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Precarious School Level Scalability Amid Network Level Resilience:

Insights from a multilevel multiscale model of scalability

Nancy LAW, Johnny YUEN & Yeung LEE
The University of Hong Kong

Abstract:

This paper presents the scalability analyses of two teacher networks in Hong Kong supported by university researchers. The Learning Community Projects (LCP, 2001-2012) promoted knowledge building pedagogy (Scardamalia 2002) using Knowledge Forum® for online discussions and networked with the Knowledge Building International Project (KBIP). Learning 2.0 (L2.0 for short) was a local network that provided a Moodle-based online learning platform and pedagogical design support to teachers for implementation of Liberal Studies, a new school subject stipulated as compulsory in the education reform process for nurturing critical thinking and lifelong learning skills during 2008 to 2012. Funding for both projects ended in 2012. All network activities in LCP ended, but a number of the L2.0 schools still sought to maintain the pedagogical practices and the online platform using their own resources. This paper proposes a multilevel multiscale model for analyzing the architecture for learning in the specific contexts of three teachers, two connected with LCP and one with L2.0. The analysis reveal that different *raison d'être* for the SUNG projects, system level involvement, school level conditions and how the learning technology relate to the wider technologic environment interact, leading to the different scalability outcomes observed. The implications of these findings and the utility of the analytic model are discussed.

Introduction

Large scale education reform efforts is not a new phenomenon, though the *raison d'être* for change evolved over time, beginning with the perceived need in the Western countries, particularly in US and UK, to revamp the science curriculum in the wake of the Russian launch of Sputnik in 1957. Imbalances and the pressures for change brought about by socio-economic and technological developments inevitably led to calls for change in education. Examples of reform goals that emerged since the 1960s include: changing the goals of science education from providing basic knowledge and skills for the industrial workplace to educating next generation scientists, changing the goals of education from educating the elite to education for all with a focus on ensuring basic literacies and fostering appropriate values for the general citizenry. With the introduction and increasing popularization of the personal computers in the early 1980s and the globalization of the Internet in the early 1990s, information and communication technology (ICT) have become a pervasive force that escalates the increasing importance of knowledge creation as a driving force of economic development.

Not only has the rationale for education reform changed over time, the pace of change has also escalated. Education reforms or innovations have become an increasingly important

agenda in many countries around the world, with numerous reform initiatives driven at national government level all around the world (e.g. OECD, 2015). It is startling to find that a compendium of ICT and education policies and policy related resources collected up to January 2013 by The World Bank (2013) from over 150 countries contained more than 1000 entries of national and regional policies and policy related resources, and a further 37 global and regional policy resources related to ICT in education from 18 regional or international organizations.

The increasing policy attentions and pressures from different sectors on education to reform are accompanied by changes in the models of change adopted by policy makers, differing in the combinations and emphasis on top-down government targets and support, bottom-up and public engagement (Hargreaves, 2008). There is also widespread recognition that sustainability is a major challenge facing reforms and innovations (e.g. Fullan, 2005; Hargreaves and Fink, 2006), and a whole body of literature that analyzes the different "ways" of change (e.g. Giddens, 1999; Hargreaves and Shirley, 2009), and the need for leadership to be able to follow the right way for change to be sustained. The fourth way promoted by Hargreaves (2008) is built upon an understanding of educational change as a complex system and a set of principles for learning and collaboration consistent with a network model of change is put forward. We share this view about the nature of the challenge in sustaining change, as we believe that educational systems are ecosystems (Law, Yuen and Fox, 2011), and as such the concept of scalability as advocated by Coburn (2003) and Clarke and Dede (2009) that emphasizes the dynamic and evolutionary aspects of the change process to be more appropriate. Also, based on an ecological model of change, as well as empirical evidence from studies of scalability on diverse contexts and scales of change (e.g. Kampylis, Law and Punie, 2013), the fundamental challenges to scaling are similar whether the change is initiated as a top-down reform or a bottom-up initiative—how educational change can become an epidemic (Hargreaves, 2003).

Theories of learning are important in guiding pedagogical designs and practices, but cannot prescribe them. Advances in pedagogical theory and practice are often necessary "by-products" of initiatives in educational reform and/or innovation that successfully bring impact to learning in classrooms, in addition these initiatives being underpinned by appropriate learning theories. In the educational change literature, there has been increasing attention given to architectures for learning (Stein and Coburn, 2008; Spillane, Parise and Sherer, 2011; Sherer and Spillane, 2011; Law, Yuen and Fox, 2011; Kampylis, Law and Punie, 2013), which can be described broadly as the organizational structure, mechanisms and artifacts that are available to facilitate interactions and to consolidate change at different levels of the education system. We believe that similar to the relationship between theories of learning and pedagogical (including assessment) research, research on how different architectures for learning impacts the scalability of educational change will contribute much towards our ability to design and evaluate architectures for learning to promote scalability of educational change. The study reported in this paper is an attempt to develop a model for analyzing the architecture of learning for change initiatives, and to explore the utility of this model by examining the explanatory power of this model.

This paper comprises two main parts. The first part puts forward a multilevel and multiscale model of scalability of educational innovations constructed on the basis of literature and in-depth case studies that the author has conducted. This model is grounded on a complexity theory of change and is designed to be operationalizable, that is, it can be used to evaluate the scalability status of an innovation (aka probability of scalability), as well as to guide the implementation design of innovation projects to increase their chance of long-term

scalability. The second part of the paper applies this model to three case studies of teachers engaged in two School-UNiversity-Government partnership projects (or SUNGs in short).

Theoretical framework

The biggest challenge to educational reforms or innovations is not to get them initiated or for these efforts to achieve targeted, observable success, but for them to be sustained and scaled. Here, scale does not refer simply to numbers, but as pointed out by Coburn (2003), has multiple dimensions that exert tensions on each other. Coburn's four-dimensional model (depth, sustainability, spread and shift) of scalability is underpinned by the perspective that the nature of what is being numerically scaled matters, and that the nature of the innovation inevitably change during the process of scaling. Clarke and Dede's (2009) extension of this model to include a fifth dimension, evolution, further highlighted the dynamism in the nature of innovations during the process of scaling. This five dimensional framework of scalability is adopted in the present study.

The nature of the challenge in scaling learning innovations is fundamentally also a learning challenge—the challenge of aligning learning at multiple levels (Davis, 2008; Law, Yuen and Fox, 2011). Aligned learning across levels (individuals, classrooms, schools, SUNG projects, systems and international institutions) and across units within the same level needs appropriate and effective architectures for learning. Prior work that study the scalability of reform and innovations have identified organizational structures and mechanisms for interactions and decision making as key components of such architectures for learning within schools and higher levels of local organization such as multi-school innovation projects (Law, Yuen and Fox, 2011) and districts (Stein and Coburn, 2008). While interactions and negotiations of meaning take place through both designed and lived organizations (Wenger, 1998), Stein and Coburn's (2008) study show that the district designed structure and nature of cross-community interactions play a very important role in mediating the teachers' opportunities to learn. Further, "structures of participation" that facilitate interactions and learning around an innovation do not need to be specifically designed for the innovation. In fact pre-existing communities of practice could serve as very effective architectures for learning. Law (2008) find that education systems that have a culture of connectedness across schools and communities are more likely to set up connectedness via organizational and technology networks that support participatory co-construction of technology-enhanced pedagogical innovations, which in turn have more sustainable innovations (Law, Kankaanranta and Chow, 2005).

