Education Innovation

Chee-Kit Looi
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Scaling Educational Innovations

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Series Editors' Foreword

Readers who are interested in measuring impacts of education reforms will find this book very worthwhile, whether they are interested in research impact or the expansion and impact of best practices. To policymakers, impact is the keyword to measure successes in research and intervention projects. The question on impact always begins with application, i.e., whether the research or a particular best practice (as a result of certain intervention strategies) can be applied to other settings and to more settings. When we look into the application question in terms of whether a generic finding or practice can be applied to other settings and more settings, the concepts of translation and scalability seep in, that is, whether the finding can be translated to other settings and can be scaled up to more settings. If the translation and scalability questions can be answered in measurable terms, it will be very helpful to both policymakers and the researchers, because the policymakers can explain why the investment in this particular project is worthwhile and thus is publicly accountable and the researcher can also explain that they have provided measurable deliverables that can demonstrate the worth of their projects. Above all, the measure of worthiness of the government investment and the researchers' efforts can be demonstrated in terms of the usefulness of the deliverables as outcomes or outputs of the projects.

The concepts of translation and scaling are not new, but actually well established in the medical profession. The success of the invention of a new treatment method or medication is often measurable in terms of whether they can be applied to everyone or at least to a large majority of human population. In the field of education, the story is quite different. Many researchers will find these concepts difficult, as while human beings' biological construct seems to be universal, learners are quite different in the way they learn and also in the way they respond to certain pedagogy and learning contents. More complicated is that different teachers may have different views while transmitting the same teaching materials, and this makes it difficult for the education field to copy the concepts of translation and scaling concepts from the medical field.

This book is organized to address the complications of translation and scalability in the education field. The authors in the book are invited to be engaged in the discourse of translation and scaling from a variety of perspectives and approaches.

Some of them analyze these concepts philosophically, while others would share their various experiences of translating and scaling up their research outcomes.

This book contains comprehensive considerations of various aspects of understanding translation and scaling. The first set of discussion includes the more traditional translating and scaling processes where certain degrees of successful interventions or best practices are transferred. The second set of discussion will try to take into consideration more complicated factors such as defining invariance and variance and adaptation and transformation of the original ideas into new settings and contexts, depending on the teachers (deliverers), students (recipients), and the school (context). The inclusion of these complicated factors will bring to light that the traditional approach is rather mechanical, while the contextual approach is more organic. This brings in a third set of discussion, whether scaling can be seen as a process of transformation rather than duplication or replication, and in the case of transformation, the final (transformed product) can be quite different from its original form. The allowance for the contextual factors brings about a process of engagement and co-construction, and this will further lead to continuous improvement or success that will be seen as meaningful to the subjects involved in the new contexts. In this way, the translation and scaling efforts are successful in planting the essence (or kernel) in the new contexts, whereas the new forms may be different or even unidentifiable from its original form. This leads to the fourth set of discussion – translation and scaling can happen not only in terms of certain findings or practices but in expanding a network of the professionals. This will allow translation and scaling to go beyond a certain geographical setting and become international. And in this way, the impact of the research and/or practice will reach its ideal ultimatum target – achieving international impact. However, as this is happening in terms of process and engagement, and is a kind of organic and transformative process, the final scaled outcomes can be quite different from its original product, yet they are most successful in terms of achieving international impacts. This aspect of looking at translation and scaling leads to a fundamental question – what should be scaled up? If we take a process and transformation perspective, the target product to be scaled up may not necessarily be the "best finding or practice." It suffices to be scaled up, if it is a "satisfactory" product, as the process of transformation will improve it to fit the new contexts anyway.

