. So in the "lesson observation" activity, the STs have opportunities to observe a real classroom to make sense of how the teaching and learning looks like. Starting from February and lasted for half a year, 12 lesson observations were held fortnightly with a focus on demonstrating the STs how students learnt collaboratively, especially with use of their mobile devices, and how the EAT Jane taught/facilitated students' inquiry learning. The school administrators from each school also observed a few lessons to have a sense of what their own students might be experiencing.

The lesson co-design activity aims to develop lesson packages that the STs could later adjust or adapt according to their students' needs. The co-design of educational innovations often involves different stakeholders, such as teachers (practitioner), researchers or innovation developers, and national educational policy maker in some of the research in Singapore context (Wong et al. 2011; Ye et al. 2010). In this

Fig. 2 Model of teacher's preflective learning with preflection prompts in diffusion of innovation

study, the co-design sessions involved the EAT, the STs, researchers, as well as MOE officers forming a teacher professional learning community. After each lesson observation, the STs had 1-h session with Jane to co-design lessons for the topic themes of Primary three, and there were nine sessions of co-design in total from March to October. Teachers followed the 5E structure and brainstormed activities, with special considerations of how to leverage the affordance of technology. At the end of each session, the STs from respective school volunteered to spell out the detailed lesson plans of specific period, and uploaded it to the Google sites of the community for sharing.

In the “Elaboration of Implementation” session, school N proposed the project execution plans, and the seeded schools expressed their concerns regarding adopting the innovation. Each school had two Q & A sessions with school N, one in the starting and the other one in a later phase after the five schools gained more understanding about the innovation from lesson observation and co-design sessions. Not only the STs, but also school leaders joined the session, so the discussions on adoption and adaption were from a more holistic viewpoint. It is not only an opportunity for interactions between the seeded schools and school N, but also for mutual understanding within the seeded schools, that is, between school leaders as decision makers/support providers and teachers as practitioners. The prefection prompts were provided in the form of explicit questions in these activities. For example, in the discussions after the lesson observation, teachers were asked to address these questions in order to reflect upon their observations. In the lesson co-design sessions, the prompts were interwoven with the design activities. They were asked on how they conducted the topic previously and how would the change in curriculum design affect teaching and learning.

Method

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). Most of them thought that they taught in a teacher-centered way, which was focusing more on knowledge delivery while students passively receiving knowledge.

We also have the EAT Jane from school N, who has been working on the project of MSL since the year of 2009. She has about 6 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.

Data analysis

Various sources of data were collected, including surveys, interviews, teachers' lesson design artifacts, and field notes and audio-recordings of the lesson co-design sessions, and the elaboration of implementation session.

The survey for STs was designed and distributed online when the learning activities at school N was about to end. The purpose was to understand teachers' previous teaching practices, help STs reflect on their half-year learning experiences in school N, and elaborate their plans for implementation. We chose three out of five schools to conduct the interviews in the form of group discussion. The STs with higher participation level in the learning activities were chosen for us to get better understanding of their perceptions and plans. The interview questions mainly consisted of what was learnt from the learning experiences and how the learning activities helped them achieve those understanding and inform their future implementation plan. Two researchers conducted the interview and the audio-recordings were transcribed for further analysis. Besides STs, we also interviewed Jane for her insights about the innovation, and her views on the teacher's preflexive learning model for STs' understanding and professional development, as well as for her own development as a science teacher and as a change agent for the innovation. One researcher took field note of the lesson co-design and elaboration of implementation sessions, with focus on: (1) sequence of discussed topics (2) critical issues that were raised in those sessions (e.g. concerns raised by one teacher, solution suggested by the EAT). STs' lesson design artifacts were compiled and extracted from the Google sites for analysis.

The purpose of the analysis was to find out how teachers perceive the innovation, how the preflexive learning model help the STs form their perceptions, and how these inform their future actions. At the end of the first three stages of diffusion of innovation, teachers should have gained knowledge of the innovation and made decision to adopt the innovation, so we see their perception of the innovation, degree of buy-in and plan of implementation as the product of the preflexion, and the professional development sessions, including the four learning activities in the preflexion model, as the process leading to the product. Firstly, teachers' responses to the survey question "How do you perceive the innovation? Describe in your own words the essence of the innovation" were examined, together with their elaborations in the interview. Their responses in the survey were analyzed and categorized into a few elements. For example, Amber answered "It is a 1-1 mobile technology that enables students to be self-directed learners both in and out of the classroom". From this answer, we abstracted three elements that Amber perceived as the essence of the MSL: use of mobile technology, foster self-directed learning, and connect formal and informal learning.

