A Self-Organizing Network of Schools That Transform Teacher and Student Learning Through Socio-Technical Co-Evolution

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Abstract: Scaling up educational innovations through networks has attracted much interest in diverse research and education policy communities. Literature on scaling are often associated with top-down or partnership models of change, and the goals, resources and technology tools used are generally defined and developed by stakeholders outside of schools. This paper reports on the sustained efforts of a self-organizing network of special needs schools in Hong Kong that has worked together for more than a decade to realize the vision of providing the same educational opportunities to children with various degrees of learning disability. The analysis focuses on how their engagement in the development of a collaborative platform for teacher learning started a journey of socio-technical co-evolution that resulted in exponential scaling of the innovation both qualitatively and quantitatively. The evolution trajectory of this network shows characteristics and susceptibilities similar to those in the socio-technical innovation literature.

Introduction

Scaling up educational innovations (Coburn, 2003; Clarke & Dede, 2009) has been a central theme for education research for several decades, starting from the educational leadership and reform literature (e.g. Fullan & Hargreaves, 2009), and attracting increasing interests from the learning sciences community (Vuorikari, Kampylis, Scimeca & Punie, 2015; Fishman, Penuel, Allen, Cheng, & Sabelli, 2013). Scaling up of innovations are particularly important as countries around the world are launching various curriculum and pedagogical reform efforts since the turn of the millennium, to bring about changes in curriculum standards, and/or to bring a stronger focus on some higher level generic capacities such as collaboration, communication, creativity and critical thinking, often referred to as 21st century outcomes (Partnership for 21st Century Skills, 2009). Scalability has also been identified as a key issue in e-Learning implementation (Law, Yuen, & Fox, 2011) as use of digital technology per se would not bring about enhanced learning outcomes, and much depends on the pedagogy adopted (Watson, 2001; Fisher, 2006). In order for e-Learning to bring about transformative learning outcomes requires deep pedagogical transformation (Somekh & Davis, 1997). Hence the challenge to scaling up ICT-enabled learning innovations is primarily one of learning at multiple levels, as sustained changes in classroom practice requires aligned changes to take place within the education ecosystem from classroom to school to district and system levels (Davis, 2008; Law, Niederhauser, Christensen, & Shear, 2016).

Innovation networks have been found to be a productive model of supporting teacher learning for innovation (Hamel, Turcotte, & Laferrière, 2013; Vuorikari et al., 2015) as it provides room for teachers to engage in peer learning and engage in productive knowledge building in the innovation process. However, as educational change is located within a complex ecosystem with many established rules, regulations, practices and expectations as well as organizational, physical and technological infrastructures, the architecture for learning (Wenger, 1998) plays an important role in such situated learning contexts. Architecture for learning can be broadly defined as the "organizational structure, mechanisms and artefacts that are available to facilitate interactions and to consolidate change at different levels of the education system" (Law, Yuen, & Lee, 2015, p. 3). Comparative studies of innovation development under different architectures for learning have revealed that coupling mechanisms (Spillane, Parise, & Sherer, 2011) and the kind of organizational structures and interaction mechanisms (Stein & Coburn, 2008) impact strongly on the effectiveness and sustainability of reform efforts.

Design-based implementation research (DBIR) (Fishman et al., 2013) is an approach to scaling educational innovations that builds on the design-based research approach developed in the learning sciences community (Brown, 1992; Collins, Joseph, & Bielaczyc, 2004) to connect research and practice in an organic nexus to address the challenge of applying research-based learning principles to guide learning innovations in authentic classroom contexts. At the core of the DBIR approach is the concept of infrastructuring (Penuel, 2015), which recognizes the crucial role of the architecture for learning and interactions in the success of scaling efforts and argues for the need to engage in organizational sensemaking

through partnership between researchers and educators in order to be able to make dynamic changes to infrastructures and designs at different levels of the organization to achieve the innovation goals.

