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Implementing Mobile Learning Curricula in Schools: A Programme of Research from Innovation to Scaling

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ABSTRACT
Many countries, regions and education districts in the world have experimented with models of one-device-per-student as an enabler of new or effective pedagogies supported by mobile technologies. Researchers have also designed innovations or interventions for possible adoption by schools or for informal learning. Of critical interest to the community is the question of how the more successful of these top-down or bottom-up models or innovations can proliferate to more usage, adoption and adaptation across levels of the education system. This paper describes a research programme that demonstrates how to make successful research innovations count in practice and that delineates what types of educational R&D involving scaling need to take place to make the critical link to impacting practice. We do this in the context of one such curricular innovation in a Singapore school that moves through the various phases to where the innovation is becoming an integral part of routine classroom practices.

Keywords
Mobilized curriculum, Translation and scaling up, Seamless learning model, Design-based research, Science education

Introduction

The literature on educational technology research is packed with examples of pilot studies and proofs-of-concepts. It is rarer, in fact, in the literature, to see a project move through the various phases to where the innovation actually has become an integral part of routine classroom practices. In our collaboration work with a primary school in Singapore, we have developed a viable innovation model (the Seamless Learning Model or SLM in short) by working with a class of primary school students over a period of two school years. The innovation involves the transformation of the existing science curriculum into an inquiry-based one which leverages the affordances of mobile technologies. Because SLM demonstrated increased student achievement, the school has decided to scale-up the roll-out of the transformed curriculum to more classes and more subjects in the coming years, thus providing the opportunity to study an innovation as it scales up.

In this article, we trace the journey of this research programme that started with the co-design of a 1:1 (one-mobile-device-per-student) mobilized curricular innovation for a primary school in Singapore, leading to the establishment of efficacy findings by researchers, the decision to scale-up by the school, and the plans for scaling-up. In doing so, we elucidate a multi-term research agenda on an 1:1 mobilized curriculum that studies scaling beyond the initial proof-of-concept to broad and deep usage in the context of a research-based innovation in a school in Singapore. Such an agenda articulates the research questions and posits the scaling research framework and approaches involved. We hope this can provide an existential example of how researchers can do research that addresses the multi-term, multi-pronged, multi-level and systemic aspects of school-based innovations, and that ultimately benefits schools and yet at the same time, derive and refine scientifically and empirically theoretical frameworks, design principles, resources and strategies for learning.

Our research approach: Design-based research and our roles as meso-level mediators

With the goal of working towards scalable and sustainable classroom practices, we took a design-based research (DBR) approach to address complex problems in real classroom contexts in collaboration with practitioners, and to integrate design principles with technological affordances to create solutions to real needs of teaching and learning. The goal of design research is to conduct rigorous and reflective inquiry to test and refine innovative learning environments as well as to refine new learning-design principles (Brown, 1992; Collins, 1992). DBR is iterative as researchers strive to engage in design, work with teachers to enact the design in classroom settings, do research on the contextualized learning processes, develop or refine theories of learning, engage in iterative re-design, and thereby continue the cycle of design and implementation. It is characterized as being interventionist, iterative, process-oriented, utility-oriented and theory-oriented (van den Akker, Gravemeijer, McKenney, & Nieveen, 2006). It is distributed across teachers and is ongoing, as opposed to a completed trajectory that we as researchers can foresee and oversee. DBR can 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).

Cognizant of the multiple level constraints that act on teachers adopting new curricular innovations in the classroom, we recognize the complex interplay of multiple dimensions of education reforms. Thus, we approach our programme of research from a systemic change perspective that recognizes the micro, meso, and macro levels of educational systems (Looi, 2011; Looi, So, Toh, & Chen, 2011). 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. By meso levels, we adopted the view of Jones, Dirchinck-Holmfeld, and Lindstrom (2006) where they define: "meso is an element of a relational perspective in which the levels are not abstract universal properties but descriptive of the relationships between separable elements of a social setting" (p. 37). Meso-level agencies can be perceived as the "recontextualizers" or "constructors of pedagogic discourse who de-locate and re-locate discourse, moving it from its original site to a pedagogic site" (Jephcote & Davies, 2004, p. 549).