In this study, we define architectures for learning as (1) organizational structures (design or pre-existing, which could be formal, or informal but stable), and (2) interaction mechanisms for interaction and participation, as well as (3) reification artifacts that communicate ideas and consolidate consensus and alignment. As technology often plays an important role in mediating interaction and participation within and across communities, it should also be taken into consideration as part of the architecture for learning, but it functions very differently in terms of the necessary characteristics compared to the other three components in the architecture for learning, as will be elaborated in a later section.

Most studies of scalability examine conditions of learning within a specific, well-defined network/group of schools, and comparative case studies generally comprise units of similar grain sizes. However, the European Commission funded meta-study of seven ICT-enabled learning innovations in Asia and Europe is unique in comparing the conditions of scalability in seven cases of varying scale from a single school to system-wide mainstreaming, to cross-

national initiatives (Kampylis, Law and Punie, 2013). All of these seven cases have been sustained and evolved to some extent over a minimum of several years, and a few have evolved over more than a decade. Also, with the exception of one case, the scale of these six cases varied from over 60 schools for the e-Learning Pilot project in Hong Kong (Law, 2013) to engaging over 200,138 teachers and other practitioners from 104,567 schools in 33 countries for the eTwinning project (Kampylis and Punie, 2013). The meta-analyses of these cases show that there is a competition between scale and level of innovativeness of the case. While designed-based research involving SUNG partnerships are generally limited in scale and start with some clear pedagogical vision and guidelines, as in the case of the three papers in this symposium, the presence of SUNG partnership vary among the schools within each of the other six cases. eTwinning is a most inspiring case in that it did not start with any clear pedagogical objective. The focal concern was connecting classrooms across different countries in Europe. It started with providing the technological infrastructure and support for connecting classrooms to provide "an opportunity for all students to learn and practice ICT skills and to promote awareness of the multicultural European model of society" (Kampylis and Punie, 2013, p.21). Over time, eTwinning provided a secure and democratic socio-technical platform for teachers and students to learn. In particular, with the evolving engagement and support from different levels of the European Union, from the European Commission to national support services, local and/or regional ambassadors to eTwinning teachers in schools, the project has engendered in participants a sense of involvement in an international community and created professional learning and critical reflection opportunities for teachers (Holmes, 2013). eTwinning illustrates an organic model of fostering innovations, which leverages the agency of teachers to innovate and improve. Advances in teachers' adoption of more learner-directed pedagogies were promoted through support at the higher levels such as providing professional development workshops and resources at regional or national levels, and competitions and awards at regional, national and pan-European levels to nurture self-organizing innovations that broadly align with the goal of nurturing 21st century learner capacities.

The case of Singapore's Masterplan 3 for ICT in education (Looi, 2013) in this set of seven case studies also reveal how system level intentional efforts to fine-tune over time the education goals and pedagogical focus of their IT in Education Masterplans, the organizational structures and foci in implementation, as well as the evolving reification artifacts including curriculum and assessment helped to align and advance learning at the system level to achieve pedagogical change alongside the integration of ICT across the curriculum.

An ecological perspective (Davis, 2008; Law, Yuen and Fox, 2011) for analyzing the scalability of ICT-enabled learning innovations needs to take account of the fact that classrooms and pedagogical practices are nested within multiple levels of the education system and the wider societal milieu, and scalability issues exist at each of these levels. The European Commission funded meta-study of seven ICT-enabled learning innovations (Kampylis, Law and Punie, 2013) further shows that scale matters for scalability, just as in biological ecosystems where the size of the habitat is one important determinant of the carrying capacity of the habitat for a specific species. The construction of highways often pose threats to the sustainability of the existing ecology as the carrying capacity of the resulting isolated spaces become much lower. One way to reduce the environmental impacts brought about by the construction of highways is to construct underpasses that allow animals to circulate across these separate spaces. These underpasses provide the architecture to reconnect these separate spaces to recreate a much bigger carrying capacity. Similarly, for architectures for learning to sustain pedagogical innovations, the architecture has to scaffold

interaction and participation not only across levels, but also across units at the same level to achieve some form of scale at each level.

Based on the above review of literature, we put forward four hypotheses on the scalability of technology-enhanced learning innovations:

1. Aligned learning needs to take place at multiple levels of the educational ecosystem in order that changes can gain depth, spread, sustain, shift in change ownership and evolve.
2. Just as peer-learning is found to be effective for supporting student learning and teacher professional development, learning of school leaders, administrators and policy-makers can be fostered through connected peer-learning within each of these levels within the educational ecosystem.
3. There are four important elements in the architecture for innovation-focused learning: organizational structures that directs and guide interactions; mechanisms for sharing, interactions and decision-making; artifacts that serve as reifications of outcomes of interactions to propagate decisions and advances in understanding; and technology infrastructure that support communications, interactions and knowledge management of individuals and communities.
4. Innovations that have better developed architectures that connect learning across levels and across units would be more scalable in all five dimensions of scalability.

Based on the above model, we have developed an operationalizable framework for analyzing the architecture for learning, i.e. the organizational structures, interactional and decision-making mechanisms, artifacts and technology that exist to *connect* agents (i.e. actors) at different sites and at different levels of the system. A schematic representation of the analysis framework is presented in Table 1.

Table 1. A schematic representation of the multilevel multiscale analysis of the architecture for learning within and across different contextual units of the hierarchical nested education system, and their effect on scalability.

	Within level		Cross level		Effect on scalability (depth, spread, sustainability shift & evolution)		Breakdown
Level	Within unit	Cross unit	Within unit	Cross unit	For itself	For other units	
International	*	*	*	*	*	*	@
System	*	*	*	*	*	*	@
SUNG Project	*	*	*	*	*	*	@
District/multi school org.	*	*	*	*	*	*	@
School (leadership)	*	*	*	*	*	*	@
Teacher	*	*	*	*	*	*	@
Student	*	*	*	*	*	*	@
Technology	#	#	#	#	#	#	@

* The researcher examines the organizational structures, interaction mechanisms and artifacts that may be present to scaffold learning and interactions among agents within each of these cells.

Unlike the other three elements in the architecture for learning, namely organizational structures, interaction mechanisms and artifacts, which are usually different for the different cells, there is the

same set of technology tools that serve to scaffold the many within- and cross- level and unit interactions. Hence instead of including technology as a fourth element in the identification of architectures for learning for each cell, technology is placed in the table as if it is a separate level and the analysis examines the role played by the technology in supporting communication, interaction and knowledge management in the respective cells.

@ Breakdown refers to the specific situations that challenged the scalability of the innovation at the respective levels, which in some cases actually led to the demise of the innovation at that particular level.

In this framework, the ecosystem comprises seven levels (student, teacher, school leadership, district or multi-school organizational units, SUNG projects, education systems and international organizations/societies) of actors, with technology that plays a role in mediating and scaffolding learning interactions as another separate level. For the actors at each of these levels, we would identify the architecture for learning for four possible kinds of learning interactions. Taking teachers as an example level, we can identify the following:

- Within level and within unit—architecture that scaffolds learning interactions among teachers within the same school.
- Within level and cross unit—architecture that scaffolds learning interactions among teachers in different schools.
- Cross level and within unit—architecture that scaffolds learning interactions among teachers and actors at other levels, such as the leadership, within the same school.
- Cross level and cross unit—architecture that scaffolds learning interactions among teachers and actors at other levels, such as the leadership, in different schools.