Thus, the various chapters from the book offer different frameworks, perspectives, and emphases in the scaling efforts, in particular, how different innovations are contextualized at the ground level, enabling diffusion to take place. Local adaptations allow for agency and decision making, interpreting the policy and implementation intents to suit the desired purposes. Significant stances on professional development and expertise building are necessary. Apart from the Singapore experience, the international contributors such as those from the United States, Europe, and China share on their scaling and sustaining stories and challenges. The common systemic dimensions of scaling across different countries include understanding contextual nuances, forward planning where designs for scaling from the onset would alleviate future issues of broader implementation, and the alignment of policies to enable reform and change in the scaling agenda. There are also

cross-examinations on top-down and bottom-up models of scaling. It is obvious that a combination of the two models, taking into the contextual factors, is necessary to make translation and scaling successful.

If you are interested in the stories leading to these observations and conclusions, we recommend you to read the whole book.

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Foreword

Scaling up a locally successful innovation to many diverse educational contexts and then sustaining at each setting the shifts in practice and policy this improvement requires are two of the most difficult problems schooling faces. Widespread educational effectiveness depends on each teacher not "reinventing the wheel" of enabling learning for every student, yet insights on how to accomplish this goal often do not transfer even down the hall in the same school, let alone throughout a district, a region, or a nation. Even when an innovation is successfully implemented elsewhere, all too frequently it persists briefly, then fades away as the unaltered practices and policies in that educational system undermine its viability. Sadly, our best stories of improvement are typically about the personal heroism of individual teachers or educational leaders who "swim against the tide," rather than about research-based, systemically applied, sustained shifts in educational structures, practices, and policies.

Other sectors of society find scaling up and sustaining innovation much less difficult. In medicine, interventions such as antibiotics or immunizations work uniformly regardless of the patient's socioeconomic status, native language, prior academic history, race, ethnicity, etc., yet all of these factors greatly influence whether an instructional intervention will succeed or fail with a particular student. In industrial settings, following an algorithmic process will lead to a uniform result (e.g., robots making cars, fast-food restaurants preparing meals)—but how to foster effective learning varies considerably among people. As a result, one-size-fits-all instructional strategies may work in one setting with a particular teacher and student population, yet be unscalable, failing when generalized to contexts where students and teachers, schools, and communities are different.

More than any other part of society, education faces the challenge of individual and contextual variation strongly shaping which promising interventions are actually scalable: adaptable to sites that lack some of the conditions for success the innovators enjoyed in their initial development. Further, potential users of an innovation must accurately determine how to adapt it to their setting and whether sufficient conditions for success exist to make adaptation successful. Not every type of seed can grow in any type of ground, regardless of the care a gardener provides; educational innovation also embodies this precept.

Sustainability of innovations is also a difficult problem in education. When the leader of a hospital changes, its doctors are not forced to completely alter their protocols for treating diseases, nor, when the executive in charge of a business retires, do all its effective workplace practices and processes alter. But in education, a shift in superintendent, school board, or regional political system often results in massive changes in what practices and policies are considered suitable, and laboriously implemented, effective innovations are swept away by ideological tides.

This book makes a major contribution to addressing these perennial, crucial educational challenges. A broad range of frameworks for successfully achieving scale and sustainability are articulated, and cases are provided that illustrate how each strategy is useful for particular types of educational improvements. The core insight linking these varied approaches is the recognition that, in education, scale is not about adopting innovations with complete fidelity to their initial setting, but instead adapting them to variations in students, teachers, and settings, simultaneously creating their conditions for success to the extent locally possible. As many of the chapters discuss, digital technologies are playing an increasingly powerful role in aiding these adaptations.

Some frameworks, such as my work, are primarily about the multiple dimensions involved in designing innovations to be scalable and how technology can be useful in this. Other frameworks center on the complexities of implementing adaptations of innovations, then sustaining them. Cases that illustrate success frequently involve, for a particular educational context, using multiple frameworks to guide decisions about which innovations have sufficient conditions for success and how to adapt these interventions. Further, as the frameworks and cases illustrate, to be sustained innovations must be coherent, aligned, and cumulative.

This book has insights about scaling and sustainability useful for every decision maker in education: teachers, administrators, parents, politicians, policy makers, and leaders. Its chapters provide a strong platform for developing further heuristics and theories to raise our capacity to scale and sustain educational innovations. Through achieving breakthroughs in overcoming these difficult challenges, we can greatly enhance our ability to attain educational excellence and equity, a vital attainment for prosperity in our global, knowledge-based, innovation-centered economy and civilization.