Macro-level actors: Policymakers or other actors who set the climate or policies for educational reforms in schools and in learning **Macro-level environment:** As seen in national plans or Masterplans where a conducive macro-environment for innovative practices is enabled by governance practices through: - Setting up the infrastructures - Creating readiness - Phasing changes - Institutionalizing and undergoing creative renewals - Providing resources **Macro-level emphases:** Setting broad educational outcomes - Scanning trends and directions, and reviewing research at *meso-levels and micro-levels* that inform pedagogical and technological practices	**Meso-level actors:** Researchers as re-contextualizers who moved discourse from original to pedagogic site **Meso-level environment:** The socio-cultural factors that make up the school's learning ecology such as the classroom setting situating between individual activities, small groups and larger communities. **Meso-level emphases** Interpreting and operationalizing *macro-level* emphasis by: - Effecting the desired epistemological and socio-cultural changes via design research - Mapping to effective classroom orchestration and implementation that seeks to achieve the desired micro-level interactions and outcomes, via design research - Considering systemic forces and mediating inter-related tensions to lead to sustainability and scalability	**Micro-level actors:** Individuals such as students and teachers **Micro-level environment:** Interactions or discourse within small group and classroom settings **Micro-level emphases** Informing *macro and meso-level* emphases by: - Studying contextualized group or classroom-based interactions in an in-depth manner - Eliciting feedback from participants

Figure 1. A systemic framework for enabling innovative practices via the alignment of macro, meso and micro levels (adapted from Looi et al., 2011, p. 11)

The socio-cultural factors of the school's learning ecology constitute the meso-level environment. As researchers from the university, we serve as meso-level actors who work in that environment to recontextualize pedagogic discourse. This re-contextualization process is a "meso-level" mechanism. The orchestration of efforts from all actors will contribute explanatory power to the sustainability of an intervention. By approaching this pedagogy-driven reform at the macro, meso and micro levels, we seek the alignment of systemic forces at work to provide a buttress for sustainability. Thus we, as researchers as the meso-level actors, help the school practitioners understand and interpret policy imperatives and actualize them into classroom teaching and learning practices in ways that are informed by research and theories. Figure 1 shows the roles of actors in these three levels in enabling and sustaining innovation.

The curricular innovation informed by the seamless learning notion

Through a DBR approach and a lens of researchers serving as meso-level mediators to work with the teachers, we first conducted several research cycles in the three-year research project entitled "Leveraging Mobile Technology for Sustainable Seamless Learning in Singapore School." The work helped us to develop a viable innovation model (the Seamless Learning Model or SLM in short) by working with a class of primary school students over a period of two school years. The innovation involved the transformation of the existing science curriculum into an inquiry-based one which leverages the affordances of mobile technologies. The project was framed in the broader context of constructing "seamless learning" environments to bridge different learning contexts (such as between formal and informal learning settings, individual and social settings, and learning in physical and digital realms), mediated by mobile devices in 1:1, 24x7 basis (Chan et al., 2006; Wong & Looi, 2011). The basic rationale is that it is not feasible to equip students with all the skills and knowledge they need for lifelong learning solely through formal learning (or any other single learning space); henceforth, student learning should move beyond the acquisition of content knowledge to develop the capacity to learn seamlessly (Chen, Seow, So, Toh, & Looi, 2010). Nevertheless, as such a learning approach is a tall order for students who are more accustomed to the present instructivist-dominated education system. In this regard, we envisaged the design and enactment of long-term seamless learning curriculum where teachers engaged learners in an ongoing enculturation process (Wong, 2013b) in nurturing their habit-of-mind in seamless learning.

We first describe the underlying intent and the guiding principles of this curricular innovation enabled by mobile technologies. These were what shaped the curricular innovation, and they had been iterated and improved progressively through a process of DBR by working with teachers over three years. The process was marked by in-situ iterative and collaborative cycles of co-design by researchers and the teacher, leading to enactment by the teacher in one experimental class with data collection. The researchers observed the classes, and provided feedback to the teacher to improve the design and subsequent enactments. The class was a mixed-ability class.

The design of the learning units in the mobilized curricula for science is designed based on these design principles (Zhang et al., 2010):

- Design student-centered learning activities (to promote engagement and self-directed learning)
- Make students' thinking process visualizable (so that they can be shared and subject to further refinement)
- Incorporate different learning modalities (to personalize learning)
- Design for holistic and authentic learning (make science learning meaningful)
- Facilitate social knowledge building (to promote collaborative learning)
- Ensure that the teacher plays the role of facilitator (to move away from didactic teaching)
- Provide an environment to integrate all learning activities (students have a hub to launch or continue their learning activities)
- Assess formatively (through the learning activities, students can receive feedback for their own ideas from peers or the teacher)
- Extending classroom learning activities beyond school hours and premises (to support the notion of seamless learning).

In the co-design process, researchers worked with teachers to revise and mobilize two years' worth of the national curriculum for Primary 3 and 4 Science by considering the opportunities afforded by ubiquitous access to mobile devices. Activities were designed which seeks to extend learning activities beyond the classroom. To support the continuous and long-term learning activities, 34 students from the experimental class were each assigned a smartphone 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 artifact creation, among others.