As learning interactions within the same unit as well as across multiple units are equally important with respect to ensuring long-term scalability, we refer to this as multiscale learning. Hence, we refer to this model for analyzing the architecture for learning as multilevel and multiscale.

Table 2 also provides a framework for recording evidence of scalability for each of the five dimensions as in Clarke and Dede (2009), and breakdown at each of the eight levels. Two kinds of scalability are being differentiated: evidence of scalability *within the same unit*, for example enhancing teacher level scalability in the same school, and evidence of scalability *in other units*.

Data sources and analysis method

In this paper, we apply this model to analyze three cases, each centered on the trajectory of learning and engagement in innovation for one teacher to examine the architectures for learning within a specific school and SUNG context within the broader Hong Kong education system, to examine the usefulness of this model in explaining the scalability challenges faced in each of these cases. Two of the cases (teachers A and B) participated in the same SUNG, the Knowledge Building Teacher Network (KBTN, http://kbtn.cite.hku.hk), but working in two different schools. The third case is Teacher C, who participated in another SUNG partnership, the Learning 2.0 project (L2.0 for short, http://learn20.cite.hku.hk), which was led by the same researcher (principal investigator) in the same research centre. These three cases were chosen to highlight how variations in architectures for learning at the international, SUNG project and school levels led to differences in scalability and sustainability of these three innovation cases.

Both KBTN and L2.0 are innovation teacher networks conducted as design-based research projects. Logfiles of online activities and interactions, field notes and audio recordings of meetings and interviews, teacher-generated curriculum materials and teaching plans, students' artifacts, videos of lesson observations, etc. have been collected throughout the duration of these multi-year projects. Systematic analysis of these data were carried out to identify the architectures for learning available for each of the cells in Table 1 for each of the three cases. The results of the analysis is reported in the next section.

In-depth case analysis of scalability for Teacher A's TEL innovation

Architecture for learning available to Teacher A

Teacher A became interested and motivated to try and implement the knowledge building pedagogical approach when she was introduced to examples of how students gained deeper understanding of subject matter knowledge through online discussions on Knowledge Forum® by other teachers in a workshop organized by KBTN. Law and Yuen (2011) provided a detailed description of how Teacher A improved her understanding of knowledge building, and refined her pedagogical design in KB implementation over the course of three years, demonstrating impressive advancements in Technological Pedagogical Content Knowledge (Law 2014). Much of Teacher A's learning took place through her interactions with other teachers in the KBTN, which in turn has benefitted greatly from the Knowledge Building International Program (KBIP, http://kbip.co/). KBIP was launched in summer 2007 at the Knowledge Building Summer Institute at the University of Toronto as a design-based international collaborative research initiative to advance knowledge building theory and practice, involving students, teachers and researchers from various active Knowledge Building sites around the world (Laferriere and Law, 2010). An overview of the first phase of the KBIP program (2007-2009) is described in Laferriere, Law and Montane (2012). Participation in KBIP is voluntary and only a small number of teachers in KBTN were interested and had the institutional support from their schools to be able to extend their KB pedagogical innovations to include this international collaboration component.

Two of the eight levels listed in Table 1 were totally absent in Teacher A's architecture for learning: system and district/multi-school organization levels. KBTN was supported by the HKSAR government as one of the many government funded initiatives to provide professional development support to teachers to advance the overall educational reform goals at the system level. However, there was no further involvement of the government in the project beyond the provision of funding. There was not even formal evaluation of the project and hence there is no learning at the system level from the project. The absence of system level involvement also meant that there was no cross-level learning facilitated by the HKSAR government for KBTN. In Hong Kong, there are also school districts, but the district offices of the Education Bureau only look after administrative and budget matters, and do not play any role or take any interest in curriculum or pedagogical matters. The absence of involvement at these two critical levels contrasts starkly with the architectures for learning available in the Remote Network Schools project described by Laferrière and Breuleux (2015) in this symposium.

Table 2 is a summary of the architectures for learning available to Teacher A at each of the six levels. At the international level, the KBIP as an *organizational structure* provided *learning and interaction mechanisms* through the Tomorrow's Innovators and associated IKIT Summer Institute (http://ikit.org) programs to participants from all levels. In the case of Teacher A, the KBIP facilitated cross-level and cross-unit interactions with other researchers,

Table 2. A summary of the architecture for learning available to Teacher A (black text documents the organizational structures, green text document the interaction mechanisms, brown text documents the artefacts that serve to reify and disseminate the innovation ideas and practices, red text describes scalability breakdown).

	Within level		Cross level		Effect on scalability (depth, spread, sustainability, shift & evolution)		Breakdown
Level	Within unit	Cross unit	Within unit	Cross unit	For itself	For other units	
International			• KBIP, IKIT • Summer Institute, Tomorrow's Innovators • Students' & teachers' online discourse on KF, Summer Institute Proceedings		Disseminate ideas, support bootstrapping in new sites and KB advancement of whole community (**depth, spread, shift, evolution**)		When affiliated innovation project funding ends, network sustainability challenged, esp. in teacher connectivity
System							
SUNG Project			• KBTN—network, clusters, seconded teachers, teacher associates • Weekly team meetings, monthly workshops, peer lesson observations • Online discussion database, handbooks, PD resources	• KBIP • Summer Institute, Tomorrow's Innovators • Conference Proceedings, Students' and teachers' online discourse	Advancement in PD support to teachers (**depth, evolution**)		When KBTN project funding ends, network activities not sustained
District/multi school org.							
School (leadership)							When Teacher A left the school, KB practices ended
Teacher		All 3 elements provided by KBTN SUNG network architecture.		All 3 elements provided by KBTN SUNG network & KBIP	Improvement in KB practice (**depth, shift and evolution**)	Some **spread** to other teachers within HK & in other countries	Participation in KBTN ended after moving to another school
Student	• Class and subject teacher allocation • Classroom T&L activities • Online discourse on KF, assignments & other artefacts as required by teacher	• KBTN award scheme & KBIP Tomorrow's Innovators • Activities of above 2 projects (optional) • Online KF discussion database, presentation in project activities		• KBTN award scheme & KBIP Tomorrow's Innovators • Activities of above 2 projects (optional) • Online KF discussion database, presentation in project activities	Varying levels of **depth, spread, shift and evolution** in KB practices. No direct evidence of sustainability outside of school year or scalability to other school subjects	Some **spread** to teachers in other schools through interactions in KB Award or Tomorrow's Innovators	When students are no longer in the "KB classroom", the practice may not be valued and would not continue as a formal part of their learning experience.
Technology	KF has its own suite of tools	Nil—KF is primarily a standalone technology	Views, registration codes etc. support multilevel, cross-unit collaboration	Nil—KF is primarily a standalone technology	Proprietary software, no mechanism for progressive improvement		Proprietary software, even basic maintenance is challenging

teachers and students from other KB projects in other countries, as well as facilitated cross-level and cross-school interactions with teachers and students from other countries as well as from Hong Kong. Online discourse of the Tomorrow's Innovators on Knowledge Forum® served not only as a key technology-supported interaction mechanism, but also as *artifacts* to document and mediate further interactions.