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Contents

Chapter 1
Towards Critical Discussions of Scaling Up Educational Innovations

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Abstract In recent years, because of increasing expectations for the public investment in education research to benefit education policy and practice, there have been fresh impetuses for researchers to better understand issues key to the sustaining and scaling of educational innovations. Various research and implementation trajectories have resulted in strategies that can lead to successful implementation and scaling up of promising research or innovation outcomes and generated models or frameworks of scaling. It is timely now to look at this diversity of approaches and distil from them the commonalities and differences. This chapter describes our current understanding and perspectives of scaling up, which motivates this book as it presents the latest insights, contemporary models, case studies and meta-studies that can advance our understanding of the scaling up agenda.

Introduction

The types of research conducted in the educational research community span a broad and diverse range, ranging from those that seek fundamental understandings of what learning is and how it takes place to a more practice-oriented research with a view to translate the findings to teaching practice and to inform education policy-making. Even amongst the practice-oriented research projects, many focused on design issues or on establishing the efficacy of education innovations that work well within specific contexts. Because of their narrow focus on specific contexts, they typically have little impact when it comes to changing or transforming practices in schools, at a systems level, because the contexts for learning vary widely across schools. Innovations that are found to work well in one context therefore cannot be scaled up to meet the needs of a broader audience, and the conundrum of narrowing the research-practice gap remains.

There are many other reasons for the persistence of the research-practice gap: amongst others, researchers view their job as contributing to and producing knowledge

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and publishing them in academic journals and conferences for other researchers to build on and for practitioners to apply. Most researchers do not see themselves as the agents to translate or implement innovation in real-life settings beyond their research efforts. The multifaceted requirements of academic publishing, tenure and promotion and disciplinary commitments also do not require nor expect researchers to broach the issues of how to put their findings to practical use in broader contexts. Thus, despite calls in various literature to bridge the research-practice-policy gaps over the years, we have not yet grappled fully with the process and journey of educational innovations moving through the trajectory of conception, design, implementation, evaluation, redesign, reconception, etc., and eventually onto some form of large-scale implementation.

Educational research projects are usually also not organised to address the challenge of long-term systemic improvement because the research-practice partnerships that these projects support are often limited by the short-term funding of grants and programme initiatives designed by the foundations and government agencies. Fundamentally, the considerations surrounding the conduct of research in the literature are usually framed from the perspective of the researchers whose primary concern is to know than from the perspective of the practitioners whose primary concern is to use. To illustrate, the often cited 'Pasteur's quadrant', in Stokes (1997)'s seminal work, is described as 'use-inspired basic research' which foregrounds basic understanding (see Table 1.1). We have not seen 'Pasteur's quadrant' described as 'applied research which can advance fundamental understanding'. The latter perspective, unlike the former, gives primary focus to practical solutions that can directly improve human life, which we think is a more accurate description of Pasteur's original work. If the primary focus of a research project is to derive practical solutions, then due considerations must be given to the practicality, implementability and sustainability of the education innovation being researched on.

Given these considerations, the broad challenge for funding and government agencies will be: how can funding policies and mechanisms not only help to encourage and sustain successful research and implementation studies that have the potential to bridge research-practice gap but also help to sustain longer-term change in practitioner capacity, mindset and culture so as to improve learning? Similarly, the challenge to the academic community will be: what kinds of reward mechanisms can encourage researchers to take on research challenges that seek to address real problems faced by practitioners?