We analyzed all the 12 teachers' responses, and further triangulated their meanings by examining their elaborations during the interview, and counted the frequency of the elements to demonstrate teachers' overall perception of MSL. We compared these elements with the key features and design principles which were put forward by the innovation developer, as well as the EAT's perception of the innovation. If these elements are coherent, we regard the ideas of the innovation

were well diffused to the STs. Secondly, Content analysis was applied to analyze the transcripts of interviews and the field notes of the lesson co-design and elaboration of implementation sessions, with attention to find out how the learning activities helped teachers form the perceptions, and lead to their plans of implementation. When reading through the interview transcripts and field notes, we first categorized them into teachers' learning from infusion, from lesson observation, from lesson co-design and about Q & A. Then we looked into the content to obtain the macro proposition (i.e., general ideas that are conveyed in sections of discourse) (Kintsch and Van Dijk 1978), and linked them to teachers' perception and planned actions.

Findings

We divided this section to the following parts: we first described how each learning activity impacted teachers and the connection to their perceptions, and then discussed the end product, namely, STs' understanding of the MSL, and the degree of buy-in.

The infusion: "Wow, It's Impressive!"

All the stakeholders involved in the diffusion process were present in the infusion session, including the school leaders and teachers of school N, all the school leaders and teachers of the five schools, researchers from the university, and the MOE officers. After a few years of research implementation, N school has gained experiences in designing and enacting the innovative curriculum, and the students not only demonstrated significant improvement in content test, but also were found to learn science in personal, deep and engaging ways as well as developed positive attitudes towards mobile learning and science learning (Looi et al. 2011, 2014). Students' improvement in answering open-ended questions was most impressive 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.

Oftentimes we heard from teachers that when taking up an innovative curriculum package, they were concerned about the tensions between teaching in an innovative way and spending extra time covering the same content (Stylianidou et al. 2005). Awareness was brought to the STs that school N has made the innovation a routine practice in school but at the same time did not compromise the students' academic achievement, and even so gained significant improvement. Thus STs became more

convinced to try out the package. The infusion session also helped Wilson set the expectation for his students. As he expressed in the survey, at the end of the implementation, he expected his students “to use the technology effectively” and “to be more able to answer open-ended questions”.

The lesson observation: an experiential journey

The lesson observation lasted for more than half a year, covering topics within the theme of “diversity” such as classification for living and non-living things, animals, plants, fungi. In those lessons, the STs sat behind the class and were able to walk around to see students’ collaborative work. All the STs were new to the different types of software tools used, as well as to the learning environment mediated by MSL.

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.

The lesson observations helped the STs to confirm their expectations for the students after participation of the project. As we can see from the survey results, Kabir hoped to “develop the culture of learning” in the classroom, and Rohana expected her pupils to “be comfortable using ICT as part of their daily learning experience”.

Apart from students’ performance, STs also had opportunities to see how the teaching in MSL would be different from their current practices. The lesson observation provided STs a chance to see lessons from a different perspective. Some STs reflected things they might not be so conscious about when teaching, such as the questioning. In the lesson observation, Rohana paid special attention to the questions asked by Jane in classroom and summarized her questioning styles:

I think Jane plays a very important role, in the types of questions she asked her pupils. When I stepped into her lessons, I can see that her questions are scaffolds. She started from very simple questions, and she was very dynamic.

She will respond accordingly to students' responses. So if pupils are able to show higher-order thinking, she will streamline the questions to ask more complex kind of questions to trigger their learning.

Besides the questioning techniques, STs also reflected that they learnt about the skills of providing guidance to students in this type of classroom teaching, such as how to guide students to get useful information from the vast information online, and "how to gear students towards the position of a scientist" (from Amber).

In Jane's class, she emphasized to students that they could not find the so-called right answers in the textbook, and there were usually more than one answer to a question. She stressed that science is about interpretations and finding evidence to support one's interpretations or predictions. Jane held this belief and she walked the talk in her teaching. This made the STs to reflect upon their own teaching and Wilson alluded to one difference in his teaching practices comparing his teaching and Jane's:

In our class it's very much [about] what [the students] observe. [What I usually do in my classroom is] that I get them to observe and to find out and then give them a right or wrong answer. Whereas in Jane's class, [for example, in the topic of exploring animals] you see the children really go in depth into each and every animal. Each and every particular group of animals, they go in depth into looking at it. When talking about fur, [the students in Jane's class really did research to see] what is fur and what is hair you know. That is something that I seldom do in my class.