For the KBTN project that Teacher A belonged to, learning at a collective, community level also took place. Besides the architectures for learning through interactions with other KB projects made available through KBIP as described above, it also provides its own learning architecture. It created subject- and region- based clusters as *organizational structures* allocated with seconded teachers and teacher associates to plan and organize various professional development activities. The *interaction and learning mechanisms* these provide include weekly core team meetings, monthly teacher workshops, co-planning and peer lesson observations. The online discourse among network teachers on Knowledge Forum® as well as the KB Handbooks and other professional development resources developed by KBTN served as *reification artifacts* to further disseminate the learning outcomes within and outside of the network.

In 2005, Teacher A was given support from her principal to participate in KBTN and implement KB in her classrooms. She was later given approval to be on half-secondment to serve as teacher facilitators on KBTN. The fact that her school leadership supported her engagement in KB innovations and wanted to see KB spread in the school was not accompanied by the provision of architecture for learning at the school (leadership) level. Within the school as an organizational unit, there was no formal organizational structure or interaction mechanism that the school leadership assigned for KB implementation in the school. Hence, although Teacher A attempted to organize after-school teacher workshops for colleagues in her school, there was lukewarm reception and only few of her colleagues participated. There was no formal discussion of the status or development of KB among the school leadership team. There was annual reporting and sharing workshops for principals in the KBTN participating schools, no one from the school leadership team (principal, vice-principal, school-based curriculum development leader, etc.) participated in these meetings over the years.

At the personal level, Teacher A enjoyed much self-directed and peer learning opportunities provided through the KBTN and KBIP architectures, particularly during the time when she served as one of the seconded teachers on KBTN, which allow her a lot of lesson co-planning and peer-lesson observation experiences with teachers in Hong Kong and in other countries.

Students' learning in schools is generally organized in the form of formal grade level, class and subject *organizational structures* through the teaching and learning activities provided by their teachers. Students in Teacher A's KB implementation classes had opportunities to learning from their teacher as well as their classmates through the face-to-face and online *interaction and learning mechanisms* provided by A in class and on the Knowledge Forum®. For those students who opted to participate in the KBIP activities, they had further opportunities to learn from other researchers, teachers and students within the wider KBIP network.

Knowledge Forum® serves as the core technology platform to support the knowledge building discourse of all the different participants at different levels of the KBIP and SUNG partnership communities. It also provide a knowledge management mechanism to structure the themes, user groups and communities through the views and registration code functionalities. As a parsimonious digital communication and collaboration platform for the

multilevel and multi-scale interactions involved in KB pedagogical innovation, it serves as an integral part of the learning architecture for Teacher A and the different individuals and communities involved. On the other hand, as Knowledge Forum® is a proprietary software that does not provide easy connections with other learning management systems or digital learning resources and applications, there is no easy way for users to connect their learning activities and artifacts on KF with those on other platforms. This lack of ready connections between KF and other platforms also limit the possibility of users on other digital learning platforms to engage with the KB community through sharing the same common digital platform.

Impact of the architecture for learning on scalability of Teacher A's innovations

In this section, we will examine how the architectures for learning present in Teacher A's specific context affected the scalability of her innovation practices. We will examine how the opportunities for learning have contributed to increases in scalability at the different nested levels associated with Teacher A's KB innovations, the breakdowns in scalability encountered and whether these breakdowns were associated with weaknesses in the architectures for learning.

As we can see from the above analysis and the summary presented in Table 2, the most well developed architectures for learning were at the student and KBTN project levels, followed by the teacher level. At the student level, there are many ways for students to engage in peer learning within their own classrooms, as well as learning within and across levels with other schools in KBTN and KBIP. So there is evidence of increasing *depth*, *shift* of ownership and *evolution* in students learning as well as *spread* in KB practices within the student communities they have contact with (Law, Yuen and Tse, 2011). However, as class and subject level allocation of teachers in schools is organized on an annual basis, there is no direct evidence that the students' KB practices were sustained beyond the school year that they were taught by Teacher A.

At the teacher level, vivid descriptions of Teacher A's advances in pedagogical practice in terms of her understanding and implementation of KB pedagogy (Law, Yuen and Tse, 2011) as well as the Technological Pedagogical Content Knowledge that she has developed over the years (Law, 2014) have been reported. These demonstrate increasing scalability of Teacher A's KB practice in terms of *depth*, *shift* and *evolution* of her own practice as well as *spread* to other teachers in KBTN and KBIP. However, even at a personal level, when she subsequently moved to work in another school, she was not able to sustain her KB practice in the new school setting. There was no architecture for learning either within the teacher level within her own school or across different levels within her own school. This is a direct consequence of the absence of any architecture for learning at the school leadership level.

The architecture for learning at the school level was the weakest link other than the absence of any such architecture at the system and multi-school levels. The *optional mechanism* for leadership level interactions and learning provided by KBTN was not taken up by the school leaders in Teacher A's school. That proves to be the biggest challenge to scalability in Teacher A's multilevel context. Without aligned learning among teachers, among school leaders and across school leaders and teachers at the school, there was no scalability at the school level in any of the five dimensions of scalability beyond Teacher A herself. Hence, when Teacher A left, that also marked the extinction of KB pedagogy in that school.

At the SUNG project level, KBTN operated as a standalone innovation in Hong Kong. There was no formal structure or mechanisms for learning and collaboration with other innovation networks. It has structures and mechanisms to connect with learning at international, teacher

and student levels, but not locally at the school leadership or system levels. Hence the network was able to demonstrate increasing depth and evolution in the KB activities of the teachers and students over the years within the network. However, there is no formal structure or interaction mechanism for KB to spread or shift to other innovation initiatives or networks. KBTN became unsustainable when funding stopped at the end of the KBTN project funding cycle.

At the international level, KBIP is a consortium of loosely organized KB-related innovation networks. Over the years, KBIP has helped to enhance depth, spread, shift and evolution of KB in various countries via the respective local KB networks. Its sustainability is challenged when the associated local innovation networks' funding cycles end, as in the case of KBTN in Hong Kong. On the other hand, the reputation of KBIP and the associated IKIT community have spread over time, and in particular some very successful networks such as the Remote Network Schools in Quebec have contributed much to the sustainability of KBIP. The "carrying capacity" of the international community of researcher-educators is sufficiently large to remain resilient as an innovation network at the international level.

In-depth case analysis of scalability for Teacher B's TEL innovation

Architecture for learning available to Teacher B

Teacher B also participated in KBTN and all of the architectures for learning available through KBTN and KBIP described in the above case analysis were available to him. The main difference for B is the presence of architectures for learning at the school leadership level in his context. Teacher B's interest to participate in KBTN was stimulated by his former colleague, Teacher A. When discussing with Teacher B about his participation in KBTN, the principal indicated clearly that she does not see this involvement to bring much impact to the school unless Teacher B can also promise to play a role in spreading KB pedagogy beyond his own classrooms. Subsequently, the principal held meetings with her senior management team and decided that this innovation should come under the jurisdiction of the Chinese Language panel as Teacher B was a Chinese language teacher and he want to try out the KB approach with his Grade 5 class. Hence, even though Teacher B's participation in KBTN was initiated as a bottom-up innovation of an individual teacher, it became a grade level wide initiative led by B, with strong involvement and support from both the Chinese Language Panel Head and the School Principal. The formal subject panel structure, and the panel meetings, subject level co-planning meetings and peer lesson observations among teachers in the same subject panel became part of the architecture for learning among teachers within this school for propagating KB pedagogy. Lesson plans and curriculum resources were also produced by and shared among teachers in this process. Teachers' implementation of KB was also included for consideration in the regular staff monitoring and appraisal process. In fact, Teacher B was given a promotion to senior teacher after the first year of implementation in recognition of the achievements he made in refining and propagating KB pedagogy in the school, and to also formalize this role that he is subsequently expected to play in his promoted position.