Table 1.1 Pasteur's quadrant model of scientific research

Quest for fundamental understanding?	Considerations of use?	
	No	Yes
Yes	Pure basic research (Bohr)	Use-inspired basic research (Pasteur)
No	Applied research unmotivated by applications (Brahe)	Pure applied research (Edison)

Stokes (1997)

Approaching scaling and translation of an innovation as a coherent policy to resolve a practical problem, instead of viewing it as the eventuality of a basic to applied research trajectory, can surface important considerations that must be addressed if the innovation is to be successfully scaled and implemented. For example, a policy which stipulates an initiative, a programme or an intervention to be implemented and rolled-out in a large-scale basis may specify it with different degrees of specificity or prescriptiveness, may support it with varying amounts of evidence of efficacy or may be motivated by different social, political or economic imperatives for launching the new initiative. While the initiative may or may not be developed through a research programme, the process of setting up the whole infrastructure and the process of launching, implementing and monitoring the initiative are critical components that will determine whether it can be scaled successfully. The fields of policy studies and leadership, implementation science and other disciplines have developed much knowledge and perspectives towards large-scale implementations. In the fields of medicine, health science and other areas, implementation science also looms large as bodies of knowledge that informs the field. So we ask the question: where are we in education vis-à-vis the other fields and disciplines in terms of understanding large-scale implementation of innovations?

Scaling Up Educational Innovations: Different Perspectives

Policymakers typically view implementation and scaling from macro perspectives; researchers that study scaling might view implementation through lenses of fine-grained micro-sensitive issues; thus they do not always see eye to eye. Different approaches to bring innovations to bear in classrooms by practitioners have been adopted by various government agency programmes. One approach that is based on a technical rational view describes the entire scaling process as a fairly well-defined sequential cycle. According to Petersen and Smith (2011), the Federal Cycle of Innovation in Education, which is the scaling framework behind the US Department of Education's Investing On Innovations (i3) Fund, comprises of a number of stages including (a) research, (b) development, (c) evaluation and (d) scaling. The i3 Fund has therefore been structured to provide grants of different sizes to bring a researched innovation from one stage to another, i.e. from development to validation and finally to scaling, at a state, regional or federal level. Central to this cycle is the presupposition that there exist practices, strategies or programmes which can be consistently effective in improving specific learning outcomes of learners who are in widely different contexts at the state, regional or national levels. Furthermore, it also presuppose that the most effective way of identifying these programmes are through evidence of effectiveness obtained from large-scale randomised experimental or quasi-experimental studies.

Yet another approach is one that gives more balanced emphasis to the needs of the learners, the agency of practitioners and the contextual complexity in the learner-practitioner interactions, instead of the predominant focus on scientific evidences

and the assumed stable internal logic that tightly link one stage of cycle of innovation to another across levels and contexts. An example of this approach of scaling is to provide resources to schools to define the problems they would like to address and then design and implement the innovations in collaboration with education researchers in an iterative manner, often adopting a design-based research approach. This approach views the efficacy of a programme as inseparable from the agency, capacity, mindset and culture of the practitioners. The FY2014 research topic announced by the Institute of Education Science, entitled 'Continuous Improvement Research in Education', has features that are in agreement with this approach (IES 2014).

Scaling research in education is therefore important since it takes into account considerations not only in research and in practice (Schneider and McDonald 2006a) but also in policy perspectives. The specific challenge to researchers is: how can our work lead to a better understanding of the processes of designing and enacting innovations that can impact peer-researchers, practitioners and policymakers? Notwithstanding the need to keep abreast of the state-of-the-art breakthroughs in educational research, the primary goal of scaling research is to design and enact interventions, implementation and studies in various situations that provide compelling evidence of what works and what does not and why, so as to sustain innovations to improve learning at a systemic level and to address the learning needs of diverse populations of students. Research in this field that studies the fidelity of implementation can be balanced with studies of adapting innovations according to dynamic local contexts (Dede et al. 2005).

Research Approaches to Scaling

Because of the above-mentioned developments, there is increasing interest in scaling research both from the academia and from the policy and practitioner communities in the recent years. The research results have been reported in edited books, journal papers and educational reports (e.g. Anderson and Herr 2011; Barab and Luehmann 2003; Constas and Sternberg 2006; Dearing and Kreuter 2010; Dede et al. 2005; Glennan 2004; Penuel et al. 2011; Schneider and McDonald 2006a, b, c). Various perspectives, models and frameworks of scaling have been attempted.