As we can see from Wilson's example, he began to reflect the difference between his teaching and Jane's, which affects the depth of knowledge gained by students, and this reflection further impacted his future plan on teaching with respects to approaching depth of knowledge, as he expressed in the interview that he "want to have the in-depth discussion that Jane has with her students". But he was also aware of the school contexts, that his class had more students with mixed-ability while Jane's class having more higher-ability ones. Considering the difference, he said his school must "guard against having the model every class is like Jane's class" and he planned to adapt the curriculum for his own class with "students who can score in the high 80's and high 90's [with full mark of 100], as well as students who score in the mid-10's and mid-20 s".

The prelections that resulted from the lesson observations also impacted the STs' pedagogical practices. Rohana already had more than 10 years' teaching experiences, but she tried to change her teaching practices after she observed Jane's lessons. Thereafter when she taught in her own school, she started by asking questions in a different way, and she gave one example of her change:

For [the topic of] digestion, I have not actively using questioning techniques like [those] employed by Jane for my pupils. Usually I will ask what the different parts of the digestive system are. Now I ask something like how could the digestion in stomach help in supplying energy, if I remember correctly. After that I bring in something like how the circulatory system and the respiratory system also play a part in digestion. So [I began to ask] more

questions drawing linkages or inter-topical linkages, because the theme is about systems. I tried to make as much connections with other different types of system so that it make more sense, and it's more meaningful for them to learn other types of system.

As we can see, she became more self-conscious about what questions to ask, such as questions that drawing linkages between different topics to make learning more meaningful. She admitted that before the lesson observation she was inclined more towards lecture-type teaching. When she changed to ask more questions, her students were not so responsive initially; but after a few more weeks, students became accustomed and more active in answering and responding to questions posed by her.

The lesson co-design: first step of ownership shifting

Teachers co-designed the theme of “Diversity” in the nine sessions. For each chapter within the theme, teachers went through the process of (1) defining scope and content and learning objectives; (2) discuss common misconceptions; (3) brainstorm activities following 5E model; and (4) detail the lesson plan with elaboration on “class activity”, “complementing home activity” and “MSL activities”. The standardization of scope of content helps the community to implement the curricular in a similar pace so that they can have more meaningful sharing and reflection during implementation. The teachers, then, decided the total period for each chapter and discussed students’ common learning difficulties and misconceptions from their teaching experiences. One chapter often surrounds one focus topic (i.e. living and non-living things, or animals, materials) and the 5E model was used by the community to design a learning cycle for one chapter. The teachers all contributed ideas and resources they have used for the past, and appropriated those activities to fit in different stages.

After going through all the five stages within 5E, the teachers volunteered to take up one or more lessons to spell out the lesson plan. Jane provided a template for teachers to elaborate the lessons, which comprised three columns: class activity, complementing home activities, and mobile learning environment (MLE) activities. In “class activity”, the teachers described teacher’s and students’ activities respectively, while in “complementing home activities” teachers designed activities that students could do out of classroom with aids of the mobile devices before or after the lesson, and in “MSL activities” teachers specified the application they planned to use, the purpose and the objectives of using it. The last two focuses encouraged the teachers to integrate the characteristics of mobile learning, which is leveraging the mobile devices for students’ learning and linking formal and informal learning. Besides, Jane also suggested teachers to consider about differentiated instruction while designing to cater to all students with different competency and needs.

In the co-design sessions, teachers shared their previous teaching experiences and the resources that they thought well addressing students’ learning difficulties, as shown in the following excerpts. Teachers were discussing the design of bread mold

experiment for the “Exploration” stage in the chapter “Fungi and bacteria”. The chapter covers the topics of characteristics of fungi, bacteria, and yeast. The growth of the bread mold takes a few days so that teachers may not address the concepts right after the experiment, so they were discussing how to arrange the sequences and how to make it reasonable.

Jane: (to Amber).....So you will do an introduction, then later at explore stage you will do bread mold experiment. You leave it in the class for a week, and come back to the bread mold a week later to discuss about the growth of bread mold. But within that week before you discuss about the bread mold, what will you do?

Amber: We were often just giving them the knowledge, which is very sad. Can we link it like a backward design?