In this paper, we report on a study of a self-organizing network of schools that serve children with different levels of learning disabilities. The researchers first met this network in the context of a government commissioned evaluation of a three-year e-Learning Pilot Scheme in which this network was a grant-holder for one of the 21 funded projects.

Research context and methods

In 2011, the Education Bureau (EDB) of Hong Kong launched a three-year e-learning Pilot Scheme (2011-2014) in order to develop, try out and evaluate when and how e-Learning works best to bring about effective interactive learning, self-directed learning, and to cater for learner diversity in different curriculum and school contexts in Hong Kong (EDB, 2011). Two studies were carried out in relation to this e-Learning pilot scheme. Study 1 was a longitudinal evaluation of the e-learning pilot scheme (2011-14, referred to here as Years 1-3) commissioned by the EDB. Study 2 was a follow-up study (2014-16, referred to as Years 4-5) to investigate the sustainability and scalability of the pilot projects after the end of the funding period. There were wide diversities in the 21 funded projects, and the projects selected for Study 2 were already the most successful studies that showed potentials for sustainability.

A common feature of the 21 pilot projects was the inclusion of an e-Learning resources/tools development component as the technology base for the e-Learning implementation in these projects. The EDB required all the projects to include partnership involvement with the business sector, which generally served the role of technology development to serve the aspirations of the schools' pilot projects. Altogether 21 pilot projects (61 schools in total) were selected for funding; 9 were individual school projects and 12 joint-school projects. Study 1 found that the e-Learning technology developed in some of the projects was marginally used during the 3-year pilot period, and were rarely used again after the end of the 3-year pilot period. Preliminary analysis of Study 2 data found that while the e-Learning technology tool may still be used by one or two schools in some of the projects, all of the project networks stopped functioning after the project funding ended, except for one of the projects. This project (to be referred to as Project S) was an "outlier" in that after the funding ended, the schools still continued to fund further technology development from their regular school budget, and both the scale of adoption and level of pedagogical transformation taking place in the schools actually progressed exponentially. The present study is a case study of Project S, with the purpose of investigating (1) the trajectory of development of the project both in terms of technology development and e-Learning practice implementation over the five years, (2) how this school network evolved in terms of the architecture of learning that supported the innovation, and (3) if there is a connection between the innovation evolution and the network infrastructure that supported it.

In Studies 1 and 2, the research team interviewed the principal, the project core team members and teachers participating in the e-learning pilot at the beginning and at the end of each school year from Years 1 to 5. From Year 2 onwards, the participants were asked about: (1) the general status and any change of features and goals of e-learning in the school; (2) the organizational structures, organizational routines and interaction mechanisms within and outside the school related to the school's e-Learning initiatives; (3) teachers' learning opportunities and outcomes relating to e-learning, and whether these were related to their responses to (2). To evaluate teachers' learning outcomes in terms of changes in e-learning pedagogical design, teaching and assessment practices, we collected in each year the teaching plan and students' work for one curriculum unit selected by the teacher that used e-Learning. In Years 4 and 5, we conducted in addition classroom observations of one e-learning lesson within the teacher nominated curriculum unit after discussion and negotiation with the project team and teachers. The focus of the observations was on the pedagogical approaches adopted by the teacher when using ICT, and the extent to which students were given opportunities to use ICT in their learning that were oriented towards building 21st century competencies.

During the interviews in Years 4 and 5 with the principals and teachers in Project S, the research team was told that the project success can be largely attributed to the efforts of two important teams: the Network of principals from a number of special needs schools in Hong Kong (referred to as Network S) that was actually established in 2006, and the Project Accelerator Team (AC Team) that was first established in summer 2013, as well as the unfailing support from a retired University academic from UK who served as a consultant for Network S since its inception and for Project S. At the request of the research team, the project leaders were very generous in making available the entire set of minutes and related documents of these two teams, which became a primary source of data for the research team to understand what kind of architecture for learning was established for the Network, how it evolved over time, and how the architecture impacted on the innovation development and teachers' learning. Additional interviews were conducted with

the key members of Network S and the AC Team, as well as the UK consultant, to understand their role in these two organizational structures and their views on how the project evolved over time.