One approach to scale up innovations is from the perspective of setting up the infrastructures for implementation. For instance, a study calls for leaders to attend to improving capacity for professional development and organisation support by creating implementation teams (Fixsen et al. 2009). The teams provide the infrastructure to support the widespread use of selected effective educational interventions for implementing various 'good practices' and making system-level change. This approach shifts the focus from identifying the 'best practice' through accumulation of scientific evidence to developing the organisation's capacity to adopt any good practices that it comes across. Some scaling studies have made use of 'best practices' enhanced by technology in enacting research-based innovative practice as

models for scaling up success. Once a 'best practice' is identified, the focus is on key issues of coping with change, constituent support, building human capacity and effective decision-making in adopting this specific practice (Dede et al. 2005). Other studies asserted that scaling up success depends on alignments of the programme with policy, local accountability requirements and infrastructure support in order to sustain the practice in the long run (Glennan 2004).

Additionally, there are scholars who go beyond taking the perspective of technical rationality to explore the relationship between policy and programme designers with school practitioners (Mehan et al. 2010). The authors assert that to scale up the innovations, it is important to augment current dissemination practices with evidence-based concepts from diffusion science, marketing science and knowledge utilisation. Although problems exist, these studies have yielded rich resources as a guide for immediate and future efforts in scaling research and call for school practitioners, programme designers and policymakers/leaders to comply with the mandate to enact research-based practice.

Yet another line of development on scaling studies calls for a synthesis of both bottom-up and top-down approaches. For example, a study in professional development offered a theoretical framework for scaling up classroom innovations termed as 'Tight but Loose framework' implemented in different local contexts (Wylie 2008). The Tight but Loose framework proposes, on one hand, the flexibility of taking advantage of local opportunities when accommodating existing local constraints and, on the other hand, the fidelity to core principles of innovation or practice. Through comparing the context-based differences and outcomes in various programme implementation, the study discerned that it is crucial to articulate explicitly to the schools, districts or states, during the introduction and implementation stages, which components of the innovation must be strictly adhered to (tight) and which may be adapted to their local contexts (loose) when scaling up classroom-based interventions.

As for scaling up innovations in multidisciplinary areas, Penuel et al. (2011) propose using a new form of implementation research, namely, design-based implementation research (DBIR). Such research composes four elements: (a) a focus on persistent problems of practice from multiple stakeholders' perspectives;(b) a commitment to iterative, collaborative design; (c) a concern with developing theory related to both classroom learning and implementation through systematic inquiry; and (d) a concern with developing capacity for sustaining change in systems. 'Design-based' means that researchers are engaged simultaneously, iteratively and collaboratively with practitioners in designing and studying systemic change efforts (Kelly 2003). In the disciplines of medicine and public health, DBIR has a robust infrastructure and a clear focus on the interdisciplinary challenge of bringing large-scale improvements to complex systems (Fixsen et al. 2005). Research studies which are also consonant with this approach include improvement research (Bryk 2009), formative interventions (Engeström 2008) and social design experiments (Gutiérrez and Vossoughi 2010). Although these models appear to be a promising approach to bridging the gap between research and practice for scaling up innova-

tions, the theories and models of design-based implementation still needs further exploration.

Some insights can also be drawn from the 'designing for diffusion' approach when spreading the implementation of effective innovations (Dearing and Kreuter 2010). Designing for diffusion refers to 'taking additional steps early in the process of creating an innovation to increase its chances of being noticed, positively perceived, accessed and tried, adopted and implemented and, thus, successfully crossing the research-to-practice chasm' (p. S100). According to the authors, before diffusion, dissemination has to be conducted. Dissemination entails initial steps of providing access to information for potential adopters of an innovative practice, and diffusion is the activation of influence amongst potential adopters when they weigh over the benefits and pitfalls of the innovative practice.