Jane: Initially our plan is that first of all we do an introduction, and then we prep them [about how to set up and conduct the experiment], and in the following period, we have the discussion on the experiment. But right now our concern is [that] from that [prep] lesson to the lesson you want to discuss about their observations about the bread mold, the duration is too short. They may not have time to discover or see anything out of [the experiment]. So we are thinking that discussion will come later, correct? Then what do you do before you discuss about bread mold?

Wilson: okay, now I think back, if we leave it to the class, they also don't know why they are doing the experiment.

Amber: yeah, the “why” is important, you know.

Wilson: so the “why” should come before or after [the experiment)?

Anna: I think the “why” is not very difficult, because they have finished the chapter of) “Plants”. So while we are discussing the characteristic of fungi, we can draw them back that plants need something to grow, [we can ask them] “then what about fungi?”, which they may or may not know, then we prep them how to conduct the experiment. I'm not sure whether [my suggestion is] conventional, but while they start to do the experiment, we can move on to the yeast and the bacteria, then we come back to wrap up [the bread mold experiment], and compare between bacteria and fungi

As we can see, teachers drew upon their previous experiences and came up with a refined design together. We can see that during the process, Amber reflected upon her previous practices of directly giving the knowledge to students rather than allowing them to discover from doing it, which was regarded by her as “very sad”. She intended to change it to an inquiry way, and through group discussion she got a solution to the problem. Actually this scenario was not rare, but happened across the whole design process. Teachers reviewed the content together, discussed good practices and the strategies not working well, and shared resources. The five schools had varied profiles, and the teachers were using various platforms and resources for their current teaching, which made the sharing valuable to each other. What's more, having to re-look at and re-design the innovative curriculum would render the STs a sense of ownership of the innovation in that they could actually customize/adapt the curriculum to their own school culture and contexts.

Some STs commented that through discussion in the lesson co-design, they gained clarification of certain science concepts, and hence improved their content knowledge. As Anna expressed in the interview, she felt through co-design sessions, she gained “clarity in terms of main conceptions within the topic, like difference between the fungi and bacterial, what are some alternatives, let’s say, some non-examples of a group of animal [like whale as a non-example of fish]”. The clarity in content knowledge helped teachers to be more confident when teaching the students, as Aaron said he “learnt a lot of things that he was not aware before, so I am more ready to teach my students”. The diversity of the school context also provided teachers with more ideas to integrate the innovation and improve their lesson design. Anna mentioned that the community of the five school teachers was different from their own school teachers learning community, and the knowledge gained regarding designing learning journeys was valuable to her.

At the end of the lesson co-design sessions, the STs got a package of lesson designs incorporating the ideas of MSL, but they need to adjust the package to their students. Some schools had their special focus on school development, such as the niche areas which were introduced by the national education for schools to develop their strength, spanning across sports, uniformed groups, aesthetics, information and communications technology (ICT), character education, and environment education. Anna was from the school whose niche area is environmental science and she was planning how to merge the MSL with the niche area of the school:

I think we need overall consolidations of ideas from all the teachers [within our school] of how to run it. Generally, as I said previously, environmental science is not only about the content associated with elementary science, but the dispositions that are necessary like problem solving. So this seamless learning, as a form of inquiry learning, can also be unpacked and customized for our students.

The co-design benefited not only the STs, but also Jane. She reflected that when designing the lessons with the five school teachers, she applied a more “macro-view”, which was different from the “micro-view” way in her own school. Jane took different approaches to preparing the teachers, which was leaving decision of activity details, resources and application to the STs so as to shift the ownership of curriculum design to them step by step. Jane also reflected that the dynamics between her and the STs were different from her and her school teachers. When communicating with the STs, she avoided to telling them what to do but suggested them to try out something since the context was very different.

The elaboration of implementation session: concerns articulated and assurance of support

The school leaders and STs from each of the five schools took part in the Q & A sessions twice with school N. The session was held after the lesson observation and co-design sessions, so the questions raised by them were more specific. Teachers expressed different types of concerns across the progress of implementation as we can see from previous research. In the initial stages, teachers had concerns of how to

get information of the innovation, how to deal with the management issues, how the participation in the technology-afforded innovation would impact themselves, as well as how to leverage the use of technology to meet students' needs (Donovan et al. 2007). As the implementation of innovation went on, the concerns shifted to how to collaborate with colleagues and adjusting the innovation to their own context (Oleson 2010). From our observation of the sessions, the school leaders asked questions from an administrative perspective, such as about the details of the gadgets, the provision of training for teachers, the requirements and roles of teaching assistants and IT technicians, and sought advices on how to set routines for students to use the devices with discipline, as well as objectives and key performance indicators of the project. The teachers were concerned more on the curriculum aspect, for instance, about the possibility of off-loading some other teaching responsibilities when enacting the new curriculum lessons, appropriate assessments for this kind of learning, curriculum design in terms of use of applications, differentiated curriculum, conflicts between the new curricular activities and the more traditional worksheets and activity books. The seeded schools also were also concerned about parents' buy-in, diversity of students and other issues.