The key epistemological design commitments of the curricular innovation are: learning as drawing connections between ideas, and learning as connecting science to everyday lives, across multiple learning spaces. The curricular commitment is seamless learning, and inquiry-based facilitation and learning. The technological commitments include: technology for construction, technology for communication, and technology for searching information anywhere anytime.

Concerning the curricular commitment, in science teaching, the Ministry of Education of Singapore has advocated the use of the BSCS 5E Instructional Model (Bybee, 2002). This 5Es model consists of the following phases: engagement, exploration, explanation, elaboration, and evaluation. Each phase has a specific function and contributes to the teacher's coherent instruction and to the learners' formulation of a better understanding of scientific knowledge, attitudes, and skills. The model is used to sequence the learning activities in a science lesson or over a series of science lessons.

The designed curriculum was developed with the use of software apps on the GoKnow™ MLE (Mobile Learning Environment) that runs on a Microsoft Windows Mobile operating system. The GoKnow MLE enables teachers to create differentiated lessons easily via its online learning management system, GoManage, and it enables students to easily personalize their learning experiences (Looi et al., 2009). MLE supports teachers in creating complete, coordinated, curriculum-based lessons that employ multiple media and applications (e.g., text, graphical, spreadsheet, animations, and the like). It is an environment in which students engage in the specified learning activities and create various artefacts. It includes software tools such as:

- KWL (what do I already Know? what do I Want to know? What have I Learned?) to allow students to learn in a self-regulated way,
- Stop Watch that supports timing of events,
- Sketchy™ as an animation/drawing tool, and
- Picomap™ that allows students to create, share, and explore concept maps.

Typically, the lesson is designed to provide opportunities for the student in the Explore, Explain and Elaborate phases of 5E to use the software tools to do their science inquiry. In the Engage phase, the teacher motivates the inquiry by doing some classroom science demonstration or posing some science questions. In the Evaluate phase, the teacher or student peers review the work done on the software tools to detect and correct students' developing conceptions of the science concepts.

We designed a total of twelve MLE units in the two years of intervention. Note that we did not design the whole curriculum in one go before the intervention commenced. During and after each design-enactment cycle for a MLE unit, we reflected upon the lessons and apply such understanding to inform the design of the next MLE unit. In addition to offering a logical flow for learning the domain knowledge, we had progressively incorporated various types of inquiry/seamless learning activities, from simpler to more demanding ones. This was to facilitate the students' gradual changes in their habits of mind moving towards learning seamlessly. For example, while the earlier activities involve the students expressing their understanding using the software tools or capturing artifacts outside of the classroom and relating them to the curriculum concepts, the latter activities involve some form of parental involvement in the students' learning.

Through a process of considering the space of activities enabled by the affordances of the software tools and the smartphones, and the kinds of activities that would be beneficial for primary school science students, we develop a categorization of the 10 major types of smartphone-mediated activities as shown in Table 1. Table 2 summarizes the essential information, including what smartphone-mediated activities were incorporated, of the twelve MLE units.

Table 1. Types of mobile-assisted activities incorporated in the MLE curriculum (Wong, 2013b)

Activity ID	Activity Type	Mobile Affordances
KWL	Self-regulation of learning progress	KWL
Anim	Animation creation	Sketchy
Ph	Photo taking	Built-in camera
CM	Concept mapping	PicoMap
Dsc	Online artifact sharing and discussion	Blog / Mobile Forum
Trp	Field trip	Video, photo & note taking tools
Exp	Scientific experiments	Video, photo & note taking tools

Par	Activities with parental involvement	Videos & other tools
Web	Web search and media playing	Internet Explorer, YouTube app
Col	In-situ multimedia content creation & forum discussion	ColInq (with geo-tagged postings, each served as a discussion thread)

Table 2. List of MLE units designed for the mobilized curriculum (Wong, 2013b)

Level & time period	Topic	Anim	KWL	Ph	CM	Dsc	Trp	Exp	Par	Web	Col
Feb 2009	Classification for living & non-living things	√									
Feb & Mar 2009	Classification of animals	√	√								
Mar & Apr 2009	Plant	√	√	√	√						
Mar & Apr 2009	Plants & their parts	√	√	√	√	√					
Mar & Apr 2009	Fungi	√	√	√	√		√				
Apr & May 2009	Materials	√	√	√	√			√			
Aug & Sep 2009	Body systems	√	√						√	√	
Jan & Feb 2010	Cycles	√	√			√	√			√	
Feb & Mar 2010	Matter	√	√	√							
Apr 2010	Light & shadow		√					√			
Apr & May 2010	Heat & temperature	√	√	√							
Jul 2010	Magnet		√		√			√	√	√	√

Note. The first seven units constituted the Primary 3 mobilized curriculum; the last five belonged to the Primary 4 curriculum