Despite the above research, policymakers, practitioners, researchers and other stakeholders, including funding agencies, are still largely not well informed about how effective innovations can be made more widespread to benefit more students. A literature scan cannot develop profound theories resulting in the best model for scaling up research that can accumulate into generalisable findings. This is because the process of large-scale adoption of innovations concerns not about simply 'rubber-stamping' the same programme into multiple contexts, but on empowering teacher-directed design, fitting and adaption for local circumstances (Barab and Luehmann 2003). There is not just one model for successful implementation – there are probably as many models as there are the unique contexts (Leusner et al. 2008).

Much greater complexity is involved when educational professionals seek to understand and improve the enactment of innovations and take it to scale. One such systemic approach is therefore needed to spread innovations to improve student learning by taking into account the interconnected relations between curriculum standards, curriculum materials, learning activities, formative and summative assessments, professional development practices and educational leadership (Looi et al. 2011; Pea and Collins 2008), as well as taking into account the aspects of organisational learning (Spillane et al. 2009).

Different Types and Levels of Education Research Towards Implementation and Scaling

With a wide spectrum of educational intervention research work spanning the initial conceptual and maturation of design ideas and infrastructure to the intervention studies and implementation research to large-scale deployment, it would be useful to situate the different types of intervention research. Towards this, we extracted a framework of the types of education research on implementation and scaling adapted from Sabelli (2008) and summarised them as shown in Table 1.2.

The journey of conceptualisation of an innovation, codesign, pilot trials and implementation, redesign and evaluation eventually to practice requires different levels of research analysis to study and explore the progression at different levels,

Table 1.2 Different types of education research

Descriptor	Definition	What the study entails	Question	The 'system' intention
Innovation	A new curriculum, technology, material, etc. and associated pedagogy	May include isolated classroom studies	Does this work and how does it work?	Classroom only
Intervention	The use of that innovation in one or more classrooms	May include outside evaluation	Is this ready for adoption and dissemination?	Classrooms and school
Intervention study	Systematic study of an intervention	Includes extensive evaluations	What are conditions for successful implementation?	Classrooms and school
Implementation research	The iterative study of adaptation or localisation	Ongoing work by the site and the researchers	Do sites learn from the work? Can they sustain and grow the intervention?	Local structure considered
Scaling research	The meta-study and aggregation of multiple implementation studies	Evidence-based frameworks for scaling	What guidelines have we learned from the implementation research? What have been scaled?	Policy perspectives to be considered

Adapted from Sabelli (2008)

comprising the level of learners, the classroom level, the school level, the school district level and the system level. Learner-level analysis mainly considers the learning processes pertaining to cognition, metacognition, motivation, etc. Classroom-level analysis pays more attention to issues of teacher professional development, teacher enactment, classroom dynamics and differentiated support to learners. For school-level analysis, more sociocultural factors need to be included to enable the investigation of school culture, leadership and strategic planning for school improvement. At a higher level of system study, a more systemic understanding of implementation and scaling is sought which require framing and studying the problems of the intertwining intersections of innovation enactment and adjustment of national policies, the culture to ensure survival and thriving of innovative practices, the emergence of communities for capacity building and networking collaboration and so forth.

Context of This Book

One characteristic of education research in Singapore is the close partnerships between researchers, practitioner communities like schools and policymakers/programme designers in the Ministry of Education (Teh et al. 2013). The Singapore

government has funded educational research at the National Institute of Education in the Nanyang Technological University (NTU) over the past decade that is intended not only to advance the body of knowledge of designing, implementing and supporting educational innovations but also to help inform educational policy and practices. In Singapore, there are scaling research initiatives which are akin more with design-based implementation research by their focus on the adaptation of innovations rather than adoption with fidelity. Scaling and diffusion can coevolve, creating models from the Singapore experience and yet informing the way forward. This is why we believe that in the praxis of research honed and informed by practice and policy, the research community in Singapore has much to share on translational and scaling research of educational innovations, approaches and practices. Because of the various favourable conditions for the fostering and growth of innovations in Singapore, we have many opportunities to conduct studies across the various analytical levels of scaling research, and we believe this contributes to scholarly knowledge and the knowledge base of policymakers and practitioners in a unique manner. The collection of articles in this book comprises of intervention study, implementation research and scaling research. This constellation of research emanates from centralised top-down directives, decentralised bottom-up initiatives or a symbiosis of both approaches, depending on the distinctive sociopolitical context of various nations and regions.