Recognizing that most of the concerns were about the use of the gadgets and the robustness of the technology, the school leaders of N sought to convince the seeding schools that the essence and the ultimate objective of the project lies in the capacity building of teachers, rather than using the mobile devices. The school advocated that it was inevitable that it would take time for both teachers and students to get used to the new learning environment but all the efforts have been worthwhile. Empowering teachers and students to leverage technology to achieve better learning results and to form a better learning culture is the key issue. At the same time, the school N promised to provide sufficient supports to tackle the problem resulted from the technology.

The elaboration of implementation sessions also helped the school leaders and the seeded teachers from respective schools achieve common understanding of the difficulties and challenges of the implementation, and thus plan for the future. We found that the supports from school leaders were varied from our discussions with the STs. Some school leaders were proactive and they were able to foresee the challenges. They actively involved in the decision making, and provided supports for teachers, as we can see from Anna's description of future plan:

I think that the dialogue with my school leaders helped us make the plan. She set the general direction, such as on our ends, we need to establish our pedagogical practices, free-up of teachers, ensuring that our work-load is not compromised. Also she let us know earlier of our deployment. We have off-loading, meaning previously some of our lessons have been taken out, and next year Rahana and I will co-teach the class, [the other two teachers from P3 level] will become to be observers, and on a weekly basis my ICT HOD [head of department] will come to observe, to review the lessons and refine. So it's not just us enacting, but rather collective efforts.

Understanding MSL and extent of buy-in

Following the methods we described in the previous part, we found the STs tended to describe the MSL using the following keywords the frequencies of the keywords were shown within the round brackets): inherent or intensive use of technology (8), student-centered and teacher as facilitator (4), self-directed (4), beyond classroom, or in and out of classroom (4), life-long learning (1), 21st century skills (1), and enhance students' interests in science learning (1). Teachers firstly featured the inherent and intensive use of technology, meaning that technology should be meaningfully integrated for learning, rather than superficially used for demonstration purpose. They also sensed a shift of ownership of classroom from teacher to students by saying that the MSL should be student-centered and promotes self-directed learning. They understood the seamless as connecting learning in the classroom with learning at home, which was enabled by the mobile devices.

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.

Wilson appreciated the uniqueness of the MSL in that the teacher could evaluate and monitor students' learning progress even they do it at home. Other teachers also mentioned the value of MSL lies in students' easy access to vast information online. With the mobile devices, students can search for information from internet.

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.

Fig. 3 Attitudes of the seeded teachers towards MSL

So STs see the potential of MSL as a means for students to become self-directed learners. They can spot problems, ask questions and initiate their research, which changes learning from passive receiving to constructing knowledge. Teachers recognize their role as facilitators, which might be quite a shift for them since most of them have been teaching in a teacher-centred way.

Despite of the affordances provided by the technology, teachers recognized that the key factor that leads to the success of the innovation is the teaching of the teacher, as expressed by Kabir:

It's not just using technology for its own sake, it's that how we use it in a way that students are engaged and learn further, and learning is enhanced. So the way how teachers use it to enhance the learning is most important.

Based on their understanding of MSL, teachers all held positive attitudes toward the innovation, and they demonstrated excitement in trying out the package in their school. When asked about their buy-in of the MSL, all of the teachers responded with a high level of buy-in. The survey responses of teachers' attitudes of the innovation and their confidence of conducting the curricular innovation are summarized in Fig. 3.

When we asked teachers to put their buy-in on a scale from 1 to 10 in the interview, most teachers gave scales higher than 8. They explained that they were not giving ten due to their concerns on the students' preparedness, parents' readiness, the technical issues, and uncertainty of the gadgets and applications.

Discussion and conclusion

In this paper, we situated our study of the diffusion of MSL from one school to five more schools and proposed a model of teacher's preflexive learning to get their

buy-in and prepare them for the future implementation. In the findings, we articulated how each activity in the model helped the STs to acquire knowledge of MSL and to explore what knowledge they have gained through interactions with teachers and school leaders from N school, and researchers. It was found that the learning experiences convinced STs of the advantages of the curricular innovation to teachers and students, as well as feasibility of implementation in their own school, which led to the STs high degree of buy-in of the innovation.