Demonstration of efficacy of innovation

The curricular innovation involves designing a coherent and sustainable classroom program. The unique research context is that we worked with a school with 9 classes in the cohort of Primary Grade 3 taking the science subject. The experimental class followed the same class schedule and assessment schemes as the rest of the classes. What evidence can we demonstrate in establishing the efficacy of the innovation? Our analysis of the science examination scores after the one year intervention (with the experimental class using the mobilized curriculum to replace the traditional curriculum) shows that amongst the 6 mixed-ability classes in Primary (Grade) 3 in the school, the experimental class performed better than other classes as measured by traditional assessments in the science subject (see, Looi, Zhang, et al., 2011). With mobilized lessons, students were found to learn science in personal, deep, and engaging ways as well as developed positive attitudes towards mobile learning. We feel that this result is a very worthwhile contribution to the field, as much research work on mobile learning focus only on units of at most a few weeks duration or they are add-on activities to some existing curriculum.

The use of the mobilized technologies provides many leverage points for the researchers and teachers to co-design a new curriculum that focus on inquiry learning. Once designed, the curriculum can be enacted by science teachers, and it is important for the teachers to understand the design principles behind a mobilized curriculum for inquiry learning and how to implement in the way to harness the best learning outcomes for students. We see a shift in the teacher's attitudes and behaviors towards science teaching, from a style that sees her pre-occupied with just covering the curriculum to one that allows her to watch over and facilitate students' work on the inquiry activities on their handhelds.

With the mobilized lessons, we observe students engaging in science learning in personal and engaged ways. They demonstrated their understanding of science phenomenon in multimodal ways and did self-directed learning by doing online search and exploration on questions related to the curriculum topics. They engaged in instructional activities that involve their parents, as in our mobilized lesson for the body systems. This lies in contrast to the more "traditional" way of learning, in which students learned science from the didactic instruction of the teacher or from the textbook.

Providing the basis: Explicating and theorizing the SLM model

The pilot has shown that Seamless Learning (SL) is a viable pedagogical model. SLM harnesses the portability and versatility of mobile devices to promote a pedagogical shift from didactic teacher-centered to participatory student-centered learning (Facer et al., 2004). With appropriate learning design, the mobile technology facilitated the transformation of classroom learning activities into a more student-centered, personalized, and social learning process for the students where they need to process and associate their experiences or the information received in the informal contexts with the knowledge that they have acquired or constructed in the classroom, reflect upon any discrepancy, and apply the knowledge to solve real-life.

As design-based researchers, we also seek to work towards theories for how to get students to learn as self-directed seamless learners (Looi et al., 2010; So, Kim, & Looi, 2008; Wong, 2013b). We explore how the theories and methodology of self-regulated learning (SRL), an active area in contemporary educational psychology, are inherently suited to address the issues originating from the defining characteristics of mobile learning: enabling student-centered, personal, and ubiquitous learning (Sha, Looi, Chen, & Zhang, 2012). These characteristics provide some of the conditions for learners to learn anywhere and anytime, and to be motivated and able to do so in a strategic way, namely, self-regulate their own learning. We propose an analytic SRL model of mobile learning as a conceptual framework for designing and analyzing mobile learning, in which the notion of self-regulation as agency is at the core (Figure 2). The rationale behind this model is built on our recognition of the gaps in the current conceptualization of the mechanism and processes of mobile learning, and the inherent relationship between mobile learning and SRL.

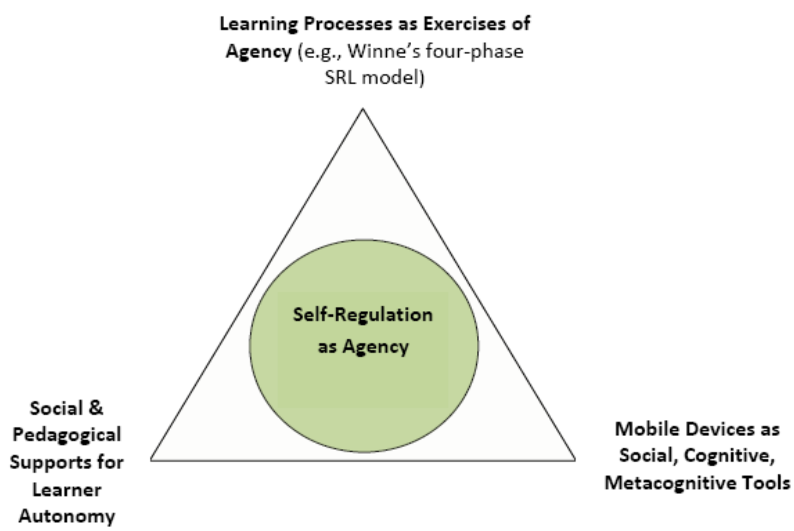

Figure 2. An analytic SRL model of mobile learning (Sha et al., 2012)