For the purpose of this study, we operationalize the concept of architecture for learning in our analysis as comprising four important elements: (1) Organizational structures that direct and guide interactions; (2) Mechanisms for sharing, interactions and decision-making; (3) Artefacts that serve as reifications of outcomes of interactions to propagate decisions and advances in understanding; and (4) Technology infrastructure that supports communications, interactions and knowledge management of individuals and communities (Law et al., 2015). Educational institutions and innovation networks are complex systems, and a characteristic of such systems is that history matters. This is no different for Project S. We will first present our descriptive analysis of the S Network, which predated Project S by 7 years, and was the initiator and change agent for the Project, in order to provide the necessary contextual background for understanding how the project and its architecture for learning evolved.

Network S: A self-organizing school network committed to providing equitable learning opportunities for children with learning disabilities

The "incubation" for Network S started in 2003, when the Hong Kong Government launched its comprehensive curriculum reform, which emphasized the goal of nurturing students' lifelong learning abilities. Some of the special needs school heads were disappointed that no guidelines or support were given on how special needs schools should incorporate the reformed curriculum into the teaching and learning of students with different levels of disability. These principals share the vision that irrespective of the nature and profoundness of a child's learning disability, s/he should be entitled to a pathway of learning that would give them access to the same curriculum outcome goals as all other children in Hong Kong. This shared curriculum philosophy was referred to by the principals as SAME, to stand for Systematic Approach to Mainstream Education.

In 2006, the Hong Kong Government changed the secondary school structure from seven years to six and launched a new school curriculum in conjunction with that change as an integral part of the overall curriculum reform. Network S was formally established in 2006 when nine of the special needs school principals joined together to bid for government funding under a University-School Support Program (USSP) to develop a curriculum framework so that students with Special Education Needs (SEN) can still be able to access the mainstream curriculum. To achieve the goal of building a direct "bridge" for intellectual disabilities to access the general curriculum, learning activities and resources need to be adapted and customized according to the developmental status and special needs of each child. The goal of this USSP project was to develop the following deliverables:

- A learning progression framework (comprising fine attainment levels) for the general curriculum;
- An assessment system called SCALE (Same Curriculum Assessment for Learning Effectiveness);
- A common curriculum framework and Scheme of Work (SoW) for teachers across SEN schools to share ideas and resources, collaborate with and learn from each other.

To carry out this USSP project, Network S established two inter-connected teams: one for principals and the other for teachers. The Principal Team took leadership in steering the direction of the project, making important decisions and providing professional advice to the teachers, seeking advice from an overseas consultant from the UK and consultants from a local university. This team conducted meetings on a monthly basis. The Teacher Team was also referred to as the Writing Team, which comprised specialist subject teachers from the nine project schools and took responsibility for writing the SoWs, lesson plans and accompanying learning resources. In fact, there were a number of Writing Teams, one for each subject area. Generally, each team would spend about two weeks on its writing tasks. Each Writing Team was coordinated by an Organizing Manager (OM, usually a specialist teacher from one of the schools) and a Strategic Manager (SM, usually one of the principals whose expertise was in that particular subject).

The deliverables from these projects provided a solid and common artefact base for teachers to use in planning their teaching activities to match the learning needs, attainment levels and learning patterns of their students. In 2010, Network S was successful in being funded for a subsequent USSP project that focused on developing resources for lesson planning: co-constructing teaching resources around the teaching units set out in the strands and key stages of each of the key learning areas.

During the process of collaboration, core members of Network S found that they were unable to maximize the uptake and utilities of the resources created without these being integrated into an advanced information technology system. The Network leaders also believed that e-Learning could enrich and enliven the learning of SEN students. Hence, Network S decided to submit an e-Learning pilot project proposal to

further enhance and build on what the Network has already developed to achieve its vision and goals.