Teachers' perceptions of the five attributes of an innovation were critical for their adoption decision making and implementation. Through the embodied learning experiences, teachers were able to see many facets of the innovation and built their own understanding of the characteristics of the innovation. Dearing et al. (2011) suggested an "exemplary demonstration" in a convincing manner to influence adoption decisions and thus increase the likelihood of diffusion, and in our study the infusion and lesson observation served the purpose of demonstration, specifically, students' significant improvement in answering open-ended questions and their engagement, enthusiasm, and thinking like scientists in the classroom, were regarded as *relative advantages* of MSL. The curriculum design activity rendered them a sense of ownership of the innovation and let them see the *compatibility*; the understanding of the innovation highlight more on the pedagogy rather than the use of applications, as well as assurance of systemic supports got from Q & A sessions convinced them of the *simplicity*. The curriculum package, which was a collective product of the community, made the innovation more *triable* at the first stages of implementation. The three types of knowledge described by Rogers (2003) were also provided for the teachers through those learning experiences, such as how-to knowledge in the lesson observation in terms of how to ask scaffolding questions, how to manage a MSL classroom, and how to guide students to think and talk like scientists. It is also provided through the lesson co-design on how to design the curriculum that incorporates MSL, and on how to integrate the package into individual school's existing package.

We find that STs were reflective through the learning experiences and their capacity was built incrementally across the learning journey. The new culture of learning demonstrated by Jane and her students urged them to reflect their own practices, such as the depth of knowledge construction as mentioned by Wilson and questioning techniques as brought up by Rahana, as well as the instructional skills applied by Jane. We found that community building is important for teachers' capacity building and professional development. Teachers reflected that they clarified content knowledge and learnt teaching skills through interacting with and learning from other school teachers. In the lesson co-design, through the discussion and sharing, they not only gained an end product of the curriculum package, but more importantly through the process they gained ability of designing MSL curriculum. With the capacity built from lesson observation and lesson co-design, the teachers were more ready to implement the innovation next year. As a result of the reflection, they have made plans of the future implementation, including adaptation of lesson plans to meet students' needs, equipment of new pedagogical practices, setting routines of students' use of mobile devices, and seeking supports from leadership.

Compared with other teacher professional development programmes, our model not only focuses on teacher's professional learning, but also emphasizes the provision of systemic and other infrastructure supports. Teachers need to deal with multiple issues when implementing, but our learning model had endeavored to establish the systemic supports (from school leaders to the IT technicians and teaching assistants etc.) for teachers to alleviate them from administrative matters and to enable them to focus on improving curriculum and instruction. Being different from other teacher PDs in the form of researcher-practitioner interaction, our model highlights the interactions amongst practitioners. Teachers share similar considerations and concerns when adopting an innovation, so the advice and tips from peers would be more pragmatic and targeted. The preflexive learning model elaborated the activities that teachers could have, but also suggested some preflexion prompts for teachers to reflect for actions. The model we proposed here not only applies to the diffusion of educational innovation as in our case, but also to the diffusion of innovation in other domains. Thus, to prepare for adopting a potential innovation, the learning cycle should incorporate the following core elements: effectiveness demonstration, embodied and preflexive learning journey, shift of ownership, learning community building, and systemic support provided.