At the center of the model is the notion of self-regulation as agency, referring to the learner characteristics that function as internal driving forces initiating and sustaining a self-regulated mobile learning process. The key personal factors include domain knowledge, prior experiences, motivation, and metacognitive awareness, epistemological beliefs, and so on. Self-regulated mobile learning processes can be understood and analyzed by means of SRL theories and methodologies (e.g., self-report survey, trace analysis). Mobile learning processes that are regarded as manifestation/exercises of agency (fundamentally composed of motivation and metacognition) can be understood, analyzed, and assessed from the theories and methodologies of SRL. Second, mobile learning activities are supposed to be mediated by mobile technologies and devices, which presumably function as social, cognitive, and metacognitive tools. The existing studies in mobile learning largely focus on the social and cognitive functions but ignore the metacognitive function.

Methodological contributions: Studying students on the move

SLM advocates continuous learning by the students inside and outside of the classroom. The curriculum incorporates components where they use their personal mobile devices to do planned activities at home or outside of the classroom, and where they also learn in emergent and unintended ways. The challenge for us researchers is how to study "seamless learning" as synergistic and continuous learning across multiple spaces and time scales which involves theoretical and methodological challenges (Toh, So, Seow, Chen, & Looi, 2013). With students constantly on the move and many of their interactions happening in informal settings, researchers face significant challenges for investigating and documenting emergent forms of learning and participation across multiple contexts. The challenges of collecting data for students on-the-move include making sense of the voluminous data collected, and navigating the complexity of ethical issues involved in the intrusive and non-intrusive data collection methods.

To fill the gap in mobile learning research, we innovated on a methodological approach for researching digital kids' learning supported by mobile technologies. The specific focus on methodological issues is significant with recent trends in mobile learning research's focus on learning beyond school settings. Building on earlier work on methodological issues (e.g., Hsi, 2007; Martin, 2004; Vavoula & Sharples, 2009), we adopt and adapt the method of cooperative inquiry to study the sense-making endeavors of digital students who are always on-the-move and learning across multiple settings. We do so by working with parents who would cooperate to collect data such as by using video-recording and taking photos of their children doing things on their mobile devices.

Moving beyond the Proof-of-concept: From innovation to scaling

Is the curricular innovation ready for scaling and how do we know to what extent scaling has taken place? One of the most cited literature on scaling is that of Coburn (2003) who defined scale as encompassing four interrelated dimensions:

- Depth: Depth refers to deep and consequential change in classroom practice, altering teachers' beliefs, norms of social interaction, and pedagogical principles as enacted in the curriculum.
- Sustainability: Sustainability involves maintaining these consequential changes over substantial periods of time.
- Spread: Spread is based on the diffusion of the innovation to large numbers of classrooms and schools which will adopt and adapt the innovations.
- Shift in reform ownership: Shift requires districts, schools, and teachers to assume ownership of the innovation, deepening, sustaining, and spreading its impact.

Building on this work, Clarke and Dede (2009) added a fifth dimension, namely, evolution, in which the innovation, as revised by its adapters, is influential in reshaping the thinking of its designers and creating a community of practice that evolves the innovation.

Our 3-year design research study in the primary school has helped achieve some successes in dimensions of scale by Coburn (2003) in four ways:

- **Depth:** The intervention has created positive learning gains for the students of the 2 classes and positive changes in attitudes and knowledge of the 2 teachers (Looi, Zhang et al., 2011).
- **Sustainability:** Clearly changes have occurred in the school with evidences from research analysis (Looi, Zhang, et al., 2011; Zhang et al., 2010) during the two years of intervention, and from interviews with the stakeholders (school leaders and teachers).
- **Spread:** In 2009, we worked with 1 teacher and 1 P3 class. In 2010, we worked with 2 teachers and 2 P4 classes. The school is spreading the mobilized curriculum for science to all P3 classes in 2012, and to all P4 classes in 2012.
- **Shift in reform ownership:** The school has taken over ownership by driving the spread of the mobilized curriculum for science to all P3 classes in 2012.

When the curricular innovation using mobile devices has been developed and studied in the context of one class, and the empirical evaluation of the mobilized curriculum has shown its potential for learning effectiveness, the school leaders decided that it was a worthwhile innovation and, in consultation with the researchers, would like to scale up the innovation.

We envisage the following four levels of scaling in the life-cycle of educational research and development work that lead to practical and policy implications for how to scale up in a school context:
Level 1: Developing the intervention as an innovation through a pilot in one or two classrooms
Level 2: Grade-level scale—spreading to more classes in a grade level and eventually to a whole grade level
Level 3: School-level scale—spreading the innovation to a whole school
Level 4: District or country-level scale—in which such work will have policy implications for the educational authorities.