We intend that this book stimulates critical discussions of the different variants of approaches to scaling and to scaling research. It is hoped that such discussion will lead to a fuller cultural understanding of scaling and translation research in a different sociocultural context from that of traditionally reported design research studies in the United States and Asia. It presents an integrated collection of diverse research studies that expounds the different facets of codesign, learning design, curriculum development, technology development and professional development and provides critical reflections on their efficacy as well as impact on practices, theory derivation and improvement. It also includes chapters that discuss the challenges and successes of scaling up technology, product, curriculum and pedagogy in different countries. For example, Chaps. 2, 3, and 4 postulate and discuss models of scaling. Chapters 5, 6, 7, 8, 9, and 10 provide case studies or meta-case studies of scaling up of educational innovations. Chapters 11 and 12 share scaling approaches to teachers' professional development with intent of and leveraging on international outreach. A synthesis chapter which draws implications from the preceding chapters then conclude the book. Altogether, this book is intended to be a timely scholarly contribution that explores the 'when', 'what', 'why' and 'how' questions of designing for scalability.

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References

Anderson, G. L., & Herr, K. (2011). Scaling up "evidence-based" practices for teachers is a profitable but discredited paradigm. *Educational Researcher, 40*(6), 287–289.

Barab, S. A., & Luehmann, A. L. (2003). Building sustainable science curriculum: Acknowledging and accommodating local adaptation. *Science Education, 87*(4), 454–467.

Bryk, A. S. (2009, April). Support a science of performance improvement. *Phi Delta Kappan, 90*(8), 597–600.

Constas, M. A., & Sternberg, R. J. (Eds.). (2006). *Translating theory and research into educational practice: Developments in content domains, large scale reform, and intellectual capacity* (p. 312). Mahwah: Lawrence Erlbaum Associates.

Dearing, J. W., & Kreuter, M. W. (2010). Designing for diffusion: How can we increase uptake of cancer communication innovations? *Education and Counseling*, *81*(Suppl 1), S100–S110.

Dede, C., Honan, J. P., & Peters, L. (2005). *Scaling up success: Lessons learned from technology-based educational improvement* (p. 265). San Francisco: Jossey-Bass.

Engeström, Y. (2008). From design experiments to formative interventions. In P. A. Kirschner, F. Prins, V. Jonker & G. Kanselaar (Eds.), *Proceedings of the 8th international conference of the learning sciences* (Vol. 1, pp. 3–24). Utrecht: Erlbaum.

Fixsen, D. L., Naoom, S. F., Blase, K. A., Friedman, R. M., & Wallace, F. (2005). *Implementation research: A synthesis of the literature*. Tampa: University of South Florida, Louis de la Parte Florida Mental Health Institute, The National Implementation Research Network.

Fixsen, D. L., Blase, K., Horner, R., & Sugai, G. (2009). Scaling up evidence-based practices in education. *SISEP scaling up brief*. Raleigh: OSEP Technical Assistance Center on State Implementation of Scaling Up Evidence-based Practices.

Glennan, T. K. (2004). *Expanding the reach of education reforms: Perspectives from leaders in the scale-up of educational interventions* (p. 749). Santa Monica: Rand Publishing.

Gutiérrez, K., & Vossoughi, S. (2010). Lifting off the ground to return anew: Mediated praxis, transformative learning, and social design experiments. *Journal of Teacher Education, 61*(1–2), 100–117.

Institute of Education Science. (2014). *Program Announcement: Continuous Improvement in Education Research CFDA 84.305H, extracted on* 19 May 2015 from http://ies.ed.gov/funding/ncer_rfas/cir.asp

Kelly, A. E. (2003). Research as design. *Educational Researcher, 32*(1), 3–4.