Project S: History of its 5-year development

Project S was a joint bid from 10 SEN schools in Network S. Their project goal as indicated in the proposal was to develop an online platform, for sharing and collaboration in adapting and customizing the learning activities and resources to cater for the special needs of each child, building on the resources that have already been developed. During Year 1, the project focus was on collating resources according to the attainment levels framework established. In Year 2, the project team found this to be inadequate and re-focused the project on designing learning activities for effective use of the collated resources. In Year 3, the project team considered it necessary to facilitate a paradigm shift in teachers: focusing on changing teachers' pedagogical practices in order to achieve the goal of catering for learner diversity through e-learning. So the school-based and joint-school activities were changing from a resource and activity focus to learning design, peer observation of lessons and documentation of evidence of students' learning outcomes. Learning design with a four-level structure (Curriculum, Scheme of Work, school, and class levels) was explicitly identified as a framework for teachers to follow. The primary focus for Project S in Year 3 was to scaffold teachers' lesson design and classroom practice. The technology Platform was modified so that teachers were no long able to access the curriculum and assessment resources available from the Project unless they go through the SoW, school level plan and class lesson plan (i.e. the four level design structure). This change was specifically introduced to force teachers to think carefully about learning design considerations through changing their lesson design practice. In Year 4, the focus moved to student-centered learning and the collection and use of analytics on students' performance data. The Project also started to transform many of the functions on the web-based platform to support mobile-based applications, making it more convenient for teachers to collect evidence of students' formative performance. More collaborative functions were also added, such as providing parental access to students' learning records, allowing students to upload their own assignments, etc. In Year 5, as the demands for e-Learning resources and collaborative activities increased, Project S established a formal collaboration arrangement with Google and another digital education portal in Hong Kong so that the resources and services from these partners can be integrated into the Project platform. Besides, the platform was gradually revised to cater for diverse e-learning development progress and context among the project schools.

Table 1 summarizes the key project changes over the five years. There are several noteworthy features in the project development trajectory. First of all, the deliverables (artefacts such as SoW, lesson plans and learning resources) developed in the years prior to the project start served as an important part of the architecture for learning as reifications (Stein & Coburn, 2008) to scaffold teachers' learning, design and classroom practices. Secondly, these artefacts were developed by the Network and so have authenticity and ownership for the schools and teachers in the Network. Thirdly, there was a learning process for the Project team, moving from a resource model of change to a strong focus on expertise development (design expertise) and on changing pedagogical paradigm and practice from Year 1 to Year 3. In Year 4, the focus was on building support for feedback on students' learning through the portfolio type assessment support platform linked to the attainment levels framework (SCALE). In Year 5, the change was further consolidated through adding platform functions that support collaboration with parents as partners in facilitating children's learning. Fourthly, by making the students learning outcomes evident and linking them to the SCALE framework, the achievability of the Network vision was made tangible and convincing. This led to an exponential increase in the uptake of the platform use as well as in the increasingly student-centred pedagogical practices adopted by the Network teachers. Fifthly, the evolution of the technology platform reflects a deepening understanding of the "nature of the beast" in terms of e-Learning adoption as a pedagogical innovation requiring a clear focus on changing teachers' practices. Further, the project leaders have cleverly changed the interaction design of the platform so as to enforce changes in teachers' work practices in lesson design: demanding that teachers pay explicit attention to pedagogical design considerations before the selection of activities and resources. In fact, the platform also required teachers to consider students' specific learning needs in the design process by requiring teachers to specify the specific students targeted when assigning learning activities, and the learning levels of the students also have to be made explicit to match the level of the learning activities. Hence this project is not simply one of developing an e-Learning support platform, but one involving socio-technical co-evolution.

Project S: Architecture for learning

To lead the e-Learning Pilot Project, the joint-school Principal Team in Network S served as the driving change agent, and a teachers' network was also set up for implementing the project on a day-to-day basis.