We note that many research interventions do not survive the first level, or they merely go through many research funding cycles to iterate and re-design the intervention, and stop at that. Our interest is those research innovations which have been shown to have demonstrated learning efficacies, and there is purpose and commitment from all the relevant stakeholders to scale-up the intervention. We know it is rare for bottom-up research interventions to move from Level 1 to Level 2, let alone to the other levels. Thus it is critically important to study and learn from the few instances out there that actually move up the levels, and this is towards exemplifying and informing how research can really bridge the research-practice gap by through such scaling studies.

To make SLM an integral part of classroom practices, what would then be useful for the school and for the Ministry of Education is to "ruggedize" the innovation for sustainability to retain substantial efficacy in diverse or even relatively barren contexts. To ruggedize the innovation, robust-design strategies are needed that will enable the innovation to be used in multiple settings (Clarke & Dede, 2009). The school has moved onto the Level 2 and has plans to share the model with other schools.

So far, we have created a successful story of research-informed technology-enabled practices in the school, but we want to study further how to sustain such successful practices over time after an initial influx of resources and other forms of external support. For sustained changes, we would reemphasize the importance of meso-level mechanisms that support teacher capacity building and reinforce school leadership and culture. Barab & Luehmann (2003) discuss issues of sustainability and local adaptation as crucial for scale. They describe the teacher's role in local adaptation as identifying local needs, critiquing the innovation in the light of those needs, visualizing possible scenarios of implementation, and finally making plans or decisions concerning the implementation. Teachers will be ultimately involved in the adoption, customization, and implementation process, and they are continually remaking and contextualizing the innovation in terms of their local context. Barab and Luehmann (2003) argues that instead of the equation

Designed Curriculum = Implemented Experience
it should be
Teachers Perceptions + Designed Curriculum + Classroom Culture = Implemented Experience

For example, stark differences would exist between the customization and implementation of an innovation by a subject-matter focused teacher who is very concerned about students' understanding of the content compared to a logistically focused, teacher who is most concerned that the activities run smoothly and in the appropriated time frame. Our current phase of research studies how different teachers would locally adapt the innovation and what the resulting implemented experiences for the students and for the teacher would be.
The critical research questions are:

1. How to adapt and to "ruggedize" the innovation for sustainability to retain substantial efficacy in diverse contexts of more classes in the grade level and more teachers, in which some of the conditions for success are absent or attenuated? This includes designing a more device-independent curriculum intervention for mobile learning. By clarifying the design principles and the design affordances, it is hoped that the new curriculum development model is more generic and less dependent on the devices the students use.
2. What is the impact on depth, sustainability, spread, shift of ownership and evolution when a school takes over ownership and scales up an innovation developed from one class to more classes and eventually to a whole grade level?

3. What are the strategies for curriculum development and professional development models needed to support the spread of a mobilized curriculum to one whole level?
4. What are the strategies for organizational, technological and institutional changes needed for such a sustainable and scalable translation of research into practice?

A key issue in scaling is how to explicate the curriculum for the typical teacher. While during a pilot, one can leave both the content and the instructional strategies "looser" and "less-defined," that strategy will not work when all teachers read, use and interpret the same curriculum. The curriculum needs to be specified (Cohen & Ball, 1999). The goal is to make the content and the instructional strategies explicit – make the curriculum transparent for the teacher to enact initially and to adapt subsequently.

Another key issue relates to ongoing professional development. Teachers need to be provided with continuous support as they transition to a new curriculum, providing the performance support (Cohen & Ball, 1999). In contrast to a pilot, where the teachers are typically highly motivated and are top-notch teachers, as an innovation goes to scale, all teachers must be brought up to speed. Some of those teachers will be motivated and some less so; some teachers will be highly competent and some less so. Thus, professional development that is ongoing, continuous must be put in place to help all the teachers, especially the weaker ones, understand how to rollout the innovation.

The teachers need more collaborative work sessions so they can help each other with suggestions on instructional strategies and with tweaks to the curriculum. Those additional collaborative work sessions are critically important. If teachers feel isolated, they will not enact the innovation. They need to form their own learning community for mutual support and rely less on the research team. Moreover, the fundamental issue is to shift the teachers' epistemological and educational beliefs from being a transmissionist and behaviorist to being a socio-constructivist – without the shift, all the curricular mobilization efforts will become a mere formality.

Aligned with the issue of teachers adopting and adapting a new pedagogy, there is a need to make the formative evaluation techniques explicit and to show teachers how to use the formative assessments in order to tailor their instructional practices to the specific needs of the individual students. In order to go to scale, all teachers need to use the same formative assessment techniques and thus these techniques must be made explicit and teachers must be given support as they learn how to administer and use those formative assessments.