Another difference in the architecture for learning for Teacher B was that he did not participate in KBIP as such activities were typically conducted in English. This limited B's peer and cross-level interactions to be limited to those within Hong Kong.

At the school leadership level, in addition to setting up the architectures for within school learning, the principal also took part in the optional leadership meetings organized by KBTN

and shared her views and experiences with other principals. She also attended the students' presentations of their learning in the annual KB award competition.

Impact of the architecture for learning on scalability of Teacher B's innovations

Given the relatively strong school level architecture for learning, there were observable differences in the evidence of school and teacher level scalability. At the school leadership level, the role of promoting and monitoring KB implementation was shifted from the principal to the Chinese Language Panel Head. At the teacher level, B advanced in his curriculum design and pedagogical facilitation in his teaching practices, demonstrating depth, heightening ownership, and evolution in his KB practices. There was strong evidence of spread as the other two grade 5 Chinese Language teachers were also exploring KB pedagogy in their classrooms.

While the conditions for scalability at the school level was relatively good in B's school, the practice was unfortunately not sustained beyond the funding period of KBTN. The challenge to sustainability encountered was not only the lack of network professional development activities to sustain and advance engagement, but also because of the absence of funding to maintain the KF platform and associated technical support. Table 3 summarizes the architectures for learning available to Teacher B at each of the six relevant levels of context, the impacts of these architectures and the specific breakdowns encountered.

In-depth case analysis of scalability for Teacher C's TEL innovation

Learning 2.0 v.s. KBTN as a SUNG partnership project

Teacher C was a teacher participant in the L2.0 project, which was also supported through government funding and led by the same researcher (principal investigator) as KBTN (http://learn20.cite.hku.hk/index_en.htm). L2.0 also shared similar project goals of promoting knowledge building pedagogical understanding and practices through professional development support to teachers and learning technology provisions and support to teachers and their students. The L2.0 project proposal was crafted towards the end of the KBTN project, and several design considerations were taken into account in view of the lessons learnt earlier to enhance the probably of scalability of the project outcomes at the end of the four years of the project lifespan (2008-2012). In particular, much attention was given to crafting the architecture for learning at system, school and technology levels.

Our experience in KBTN shows that if an innovation is simply to achieve a generally accepted desirable outcome, but does not relate to specific concerns or goals at the system or school level, it may succeed in getting funding support and permission to implement at these two respective levels, but would not be likely to engage agency at these levels to the extent that they will participate in learning interactions associated with the project. The focus of L2.0 was to solve an authentic problems that all upper secondary schools in Hong Kong face at the time: how to effectively cope with the introduction of a new compulsory subject, Liberal Studies, and in particular to ensure that they were able to guide and document students' ability to engage in extended Independent Enquiry Study projects that take one full school year to complete. The documentation part is linked with the requirement that IES assessment has to be carried out by teachers in the form of school-based assessment, and teachers need to be able to provide evidence that justify the scores they give for process (60%) and outcomes (40%) of the entire learning process.

Table 3. A summary of the architecture for learning available to Teacher B (black text documents the organizational structures, green text document the interaction mechanisms, brown text documents the artefacts that serve to reify and disseminate the innovation ideas and practices, red text describes scalability breakdown)

	Within level		Cross level		Effect on scalability (depth, spread, sustainability, shift & evolution)		Breakdown
Level	Within unit	Cross unit	Within unit	Cross unit	For itself	For other units	
International	SAME AS FOR TEACHER A in Table 2						
System							
SUNG Project	SAME AS FOR TEACHER A in Table 2						
District/multi school org.							
School (leadership)	• Senior management team • Leadership team meetings • School strategic development goal as basis to support KB	• Optional KBTN annual meetings of principals	• Staff monitoring & appraisal of teachers • Lesson observation & staff appraisal meetings	• Optional participation in annual KB award student event	Principal appointed panel head to support initiative (**shift**)		When KBTN funding ended, leadership attention moved to other initiatives
Teacher	• Subject panel • Panel & subject level co-planning meetings • Curriculum resources & plans shared	• KBTN—network, clusters, seconded teachers, teacher associates • Weekly team meetings, monthly workshops, peer lesson observations • Online discussion database, handbooks, PD resources		• KBTN—network, clusters, seconded teachers, teacher associates • Weekly team meetings, monthly workshops, peer lesson observations • Online discussion database, handbooks, PD resources	Improvement in KB practice (**depth, shift and evolution**)	Some **spread** to other teachers in the school	When KBTN funding ended, weak motivation to continue use of KF, KB practices subsided
Student	• Class and subject teacher allocation • Classroom T&L activities • Online discourse on KF, assignments & other artefacts as required by teacher	• KBTN award scheme • Activities of KBTN award (optional) • Online KF discussion database, presentation in project activities		• KBTN award scheme • Activities of KBTN award (optional • Online KF discussion database, presentation in project activities	Varying levels of **depth, spread, shift and evolution** in KB practices. Some sustainability within duration of KBTN as school decided to continue KB beyond school year.	Some **spread** of good practices to teachers in other schools through interactions in KB Award	When students are no longer in the "KB classroom", the practice may not be valued and would not continue as a formal part of their learning experience.
Technology	SAME AS FOR TEACHER A in Table 2						

By choosing pedagogical and assessment support for Liberal Studies as the focus for the SUNG project, L2.0 lost the ideological and conceptual focus on pedagogy that KBTN had. In KBTN, the teachers who joint were attracted by the ideological ideal and concept of knowledge building, even though they may not have a full understanding of the philosophical underpinnings or its implementation requirements and complexities. L2.0 highlighted a pragmatic focus of addressing a real life problem. Participation in the project was required to be a school level decision (unlike KBTN that required an individual level commitment from the teacher). While the subject Liberal Studies did stipulate a curriculum focus on fostering students' inquiry skills and lifelong learning capacity, we did find a much stronger pragmatic focus on the part of the participating schools and teachers to seek university support in deploying technology to support school-based assessment of students' inquiry. Whereas the KBTN participating teachers' primary focus was on whether they were actually implementing KB pedagogy, and whether they could improve their curriculum design, facilitation and assessment practice to help their students to achieve higher levels of KB outcomes, the L2.0 teachers rarely raised conceptual or pedagogically focused questions of their own accord.

There are two further important differences between L2.0 and KBTN as SUNG partnerships. Firstly, as a project focused around a local curriculum subject, it lacks the conceptual/ideological connection to any specific international innovation community. Secondly, the technology platform has to be designed and developed as part of the innovation project by the University research team as a key deliverable in order that the technology support can be customized to meet the curriculum and assessment needs of the Liberal Studies subject. Moodle was selected as the technology platform to serve as a base for the customization of the digital Learning Support Environment usually referred to as Learning Management System (LMS). We consider LMS to be a misnomer as the focus is on learning support and not on management. Hence we named the customized digital learning support environment iLAP, standing for interactive Learning and Assessment Platform.