The latter had specialized sub-networks under it for IT coordination and for the different subjects in Years 1 and 2. These two teams were interconnected through a formal coordination mechanism of regular meetings to exchange ideas, concerns and explore solutions. During these meetings, the teachers would report on problems the Teacher Teams identified to the Principal Team. The Principal Team then held meetings to discuss the issues raised, which could concern administration, resources, technology, or pedagogy, and come up with solutions to feedback to the Teacher Team. In addition, both teams would conduct lesson observations across schools. In Year 2, the project leaders found that the communication between the technical group and the subject groups was not effective as these two groupings of teachers did not have sufficient expertise on both technology and subject teaching to understand each other's concerns. Further,

Table 1: Project S developmental trajectory, Years 1 to 5.

Year	Innovation development focus	Platform features developed	Innovative practices implemented	Students' learning outcomes observed	Scale
1	Transforming the SoW, attainment level, and related learning resources to e-copies for more convenient sharing among network members.	Teachers creating, uploading and sharing teaching resources	No pedagogical practices at this stage. Teachers were trained to prepare lesson plans & other learning resources on the platform	Students work appeared to be paper-based drill and practice. No 21st century competency was observed.	Teachers involved in SoW writing team (Chinese and PSHE)
2	Starting the introduction of e-learning resources into classroom teaching	- The major progress of this period was to try-out & revise lesson plans through classroom teaching. - Teachers' use of this platform increased & more resources were created and shared. - An e-forum was established for teachers to share their good practices.	Introduced collaboration activities among students, such as online discussions, peer assessment.	- Some high-ability students started to use tablets. - Differentiated outcomes goals: high-ability students prepared a short presentation & weak ones did a paper-based assignment. - Some students were able to engage in collaboration online.	Try-out teachers from writing team (Chinese and PSHE)
3	Facilitating paradigm shift in teachers: encourage the modification of pedagogical practices to cater for learner diversity	A clear structuring of a four-level learning design pathway through the online platform (Curriculum, Scheme of Work, School, and Class levels) for the teachers.	Teachers were required to use an online teaching plan to organize the teaching materials, and students' learning materials and learning artefacts.	Collaboration; inquiry within groups; information literacy such as searching, organizing and ethical use of information (for high ability students).	Use of the e-Learning platform in teaching practices in all Network schools.
4	Student-centred learning and analytics on students' performance data (how the data collected on the platform could better serve student-centered learning)	Capture students' learning process in the form of qualitative evidence of students' performance; development of mobile apps to support the web applications.	Teachers continued to explore implementation of collaborative learning among students, use of mobile devices in outdoor activities & differentiated designs for learner diversity.	Collaborative inquiry in groups; information literacy such as searching, organizing and ethical use of information (for high ability students).	The scale increased in each network school
5	Sustainability of the project; e-learning design to cater for diverse learner developmental context in the project schools; learning analytics and big data	- Develop media capture apps (iOS, student version) - Student login data added for analysis - Single sign-on between project platform and Google/ HKEdCity for easy access to external	Teachers continued to explore implementation of collaborative learning among students, use of mobile devices in outdoor activities & differentiated designs for learner	- Collaborative inquiry in groups; information literacy such as searching, organizing and ethical use of information (for high ability students). - Using IT tools as productivity tools in	The scale increased in each network school

		resources.	diversity.	everyday life (For low ability students.)	

more and more problems were emerging from the teachers in the participating schools in the process of implementation, but the technical team did not have adequate knowledge and expertise to address the diverse problems arising in the different school contexts. To address these challenges, a new organizational structure called "Accelerator Team" (AC) was created in Year 3, comprising of senior teachers who have knowledge both in technology and pedagogy from each of the participating schools. The role of the AC Team was, on the one hand, to refine and improve the function of the technology platform based on teachers' feedback, critiques and suggestions the team members solicited in their own schools; and on the other hand, to provide in-situ support to the school teachers in the form of peer coaching and school-based training workshops. From Year 3 onwards, the AC Team had been playing a crucial role in connecting the teachers and the project leaders, providing instant support to and receiving feedback from the classroom teachers on the ground, and proposing revisions to the platform and implementation strategies to the project leader network on the top.