The curricular innovation is enabled by mobile technologies. A more sustainable approach is to adapt the curriculum for a more generic mobile technology. This makes the curriculum and the formative assessments work with a broader range of mobile technologies and applications. While initially the innovation used smartphones, the goal is to create materials – curriculum, instructional strategies, and formative assessments that are mobile technology agnostic. Mobile technologies are changing very quickly; thus, we do not want our learning resources to be tied to a specific mobile technology. Moving towards the blending of mobile and cloud computing technologies (Wong, 2012) is a direction in our agenda for scaling up. The new direction will not only offer a feasible solution to the above-stated challenge of changing technologies, but also has the potential to open up new opportunities for developing more advanced affordances to mediate a wider range of seamless learning activities.

What have we learned about scaling so far?

At the school, we have moved from serving 80 students (2 teachers) to serving 320 students (6 teachers). That almost order-of-magnitude jump in who is supported requires R&D if that transition is to be effective. What we learned in the pilot was critically important, e.g., that SLM can be an effective pedagogical model in supporting students as they engage in inquiry-based learning. However, in going to scale, the issue is no longer one of efficacy but one of infrastructure – how do we take an innovation that was hand-crafted and make it more rugged, more robust, more stand-alone, more transparent.

By the end of academic year 2012, all teachers of P3 have enacted the curriculum. What have we scaled up to enable this spread to all teachers and all classes in P3? The scale-up comprises these multiple dimensions:
1. Mobilized curricula (to lead students to self-directed learning and to bridging informal learning spaces)
2. Teacher facilitation skills
3. Teacher readiness

4. Student readiness including hardware and software training
5. Technology infrastructure, e.g. WiFi and 3G Connectivity; availability of mobile devices in 1:1, 24x7 basis

On assimilating the curriculum into the classroom culture (Squire, MaKinster, Barnett, Luehmann, & Barab, 2003), we summarize the challenges the teachers faced in doing a new curricular innovation that builds new skills and competencies beyond what is usually assessed in the standardized assessments used in the school. In the researchers' interviews with the teachers, the teachers raised these concerns:

- They are not sure if they are conducting the designed curriculum lessons in the right way. Some teachers expressed doubts on the students' ability for doing self-directed learning.
- Some teachers expressed that they needed help in developing and practicing questioning skills in the classroom.

What support was provided to the teachers to help them to address these challenges? The response to the first concern was for the researchers to provide support to the teachers by giving personalized feedback after each lesson enactment, and by helping the teachers to adapt the lessons for different ability students. The response to the second concern was for teacher sharing facilitated by the researchers in the weekly curricular design meetings to discuss questioning skills via modelling by a teacher or researcher, and by lesson study discussions on a recorded classroom sessions. While researchers provided these initial scaffolding, the plan was to build up the capacity of this group of primary 3 science teachers so that they can sustain the innovation in the coming years with fading from the researchers in the subsequent year.

In levelling up the capacity of the teachers, some new activities were planned. Arrangements were made for teachers to observe their peers conducting the lesson activities. There were some discussions for each teacher to co-teach with another teacher, but this was later not followed up on because of time constraints and time tabling issues (for example, when the teachers are teaching concurrently thus making it difficult to visit other classes for co-teaching). The researchers decided to edit short clips of videos which they found out to exhibit good teaching and learning scenarios to be shared with other teachers.

Scaling to Chinese and English language learning

In previous sections, we reported the outputs of our past research – the explication of the SLM, the curriculum development principles, the research methodology to study learners on the move, the PD model, our experience and understanding in fostering the technological and systemic conditions for the establishment of a sustainable 1:1 seamless learning environment, etc. Apart from the scaling up of the science curriculum, these research findings and deliverables are also serving as the basis for scaling the SLM to other school subjects. To date, two language subjects, namely, Chinese and English, have embarked on their respective journeys of transforming their curriculum into seamless learning environments, again with the eventual aims of cross-school scaling up.