In summary, L2.0 as SUNG partnership research project was guided by ecologically inspired design principles to structure architectures of learning that would maximize the possibilities of engaging aligned learning at both system and school levels. The detailed architectures for learning available to Teacher C under this broad SUNG partnership context are described in the next section.

Architecture for learning available to Teacher C

Teacher C was the Panel Head for Liberal Studies in her school. The principal of C's school was in fact the most enthusiastic and supportive of the principals in the L2.0 network. He was a firm believer that ICT has the potential to bring about much richer learning experiences to students and serve as a valuable knowledge management tool for assessment and teaching.

A summary of the architecture for learning available to Teacher C is presented in Table 4. In order to engage system and school level personnel in the L2.0 project in some ways so that they will have some knowledge of this SUNG Partnership, and interact with different elements of the project, including the offering of advice on directions and implementation, a Steering Committee for the project was set up. One of the Curriculum Officers in the Education Bureau in charge of Liberal Studies was invited as a Steering Committee member to facilitate communication and mutual learning between the Liberal Studies curriculum officer community and the L2.0 teacher and researcher community. The Liberal Studies curriculum guide and assessment syllabus served as the reification artifact to guide the liberal subject development.

Table 4. A summary of the architecture for learning available to Teacher C (black text documents the organizational structures, green text document the interaction mechanisms, brown text documents the artefacts that serve to reify and disseminate the innovation ideas and practices, purple text denote rudimentary scalability).

	Within level		Cross level		Effect on scalability (depth, spread, sustainability, shift & evolution)		Breakdown
Level	Within unit	Cross unit	Within unit	Cross unit	For itself	For other units	
International							
System			• LS curr officers participate in L20 SC* • Curriculum guide & assessment for Liberal Studies				There was little personal commitment/contribution from curriculum officer. Acknowledge L20 useful for LS implementation
SUNG Project	• Informal meeting of project team members from KBTN & L2.0 (both were projects operated under CITE)		• L2.0 SC*, project clusters • Half-yearly meetings, • Joint school co-planning (occasional) • Minutes of meetings recording agreement on dates & events		Advancement in PD support to teachers (**Spread** in reach within schools & to new schools, **depth, evolution,** some **shift of ownership** to teachers)		When L2.0 project funding ends, a few schools pay service fee to CITE to continue using software platform & technical support, not professional support.
District/multi school org.	• Leadership & joint PD organization structures in sch. operating body • Joint school PD events		• Various joint PD organization structures in sch. operating body • Joint school PD events		Participation in project **spread** to another school under the same sch. operating body		There is no formal role of school operating body in project.
School (leadership)	• Senior management team • Curriculum leader-ship meetings • School strategic development goal	• L2.0 SC • Half-yearly SC* meetings, principals (occasional) in joint school co-planning & lesson observations	• School strategic development team for new school subject LS • Curriculum leadership meetings • Decisions on sch routines: class size & staffing, timetabling, technical support, etc	• L2.0 SC (include all principals & some teacher rep) • Half-yearly meetings • Principals in (occasional) joint school co-planning & lesson observations	**Sustained** leadership support for ICT-enabled collaborative inquiry), **spread** to other subjects & levels outside of LS. Increase in leadership team's **depth** of understanding.	Some small influence on other schools through informal sharing and meetings.	When project end, leadership still value the innovation and used various means to seek funding to continue the use of the technology platform.
Teacher	• LS Subject panel • LS and IH# joint subject panel for entire school. • Panel meetings, co-planning meetings & lesson observations linked with L2.0 project • Curriculum resources & plans shared	• L2.0—network, clusters, seconded teachers, teacher associates • Monthly teacher workshop, weekly team meeting, joint school PD under sch. operating body • iLAP platform, PD resources, co-planning outcomes	• School strategic development team for new school subject LS. • L20 SC • Formal & informal strategic & sharing meetings with leadership • Staff allocation & schedule of PD for all LS/IH teachers—long term PD plan	• Informal peer-lesson observation, co-planning meetings through L20	Improvement in understanding and in practices on design & facilitation of ICT-enabled collaborative inquiry (**spread**, **depth, shift, sustainability, evolution**)	Some **spread** to other teachers in the school	When project end, teachers still supported by school to continue the innovative practice

Table 4 continued.

	Within level		Cross level		Effect on scalability (depth, spread, sustainability, shift & evolution)		Breakdown
Level	Within unit	Cross unit	Within unit	Cross unit	For itself	For other units	
Student	• Subject taught in a class by the same teacher • Classroom T&L activities • Online activities, discussions, artefacts set by the teacher				Varying levels of **depth** in students' collaborative inquiry capacity using ICT. Reasonable chance of **sustainability** through engagement in LS subject	No evidence of cross-unit impact.	When project end, students still have the opportunity to engage in collaborative inquiry
Technology	• L2.0 seconded teacher team • Weekly design meetings • Moodle-based iLAP platform to support e-Learning	• L2.0 seconded teacher team • Weekly design meetings • Single sign-on to other applications through iLAP platform	• Levels of user access allow cross-school viewing & collaboration • Workshops & peer lesson observations • Shared tools & resources on iLAP	• Levels of user access allow cross-school viewing & collaboration • Workshops & peer lesson observation • Shared tools & resources on iLAP	iLAP is further developed in other projects and used by an increasing number of schools for different purposes.	iLAP serves as a platform for introducing other tools from members for sharing among the community.	As an open source software, iLAP is reasonably stable and relatively easy to maintain.

* SC is short for Steering Committee.
# IH is short for Integrated Humanities, which is usually offered at the lower secondary level to prepare students for Liberal Studies at the high school level.

As explained in the case description for Teacher A, the district offices of the Hong Kong Education Bureau do not play any role in curriculum or pedagogical matters of schools. On the other hand, many of the publicly funded schools in Hong Kong are not operated by the government, but by various non-profit organizations such as church organizations, religious or fraternity groups. Teacher C's school is one of six secondary schools operated by a local charitable organization. There are regular meetings among the leadership of these six schools and they also organization joint teacher professional development days annually. The leadership in this school network thus learnt about L2.0 project from C's principal. One of the other five schools in this network also joined the L2.0 project upon the recommendation of C's school. Later, Teacher C was asked by the network to organize a special joint school professional development day for Liberal Studies teachers to share experiences from the project. Teachers in the L2.0 project unassociated with this charitable organization's school network as well as the project researchers were also invited to contribute as speakers at this professional development event.

At the school level, the senior management team led by C's school principal played an even more proactive role in the school's participation and implementation of the SUNG project compare to that in B's school. C's principal identified L2.0 as the professional development support project that the school should participate in after receiving request from his Liberal Studies teaching team that they would like to have support on using ICT to help them in the implementation of Liberal Studies. Hence, similar to the case of B's school, C's principal participated in the half-yearly L2.0 Steering Committee meetings to discuss and liaise with other principals on planning for project development over the four years of the project duration. The school has also established its own strategic development team to prepare for the implementation of the Liberal Studies subject, which all schools offering grade 10 programs had to launch in September 2009. Hence engagement of the school in L2.0 became a formal part of the agenda for the Strategic Development Team, and subsequently incorporated into the Liberal Studies Panel meetings after the subject was launched. Performance and contributions of teachers to the implementation of L2.0 was also taken into account by the school leadership as an integral part of the staff monitoring and appraisal process. In fact, Teacher C was subsequently promoted to Vice Principal position in her school in the final year of the project to take charge of school-based curriculum development.