In reviewing the Network documents, it was clear that the Principal Team played a leadership role in driving the project in two important aspects: (1) steering the strategic direction of the project in alignment with the Network's educational vision, (2) assignment of roles and allocation of human and other resources throughout Years 1 to 5. While the principals' leadership was important, the compositions and modes of work of the specific working teams (hereafter referred to as innovation teams) were also critical. The innovation teams played the quintessential role of leading from the middle: these teams comprise the teachers who designed, constructed, and piloted the e-Learning platform, and who interacted with classroom teachers to develop pedagogical implementations using the technology platform and tools on a day-to-day basis. They made and implemented school-based plans to realize the project vision and goals, and mediated between the project leadership, school leadership and classroom teachers in the participating schools.

In Years 1 and 2, the innovation teams were structured similarly to those set up in the USSP projects conducted by Network S in the years before Project S came into existence. Essentially, the project was carried out by a small number of task groups, each led by a principal with teacher members drawn from the various Network schools. This was adequate when each component in the project was relatively well-defined, without strong interdependence, and no technology development was involved. In Year 2, the overseas consultant pointed out that there was a need for a central team with strong technological and pedagogical expertise to work together, and that the key challenge was a pedagogical one. There was a pressing need for the core working team to put a strong focus on teacher professional development. With professional and networking assistance from the overseas consultant, the Network S principals and some core innovation team members went on a study visit to the UK to learn about how student-centered learning can be implemented for children with special needs, and how SoW and attainment levels can be used to scaffold teachers' lesson design and assessment work. These events triggered a significant structural change in the innovation team structure, and the network schools agreed to contribute an experienced teacher with e-Learning and/or curriculum innovation expertise to set up an Accelerator Team (AC Team) in Year 3.

The AC team members were handpicked for their pedagogical experience and relatively sophisticated understanding of the role of technology in supporting student learning. Once constituted, the AC Team began by formulating a total reconceptualization of the platform functions to focus on supporting teachers' lesson design practices. Further, none of the AC team members had full-time commitments to Project S. Hence they all had teaching duties and roles within their own schools, and were able to sense quickly how the platform features were received by their colleagues in the context of their day-to-day practices. The establishment of the AC Team was instrumental to the successful refocusing of the project directions. In Year 4, the AC Team structure changed again. The reason for the change was two-fold. Firstly, without government funding for the project, some of the schools found it difficult to contribute their prized staff to work on the project. Secondly, the Network decided that the focus from Year 4 should be on developing student-centered practices, and that further technology development would be scaled down. Hence, every school was encouraged to assign one teacher to the AC team, whose role was to help and introduce the platform functions to teachers, and to scaffold innovation-focused professional development activities within their own schools. This AC Team 2 met regularly to review implementation progress in each of the schools, and to report problems and suggestions from grassroot teachers within the Network schools. The new AC Team structure was very successful in stimulating adoption by teachers in the Network. Many of the improvements such as the desirability of mobile applications as tools for collecting evidence of students' learning was gathered as teachers' voice in the innovation process.

Summary and discussion

A Technology-Enhanced Pedagogical Innovation (TEPI) is a journey and a process. An innovation journey is by definition one in which both the destination and the pathway are not clear. It is also a collaborative problem-solving process involving agents at multiple levels: classroom teachers, teacher leaders, school leaders and external partners such as consultants and technology developers to address inter-related problems that emerge on the way. Network S is a self-organizing network that came together voluntarily to achieve an educational vision through embarking jointly on Project S as a TEPI. To achieve success, the Network has to be able to undertake successful *self-organized learning* in navigating through the many challenges encountered during the journey. In this final section, we will summarize our key learning from this case study of Project S.