References

- Bannert, M. (2009). Promoting self-regulated learning through prompts. *Zeitschrift für Pädagogische Psychologie*, 23(2), 139–145.
- Bybee, R. W. (2009). The BSCS 5E instructional model and 21st century skills. Washington, DC: National Academies Board on Science Education, Retrieved March, 4, 2011.
- Chan, T.-W., Roschelle, J., Hsi, S., Kinshuk, K., Sharples, M., Brown, T., & Milrad, M. (2006). One-to-one technology-enhanced learning: An opportunity for global research collaboration. *Research and Practice in Technology-Enhanced Learning*, 1(1), 3–29.
- Chee, Y. S., & Mehrotra, S. (2012). *Reflective, reflexive guided appropriation: Facilitating teacher adoption of game based learning in classrooms*. Paper presented at the Proceedings of the European Conference on Games Based Learning.
- Cloonan, A. (2009). *Filming for professional learning: Collaborations in innovation*. Birmingham: Australian Teacher Education Association.
- Dearing, J. W. (2009). Applying diffusion of innovation theory to intervention development. *Research on Social Work Practice*, 19(5), 503–518.
- Dearing, J. W., Dede, C., Boisvert, D., Carrese, J., Clement, L., Craft, E., & Pleil, M. (2013). *How educational innovators apply diffusion and scale-up concepts*. Lanham: Rowman & Littlefield.
- Dearing, J. W., Greene, S. M., Stewart, W. F., & Williams, A. E. (2011). If we only knew what we know: Principles for knowledge sharing across people, practices, and platforms. *Translational Behavioral Medicine*, 1(1), 15–25. doi:[10.1007/s13142-010-0012-0](https://doi.org/10.1007/s13142-010-0012-0).
- Donovan, L., Hartley, K., & Strudler, N. (2007). Teacher concerns during initial implementation of a one-to-one laptop initiative at the middle school level. *Journal of Research on Technology in Education*, 39(3), 263–286.
- Falk, D. (1995). Preflexion: A strategy for enhancing reflection. *NSEE Quarterly*, 21, 13.
- Fishman, B. (2005). Adapting innovations to particular contexts of use: A collaborative framework. In C. Dede, J. Honan & L. Peters (Eds.), *Scaling up success: Lessons learned from technology-based educational innovation* (pp. 48–66). New York: Jossey-Bass.

- Freeman, M. (2012). To adopt or not to adopt innovation: A case study of team-based learning. *International Journal of Management Education (Oxford Brookes University)*, 10(3), 155–168. doi:[10.1016/j.ijme.2012.06.002](https://doi.org/10.1016/j.ijme.2012.06.002).
- Hall, G. E., Loucks, S. F., Rutherford, W. L., & Newlove, B. W. (1975). Levels of use of the innovation: A framework for analyzing innovation adoption. *Journal of teacher education*, 26(1), 52–56.
- Hord, S. M., Rutherford, W. L., Huling-Austin, L., & Hall, G. E. (1987). *Taking charge of change*. Alexandria, VA: Association for Supervision and Curriculum Development.
- Ifenthaler, D., & Lehmann, T. (2012). Preactional self-regulation as a tool for successful problem solving and learning. *Technology, Instruction, Cognition and Learning*, 9(1–2), 97–110.
- Jones, B. L., & Bjelland, D. (2004). International experiential learning in agriculture. In *Proceedings of the 20th Annual Conference, Association for International Agricultural and Extension Education* (pp. 963–964).
- Kintsch, W., & Van Dijk, T. A. (1978). Toward a model of text comprehension and production. *Psychological Review*, 85(5), 363.
- Kopcha, T. J. (2012). Teachers' perceptions of the barriers to technology integration and practices with technology under situated professional development. *Computers & Education*, 59(4), 1109–1121.
- Krajcik, J., McNeill, K. L., & Reiser, B. J. (2008). Learning-goals-driven design model: Developing curriculum materials that align with national standards and incorporate project-based pedagogy. *Science Education*, 92(1), 1–32.
- Looi, C.-K. (2012). *Sustained Innovation in Classroom Practices: The Role of Educational Researchers as Meso-Level Actors* (pp. 130–148). Selected Papers of Beijing Forum 2011, Peking University Press, Beijing.
- Looi, C.-K., Seow, P., Zhang, B., So, H.-J., Chen, W., & Wong, L.-H. (2010). Leveraging mobile technology for sustainable seamless learning: A research agenda. *British Journal of Educational Technology*, 42(1), 154–169.
- Looi, C.-K., Sun, D., Wu, L., Seow, P., Chia, G., Wong, L.-H., & Norris, C. (2014). Implementing mobile learning curricula in a grade level: Empirical study of learning effectiveness at scale. *Computers & Education*, 77, 101–115.
- Looi, C. K., & Wu, L. (2015). *Reflection and prefection prompts and scaffolding*. Thousand Oaks: SAGE Encyclopedia of Educational Technology.
- Looi, C.-K., Zhang, B., Chen, W., Seow, P., Chia, G., Norrist, C., & Soloway, E. (2011). 1:1 mobile inquiry learning experience for primary science students: A study of learning effectiveness. *Journal of Computer Assisted learning*, 27, 269–287.
- Makinster, J. G., Barab, S. A., Harwood, W., & Anderson, H. A. (2006). The effect of social context on the reflective practice of preservice science teachers: Incorporating a web-supported community of teachers. *Journal of Technology and Teacher Education*, 14(3), 543–579.
- Mustafa, J., & Al-Mothana, G. (2013). Using the diffusion of innovation theory to explain the degree of english teachers' adoption of interactive whiteboards in the modern systems school in Jordan: A case study. *Contemporary Educational Technology*, 4(2), 138–149.
- Newhouse, C. P. (2001). Applying the concerns-based adoption model to research on computers in classrooms. *Journal of Research on Computing in Education*, 33(5), 1–21.
- Oleson, V. (2010). *The impact of mathematics professional development on elementary teachers' mathematics content knowledge for teaching and implementation of innovative pedagogical practices*. Ann Arbor: ProQuest LLC.
- Rogers, E. M. (2003). *Diffusion of innovations* (4th ed.). New York: Free Press.
- Scribner, J. P., Cockrell, K. S., Cockrell, D. H., & Valentine, J. W. (1999). Creating professional communities in schools through organizational learning: An evaluation of a school improvement process. *Educational Administration Quarterly*, 35(1), 130–160.
- Stein, M. K., Smith, M. S., & Silver, E. A. (1999). The development of professional developers: Learning to assist teachers in new setting in new ways. *Harvard Educational Review*, 69(3), 237–269.
- Stylianidou, F., Boohan, R., & Ogborn, J. (2005). Science teachers' transformations of the use of computer modeling in the classroom: Using research to inform training. *Science Education*, 89(1), 56–70. doi:[10.1002/sce.20043](https://doi.org/10.1002/sce.20043).
- Sun, M., Penuel, W. R., Frank, K. A., Gallagher, H. A., & Youngs, P. (2013). Shaping professional development to promote the diffusion of instructional expertise among teachers. *Educational Evaluation and Policy Analysis*, 35(3), 344–369. doi:[10.3102/0162373713482763](https://doi.org/10.3102/0162373713482763).