At the teacher level, C had a lot of opportunities to work with other teachers both within her own school within the school's own organizational structures and mechanisms. The most important learning outcome at the school level was in fact brought about by the cross-level architecture for learning. The Liberal Studies teachers were able to negotiate with the school leadership on the kind of organizational and resource support needed for effective implementation of the technology-enhanced pedagogy promoted by the L2.0 project. In brief, the teacher team convinced the school that within the confines of existing resource allocation for implementation of the new subject, the following (changes in) arrangements would be the most cost-effective:

- Class size and teaching load allocation—instead of having 7 smaller classes (size=28) as permitted by the government funding for implementation of the new subject, it would be preferable to maintain the normal class size (=40). This will allow for co-teaching to be arranged for Liberal Studies without further extra funding. Each class was to be taught by a main teacher for Liberal Studies (who may be more or less experienced) throughout all teaching periods, and an additional co-teacher for 2 out of 6 weekly teaching periods. The co-teacher would be allocated based on the experience profile of the main teacher so that one would be more experienced and the other less.

The co-teaching periods would always be used for the teachers to try out more challenging pedagogical arrangements.

- Pedagogical technological support—In anticipation that there will be substantial extra workload associated with preparation to launch the subject, the school appointed an additional teaching assistant in the first year of the project to support the teachers. The teaching assistant who was hired was a fresh graduate with teaching qualification and good IT skills so that she was able to help with addressing technical issues as well as the development of curriculum resources and learning tasks involving the use of technology. This teaching assistant also served in a liaison role between the teachers and the L20 project team members in communicating the teachers' ideas, concerns and requests, including issues related to the functioning and desired features of ILAP.
- Timetabling arrangement—the teachers recognize the Independent Enquiry Studies component of the subject to be the most challenging, and would like to spend much of their efforts on planning, implementation and refinement of their teaching and assessment on this component, which was to be conducted in the grade 11 curriculum for this subject. The teachers wanted all five classes to progress in lock step manner in terms of timetable scheduling to allow for speedy review and agile responses based on their observations during class observations. In order to avoid the synchrony in teaching schedule to be broken by school holidays or unexpected typhoons, etc. the teachers requested the one period per week of Independent Enquiry Studies for this subject to be taught on Monday for all five classes. This period on Monday was also set as one of the two weekly co-teaching periods. This timetabling arrangement allow the team to have maximum interaction and peer observation on Monday and they also schedule their weekly team meeting right after the end of the five Liberal Studies classes.
- Computer lab access and technical support—The teachers saw iLAP to serve the greatest potential for supporting student learning and school-based assessment in the Independent Enquiry Studies component of the subject. Hence they requested that one of the three computer laboratories in the school to be reserved totally for grade 11 Liberal Studies and to arrange for one of the school's computer technicians to be on duty during the grade 11 Liberal Studies classes in the computer lab. This will ensure that they would always be able to implement their e-Learning plans during this segment of the timetable.

These requests were accepted and became decisions that were properly minuted in the School's Strategic Planning Committee records and can be considered as reifications or outcomes from the cross-level learning process. This reification then feeds back to further change the organizational structure and interaction opportunities for the teachers concerned, further improving the architecture for learning for C and her colleagues.

At the student level, while students had opportunities to engage in collaborative learning in groups, including the use of electronic tools such as discussion forums, wikis, blogs and e-portfolios, there was no special attention given to fostering interactions and peer learning with students in other classrooms within their own schools or in other schools.

At the technology level, our experience in KBTN demonstrates the value and utility of a single technology platform such as Knowledge Forum® in supporting cross-level and cross-unit communication and collaboration. On the other hand, two characteristics of KF impose constraints on its scalability as a technology platform in scaffolding innovation. First of all, KF is designed as a self-contained, standalone technology that focuses entirely on scaffolding online discussions. While discourse is a very important mechanism for knowledge building, there are many other forms of e-Learning support that is also valuable in supporting learning

and assessment. In particular, a good user management system would be necessary to keep track of the many learning tasks and students' performance in order to fulfill the needs of supporting school-based assessment required by the Liberal Studies subject. In fact, teachers who are interested in adopting e-Learning in their own pedagogical practices tend to be receptive to the many new learning tools and applications that come onto the market everyday. Particularly attractive to teachers is that many of these applications such as shared mind mapping, storytelling and annotation tools are freeware. We experienced tension with teachers in earlier projects when we were perceived to be only interested in (i.e. loyal to) one software while oblivious to other, more attractive ones.

Another constraint to scalability as a technology platform is KF's nature as a proprietary software. Even assuming that the software itself will remain sustainable as a product from a highly respected and very well established research team based in the University of Toronto, it would be hard for individual schools to continue to use the software without technical or professional support beyond one or two years after the end of a funded SUNG project. Our goal is to maximize the probability of scalability (and at the minimum sustainability) when the SUNG project ends.

Hence, we consider it important that the ecological principle be also apply to our selection and development of the learning technology in the project. Similar to the survival of a biological species, the sustainability of a technology has to be considered within the broader ecological context of the species. Species that have mutually beneficial relationships with many other successful species in its ecosystem, and species that are able to evolve at a fast rate (short reproduction cycles) are more likely to survive. Applying these principles to the case of learning technology, we decided that we should select a successful (i.e. popular with a large user base) open source Learning Management System as the base for development of iLAP. A successful open source software has a much better chance of long term sustainability with frequent updates and new features added because of the large user base. The choice of an open source software for development of iLAP also ensures that knowledge and expertise on maintenance of the software would be widely available in the community. It also means that schools can distribute the software to schools at the end of the project funding cycle without concerns about licensing arrangements. We also wanted to choose a software that provides easy single sign-on user management to connect directly between iLAP and other popular digital learning resources and applications. In the end, we chose Moodle as the base for our development of iLAP, as it has all the features associated with a high probability of long term sustainability.

Another design principle in the development of the iLAP technology platform was to involve project teachers as partners in the learning technology co-design. Identification of the key pedagogical activities and consequently features and functionalities desired of iLAP to support those activities (whether blended or entirely online), followed by incremental and iterative prototype development and field evaluation of those features and functionalities constituted the core focus of the L2.0 project meetings with teachers in the first year of the project. From the second year onwards, with the formal launch of the Liberal Studies subject, the project participants shifted their main attention towards pedagogical design, implementation and assessment. However, the continuing enhancement of iLAP as well as the co-design process did not stop, but continued throughout the subsequent three years of the project.

The learning technology co-design process was in itself also a professional development process as the project research team introduced different technologies and ideas within the authentic curriculum and pedagogical contexts of the Liberal Studies subject. The advantage

of such an approach ensures a good pedagogical understanding of the technology and its intended usage as well as ownership of the technology as a co-designed artifact. In a deep sense, iLAP also serves as a reifying artifact that captures and consolidates the technological pedagogical content knowledge and aspirations of the entire project team. In the words of Teacher C, the co-design process was for her a process of making her dreams about technology-enhanced learning come true, and the continuing iLAP development allowed the teachers to continually extend their technological pedagogical dreams.