First, the TEPI is a process of sociotechnical co-evolution. Over the five years, as illustrated in Table 1, the functions and roles of the e-Learning platform changed alongside the changes in teachers' experimentation with the technology and also with the changes in the architecture for learning set up to implement the project. In Year 1, the focus of the innovation was to develop a platform for resource sharing (e.g., teaching plan, teaching materials, useful e-learning tools, etc.), and the teachers spent a lot of time learning to transform paper-based resources into electronic format, with little impact on classroom practices. In Year 2, the innovation focus shifted to the pedagogical use of ICT in classrooms, and some teachers experimented with using the e-Learning platform in this project (referred to as Platform S) for planning their lessons, including efforts to cater for learner diversity. The availability of discussion forum and peer assessment resources on the platform stimulated the adoption of these activities by some teachers. There were also scattered efforts to design and implement differentiated learning activities based on students' based on the fine-grained SCALE specifications of learning outcomes. In Year 3, the newly constituted AC team designed a well-structured teaching plan e-form that capitalized on the teachers' interests in using the teaching and learning resources to enforce a four-stage model of lesson design. Some teachers who initially doubted the value of e-Learning for their students changed their views after interacting with other teachers and experimenting with new practices in their own classrooms. In Year 4, the focus shifted to using student data to improve their learning, and new mobile applications and interfaces were developed in Platform S to support user-friendly ways of documenting students' performance. These new tools serve as resources for students to reflect on their own learning, and to inform parents about their children's development. In Year 5, sustainability and compatibility of Project S was discussed in the Network schools and affirmed as a priority by most of the member schools. Good practice cases were shared among the network teachers to attract more teacher adoption.

A second observation is the need for a strong, cohesive and respected core at the network leadership level that constantly monitors the innovation direction and re-focuses its efforts once it deviated from the primary vision and goal. As Network S moved from the development of curriculum resources such as SoW and SCALE to the implementation of e-Learning, there was an initial shift towards a techno-centric focus on the development of digital resources for teaching and learning. The international consultant's visit in the second year of the project was instrumental in re-focusing the project team on pedagogical concerns, and the affirmation that professional development of teachers should be the primary strategic implementation goal. The seven years of prior collaboration among the Network leadership and the consultant provided a trusting relationship that underpinned the re-focusing effort and the establishment of the AC Team as a consequence of the consultant's intervention.

A third observation is that the capacity of a network to undertake TEPI has to be built up over time. The two prior USSP projects conducted by Network S fostered crucial innovation capacity for Project S as a pedagogically focused innovation. First, the SoW and SCALE developed served as the curriculum and pedagogical bases for developing the TEPI. Secondly, the Principal Team and Writing Teams that conducted those two projects served as a foundational social infrastructure to lead the implementation of Project S. Thirdly, the working relationships among the Principal Team and Writing Teams, and the successful implementation of these two prior projects helped to lay a good social milieu for Project S.

A fourth observation is the need for a "middle-layer" organizational structure and interaction mechanisms to materialize the innovation vision of the Network leadership through concrete implementation plans that engage classroom teachers "on the ground". In fact, variations in project implementation efficacy across schools in the Network often reflect differences in the strength and suitability of the middle management at the school level.

Fifth, the composition of the Network middle management teams (e.g. the Writing Teams, AC Team 1 and AC Team 2) need to have the necessary expertise and be tasked with the appropriate mission for the specific phase of the innovation, and hence will need to be changed/adjusted as necessary. Such change is also part of the sociotechnical co-evolution.

Network S is an autonomous self-organizing network connecting a group of schools serving SEN students. Project S, led by the Network, went through stages of development reflecting a co-evolution of the curriculum artefacts, organizational infrastructure and interaction mechanisms in bringing about innovations in pedagogical practices and the technology platform.

References

Brown, A. L. (1992). Design experiments: Theoretical and methodological challenges in creating complex interventions in classroom settings. *The Journal of the learning Sciences, 2*(2), 141-178.