"MyCLOUD" (My Chinese Language ubiquitOUs learning Days, 语飞行云) (Wong, Chai, Chin, Hsieh, & Liu, 2012) is a levelling up effort of the completed study of "Move, Idioms!" (Wong, 2013a; Wong, Chin, Tan, & Liu, 2010). The DBR study aims to develop a holistic and scalable mobile- and cloud-assisted Chinese Language (CL) seamless learning environment that is informed by language learning/acquisition theories for P3-P5 students. The project involves a 2 ½-year school-based intervention (August 2011-November 2013). The intention is to enculturate students in carrying out CL vocabulary learning and communicative writing activities that encompass formal and informal learning settings. Under this approach, students are assigned mobile devices on 1:1, 24x7 basis in order to stimulate and support their language learning both within and beyond the classrooms. In addition, a cloud-based, device-independent MyCLOUD learning platform leveraging mobile and cloud computing technologies has been developed for the purpose. Another aim is to design new classroom practices that will be integrated into the existing formal curriculum as well as foster students' competency to engender deep CL learning. The learning design principles developed by the researchers specifically foreground the bridging of language input (classroom, textbook-induced learning, and sharing of students' linguistic artifacts) and output (students' daily use of the target language through creations of linguistic artifacts such as photo taking / sentence making and social networking), and the bridging of learning contextualization and learning generalizations/reflections. On top of the more generic 10 features/dimensions of seamless learning as proposed by Wong and Looi (2011), the additional language learning-specific SLM dimensions rooted in various language learning theories may become the basis of the our future exposition of a Seamless Language Learning model. In addition, the research team is working towards spreading the curricular innovation to four more schools by 2014.

Aligned with the goal of implementing seamless learning and cultivating self-directed learners, smartphones were adopted in a trial design and implementation of the Primary 3 English language curriculum at Nan Chiau Primary School. This “WE Learn Project” is a scaling up of the seamless learning initiative in Primary 3 Science. By transforming the classroom from the traditional teacher-centered model to a learner-centered one, the project hopes to enhance the learning outcomes of students. In “mobilizing” the English curriculum and making it inquiry oriented, the teachers and curriculum developers drew on the two pedagogical strategies of P4C and Marzano’s

P4C (Philosophy for Children), (Lipman, 1980) draws on the Socratic method of learning pioneered initially in Plato’s dialogues and focuses on learning how to ask a question and how to respond when asked a question. Marzano’s 6-steps to Better Vocabulary Instruction, (Marzano & Pickering, 2005) help children understand words by building relationships and links amongst the words, by using words in their proper contexts.

In science, in CL and the English language learning, while the particular styles of pedagogy have their differences, the pedagogies are, at their roots, inquiry-oriented, and learn-by-doing pedagogies that reinforce each other (Norris et al, submitted). In all these three subjects, the affordances of the mobile technology enable the students to use multiple modalities and multiple media, and to carry and use the smartphones anywhere and anytime as a learning hub.

At this point of writing (in November 2012), there are now approximately 350 P3 (3rd grade) students using mobile computing devices daily for science. Out of these 350, 120 students are also using the devices for English and Chinese language (MyCLOUD) learning. The school has plans to scale to approximately 700 students in P3 and P4 in science, to 350 students on P3 English, and 350 students in Chinese language learning.

Conclusion

Within the educational research community, many research projects focused on designing or establishing the efficacy of innovations that work well within specific contexts. They typically face the conundrum of narrowing the research-practice gap when it comes to changing or transforming practices in schools and other contexts for learning, and to scaling up to meet the needs of a broader audience. Such research projects are also not organized to address the challenge of long-term systemic improvement as research-practice partnerships often go in tandem with short-term funding of grants and program initiatives at foundations and government agencies. This paper describes a multi-year research programme for doing scaling and implementation research. The agenda is contextualized in the example of a mobile learning curricular innovation in a Singapore school as it goes to scale.

In this curricular innovation on mobile learning, we established that SLM can raise student achievement in the context of one class and one teacher. We have developed models for:
1. Transforming a curriculum to harness the affordances of mobile technologies
2. Technology infrastructure and support for a mobilized curriculum
3. Teachers’ professional development through working with 1 teacher for a grade level 3 (P3) class in 2009 and 2 teachers for two grade level 4 (P4) classes in 2010.

Because SLM demonstrated increased student achievement, the school decided to scale-up the roll-out of the transformed curriculum to all the eight P3 classes, by doing the planning in 2011 and doing the scaling in 2012. The next step in the research and implementation trajectory brings us to scaling research which seeks to make research count in practice. The goal is to study the adoption and the adaptation of the curricular innovation as it goes to scale to more classes, more levels and more subjects, and to documenting the benefits of balancing fidelity of implementation with adaptation to dynamic local contexts. The programme of research enables us to articulate the SLM curriculum, the supporting resources, the teacher learning and professional development models with analysis of their impact, efficacies as well as weaknesses. The scaling research will establish a model of scaling that recognizes the range and diversity of teachers’ local needs as well as the necessary adjustments they need to make in order for the innovation to be useable and effective, and how the school can support them to know how to adapt the innovation and yet retain the essence of its efficacy.

We hope that our narration of the ongoing research journey from innovation to practice and to scale can inspire other research initiatives that will address the multi-term, multi-pronged, multi-level and systemic aspects of school-based innovations, and that yet at the same time, advance theory, frameworks, design principles, resources and strategies for effective and sustainable mobile learning.

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