An important design feature of iLAP was to enable teachers to visit each other's online courserooms, including the learning activities and digital artifacts produced by students. iLAP hence served also as a sharing and knowledge management platform for the project.

Impact of the architecture for learning on scalability of Teacher C's innovations

A comparison of the architectures for learning summarized for the three cases in Tables 2 to 4 shows clearly that the architecture for learning in the case of Teacher C was much stronger compared to that of Teacher A or B. While learning and interactions at the international level was absent for this project, because of the SUNG design features of L2.0, there was at least some presence of organization structures, interaction mechanisms and/or reification artifacts at seven of the eight levels of the education ecosystem. Based on the hypotheses presented in the theoretical framework section of this paper, L2.0 should be able to demonstrate much higher probabilities of scalability given the stronger, better developed architecture for learning in this project. In this section, we will examine the evidence of scalability or otherwise for the different levels associated with Teacher C's innovation, as was done for Teachers A and B's innovations earlier.

At the system level, even though the engagement of the Liberal Studies Curriculum Officer from the Education Bureau invited to serve as a member on the Steering Committee of the project was relatively weak, there was acknowledgement that the project contributed valuable support to Liberal Studies implementation.

At the SUNG project level, similar to KBTN, there was a limit to the approved funding period. However, unlike the case of KBTN, the teachers and school principals were very concerned about the sustainability of the project beyond the approved funding period. They started discussing with us and among themselves how the good practices develop and in particular the technology platform can be maintained for their use after the project funding comes to an end. As is usual for projects of this kind, the funding was granted to support innovation, and would not be amenable to fund recurrent expenses. In the end, some schools were so convinced of the importance of ensuring a stable access to iLAP that they negotiated a service contract from CITE. These schools have also extended their use of iLAP to subjects beyond Liberal Studies, and with grade levels from secondary one upwards. One of these schools further developed a small innovation project to secure funding to pay for two years of CITE service for iLAP. Hence while the SUNG partnership was not sustained, there were elements of it that the schools treasure deeply to have made efforts to fund their sustained presence.

At the school operating body level, the involvement was informal, and the one associated with Teacher C's school was the only one that had some direct interactions with the L2.0 project. As such, it is difficult to argue that there is a sustainability issue for this context.

At the school leadership level, there were multiple organizational structures and interaction mechanisms available to scaffold within and cross-level learning involving the school

leadership. Hence the principals were relatively knowledgeable about the actual operation of the project and its value. It is thus not surprising that, as mentioned before, some of the school leaders saw the value of the project to go beyond the designated scope of improving learning and assessment for Liberal Studies, and sought ways to sustain some aspects of the innovation after the project funding ended.

At the teacher level, there was also a rich array of supportive architectures for teacher learning and interactions among peers, as well as with school leaders and other stakeholders, within and outside of their school. Teacher C and her colleagues took great ownership of the project and over time demonstrated depth, shift, sustainability and evolution in their practices. Furthermore, the energy generated by the Liberal Studies team caught the attention of teachers in other subject areas such as Chinese language, who asked to also be allowed to use iLAP in their teaching. Teacher C and her colleagues also promoted the project to Liberal Studies teachers in other schools and succeeded in attracting one of their network schools to participate in the project.

Discussions

In this paper, we have tried to apply the multilevel multiscale model to analyze the architecture for learning for Teachers A, B and C, taking full account of the nested levels of their context from the student level all the way to the international level. We have also included the learning technology used as one of the "levels" of the educational ecosystem context for the innovations. Based on the above analyses, we have the following observations:

- The two SUNG projects, KBTN and L2.0, contributed significantly to all five scalability dimensions through scaffolding multilevel and multiscale peer professional learning and providing technological-pedagogical support.
- Differences were also observed between the two SUNG projects in some important aspects that affect their scalability. Teachers in KBTN were primarily motivated by their own pedagogical beliefs. Participation in L2.0 was a school-level commitment to serve the pragmatic need of launching a new compulsory school subject. The latter showed much stronger *sustainability* at the school level.
- Interactions scaffolded by KBTN primarily served like-minded teachers through cross-school collaboration locally and internationally. L2.0 interactions were problem-oriented, with school-based scaffolding being a major feature of the project. The KBTN teachers demonstrated greater advancement in *depth* at the individual level, while L2.0 showed more *spread* and *shift* in pedagogical practices and *evolution* in school-based implementation strategies.
- Of the two case teachers in KBTN analyzed, B received explicit support and recognition from the principal. Because of the much better formulated architecture for learning in B's school, he was able to *spread* and *evolve* the innovation more effectively in his own school.
- Continued use of the respective online platforms beyond the project-funding period was more easily *sustainable* for the open-source product used in L2.0.

This initial exploration of the architecture for learning and scalability of three cases of technology-enhanced pedagogical innovations associated with SUNG projects using the multilevel, multiscale analytic framework shed light on some important considerations in the design of SUNG projects to enhance their probability of scalability:

1. Scalability is not a quantum state but is relative and dynamic. The three cases illustrate that scalability issues have to be attended to at all levels, irrespective of who or at which level is the initiating agent if an innovation were to achieve scalability.
2. The probabilities of scalability at each of the different levels can be traced back to the differences in the architecture for learning available to that level within and across units as well as within and across levels.
3. Within unit spread at the school and teacher levels are critical to the scalability of an innovation even at the SUNG level. A robust architecture for learning is absolutely necessary at these two levels for scalability overall.
4. To achieve spread at school and teacher levels require agency to drive the innovation from within these two levels, which implies that a shift of ownership for the innovation must also take place at these levels in order to achieve scalability.
5. There could be isolated schools that have a well-developed architecture for learning at the school level as in the case of B's school. However, for a high proportion of the participating schools to have in place such a well-developed architecture, the driving rationale for an innovation has to go beyond a pedagogical ideal to link with some tangible need, for example curriculum and/or assessment reform (as in the case of L2.0), or a sociopolitical agenda at the system level as in the case of RNS (see Laferriere and Breuleux, this symposium).
6. System level involvement and support is of critical importance for the long-term scalability of a project.
7. The presence of an international level of engagement in the architecture for learning is an advantage. However, if the focus of the innovation is purely ideologically driven without explicit links to some pragmatic concerns such as curriculum or assessment changes at the system level, it is difficult to attain scale in terms of larger numbers. The international level of engagement would have stronger impact if these actors were connected directly to the system level actors, such as in the case of RNS.
8. The literature on learning technology generally focuses on the role it plays in supporting the learning process, but not in the role it plays in relation to the scalability of an innovation. The implicit assumption is that if the technology can be shown to enhance learning, then it will be adopted. Unfortunately, the history of technology in learning and education does not confirm this. In our analysis, we find that the positioning and relationship of the learning technology used within the wider sociotechnical ecosystem is important. In particular, if the technology platform already has a large clientele base as in successful open source software, and has features such as single sign-on that help to connect the technology platform to other popular applications, there is a higher chance (or lower threshold) of adoption.

To summarize, this initial exploration with the multilevel multiscale analytic framework shows that it does have utility in helping us to gauge where the weakest links are in the architectures for learning in educational change initiatives. Further research is needed to explore the explanatory, predictive and prescriptive potential of such a theory.

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