- Urhahne, D., Schanze, S., Bell, T., Mansfield, A., & Holmes, J. (2010). Role of the teacher in computer-supported collaborative inquiry learning. *International Journal of Science Education*, 32(2), 221–243.
- van den Akker, J. (2003). Curriculum perspectives: An introduction. In J. van den Akker, W. Kuiper, & U. Hameyers (Eds.), *Curriculum landscapes and trends* (pp. 1–10). Dordrecht: Kluwer Academic Publishers.
- Vanderlinde, R., & van Braak, J. (2011). A new ICT curriculum for primary education in flanders: Defining and predicting teachers' perceptions of innovation attributes. *Journal of Educational Technology & Society*, 14(2), 124–135.
- Wong, L.-H., Gao, P., Chai, C. S., & Chin, C. K. (2011). Where research, practice and the authority meet: A collaborative inquiry for development of technology enhanced Chinese Language Curricula. *The Turkish Online Journal of Educational Technology*, 10(1), 232–243.
- Wong, L.-H., & Looi, C.-K. (2011). What seams do we remove in mobile assisted seamless learning? A critical review of the literature. *Computers & Education*, 57(4), 2364–2381.
- Ye, X., Zhang, B., & Chia, P. C. (2010). *A tripartite model of co-designing for an iMVT integrated science curriculum*. Paper presented at the 18th International Conference on Computers in Education, Putrajaya.

Longkai Wu is currently a Research Scientist and faculty member at the Office of Education Research, National Institute of Education, Singapore. He holds a Doctor of Philosophy in the area of Learning Sciences and Technologies at Nanyang Technological University (NTU), Singapore. As part of institutional effort in scaling and translation, his research is on the development of sustainable frameworks to translate and scale education innovations into classroom practices in Singapore school system. He has worked closely with local primary and secondary schools, as well as Ministry of Education, to formulate the nexus among research innovations, scaled practices, and education policies.

Xiaoxuan Ye is a research associate at National Institute of Education, Nanyang Technological University, Singapore. She received her B.S. from Huazhong Normal University, China and M.Ed from Beijing Normal University, China. Her research interests include ICT-integrated science learning and teaching, teacher professional development, science curriculum and instruction.

Chee-Kit Looi is a Professor of Education in the National Institute of Education, Nanyang Technological University, Singapore. He was the Founding Head of Learning Sciences Lab, Singapore, the first research centre devoted to the study of the sciences of learning in the Asia-Pacific region, from 2004 to 2008. His research interests include mobile and ubiquitous technologies, and computer-supported collaborative learning. He serves on the editorial boards of the IEEE Transactions in Learning Technologies, International Journal of CSCL, and Journal of the Learning Sciences. He is an honorary advisor of the Journal of Computers in Education.