Clarke, J., & Dede, C. (2009). Design for Scalability: A Case Study of the River City Curriculum. *Journal of Science Education and Technology, 18*, 353-365. doi:10.1007/s10956-009-9156-4

Coburn, C. E. (2003). Rethinking scale: Moving beyond numbers to deep and lasting change. *Educational Researcher, 32*(6), 3-12.

Collins, A., Joseph, D., & Bielaczyc, K. (2004). Design Research: Theoretical and Methodological Issues. *Journal of the Learning Sciences, 13*(1), 15-42.

Davis, N. (2008). How May Teacher Learning be Promoted for Educational Renewal with IT? In J. Voogt & G. Knezek (Eds.), *International Handbook of Information Technology in Primary and Secondary Education Technology in Primary and Secondary Education* (pp. 507-519): Springer

EDB (2011). *Selection results of Pilot Scheme on e-Learning in Schools announced*. http://www.info.gov.hk/gia/general/201101/03/P201012310128.htm

Fisher, T. (2006). Educational transformation: Is it, like beauty? in the eye of the beholder, or will we know it when we see it? *Education and Information Technologies, 11*(3), 293-303.

Fishman, B. J., Penuel, W. R., Allen, A. R., Cheng, B. H., & Sabelli, N. H. (2013). Design-based implementation research: An emerging model for transforming the relationship of research and practice. *National Society for the Study of Education, 112*(2), 136-156.

Fullan, M., & Hargreaves, A. (Eds.). (2009). *Change Wars*. Bloomington, IN: Solution Tree Press.

Hamel, C., Turcotte, S., & Laferrière, T. (2013). Evolution of the conditions for successful innovation in remote networked schools. , 6(3), 1. *International Education Studies, 6*(3), 1-14.

Law, N., Niederhauser, D. S., Christensen, R., & Shear, L. (2016). A Multilevel System of Quality Technology-Enhanced Learning & Teaching Indicators. *Journal of Educational Technology & Society, 19*, 72-83.

Law, N., Yuen, A., & Fox, B. (2011). *Educational Innovations Beyond Technology: nurturing leadership and establishing learning organizations* New York: Springer.

Law, N., Yuen, J., & Lee, Y. (2015). *Precarious School Level Scalability Amid Network Level Resilience: Insights from a multilevel multiscale model of scalability*. Paper presented at the American Education Research Association Conference 2015, Chicago.

Partnership for 21st Century Skills. (2009). *P21 Framework Definitions*. Retrieved from http://www.p21.org/storage/documents/P21_Framework_Definitions.pdf

Penuel, W. R. (2015). *Infrastructuring As a Practice for Promoting Transformation and Equity in Design-Based Implementation Research*. Paper presented at the Keynote presented at the International Society for Design and Development in Education (ISDDE) 2015 Conference, Boulder, CO.

Somekh, B., & Davis, N. (1997). *Using information technology effectively in teaching and learning : studies in pre-service and in-service teacher education*. London ; New York: Routledge.

Spillane, J. P., Parise, L. M., & Sherer, J. Z. (2011). Organizational Routines as Coupling Mechanisms Policy, School Administration, and the Technical Core. *AERJ, 48*, 586-619.

Stein, M. K., & Coburn, C. E. (2008). Architectures for learning: A comparative analysis of two urban school districts. *American Journal of Education, 114*(4), 583-626.

Vuorikari, R., Kampylis, P., Scimeca, S., & Punie, Y. (2015). Scaling Up Teacher Networks Across and Within European Schools: The Case of eTwinning. In Scaling Educational Innovations. In C. K. Looi & L. W. Teh (Eds.), *Scaling Educational Innovations* (pp. 227-254). Singapore: Springer.

Watson, D. M. (2001). Pedagogy before Technology: Rethinking the Relationship between ICT and Teaching. *Education and Information Technologies, 6*(4), 251-266.

Wenger, E. (1998). Communities of practice: Learning as a social system. *Systems thinker, 9*(5), 1-5.

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