Leusner, D. M., Ellsworth, J., & Goe, L. (2008). Scaling up across diverse contexts: Lessons learned from five implementations of the keeping learning on track program. In E. C. Wylie (Ed.), *Tight but loose: Scaling up teacher professional development in diverse contexts* (pp. 105–124). Princeton: Educational Testing Service.

Looi, C. K., So, H.-J., Toh, Y., & Chen, W. (2011). The Singapore experience: Synergy of national policy, classroom practice and design research. *International Journal of CSCL, 6*(1), 9–37.

Mehan, H., Hubbard, A., & Datnow, L. (2010). A co-construction perspective on organizational change and educational reform. In W. R. Penuel & K. O'Connor (Eds), *Learning research as a human science*. National Society for the Study of Education Yearbook, *109*(1), 98–112.

Pea, R. D., & Collins, A. (2008). Learning how to do science education: Four waves of reform. In Y. Kali, M. C. Linn, & J. E. Roseman (Eds.), *Designing coherent science education* (Vol. 3–12). New York: Teachers College Press.

Penuel, W. R., Fishman, B. J., & Cheng, B. (2011). *Developing the area of design-based implementation research*. Menlo Park: SRI International.

Petersen, J., & Smith, K. (2011, April). *Steering capital: Optimizing financial support for innovation in public education*. Bellwether Education Partners. http://bellwethereducation.org/steering-capital

Sabelli, N. (2008) *Applying what we know to improve teaching and learning*. Report prepared for the Carnegie/IAS Commission on STEM Education. Menlo Park: SRI International.

Schneider, B., & McDonald, S.-K. (2006a). Scale-up in practice: An introduction. In B. Schneider & S.-K. McDonald (Eds.), *Scale-up in education: Issues in practice* (Vol. 2, pp. 1–12). Lanham: Rowman & Littlefield Publishing Group.

Schneider, B., & McDonald, S.-K. (Eds.). (2006b). *Scale-up in education: Ideas in principle*. Lanham: Rowman & Littlefield Publishers.

Schneider, B., & McDonald, S.-K. (Eds.). (2006c). *Scale-up in education: Issues in practice*. Lanham: Rowman & Littlefield Publishers.

Spillane, J. P., Gomez, L. M., & Mesler, L. (2009). Notes on reframing the role of organizations in policy implementation. In G. Sykes, B. Schneider, & D. N. Plank (Eds.), *Handbook of education policy research* (pp. 409–425). Washington, DC: American Educational Research Association.

Stokes, D. E. (1997). *Pasteur's quadrant: Basic science and technological innovation*. Washington, DC: Brookings Institution Press.

Teh, L., Hogan, D., & Dimmock, C. (2013). Educational knowledge mobilisation and utilisation in Singapore. In B. Levin, J. Qi, & H. Edelstein (Eds.), *The impact of research in education: International perspectives on universities and knowledge mobilization*. Bristol: The Policy Press.

Wylie, E. C. (2008). *Tight but loose: Scaling up teacher professional development in diverse contexts* (ETS Research Report RR-09-29). Princeton: Educational Testing Service.

Part I
Models of Scaling

Chapter 2
The Role of Innovation in Scaling Up Educational Innovations

Nora H. Sabelli and Christopher J. Harris

Abstract Getting innovations to scale is an increasingly important mandate for educational research, yet also a vexing challenge for researchers who have attempted to take this on. A common perspective on scaling considers it fundamentally as an issue of how to take interventions that have been shown to work in a small number of settings and transfer them to a larger number of settings. In this chapter, we develop an argument that the principal aim of scaling up is not merely to expand the use of a particular educational innovation, but to improve education. When scaling up is viewed as a matter of improving education, the focus shifts from *transfer* of research to practice, where the researcher is primarily concerned with specifying the right conditions for the best fit, toward *transformation* of practice supported by research, where researchers become intermediaries who work with practitioners to improve the education system so that the essential principles of an innovation can be sustained. This shift in how we view scale-up has significant implications for research on the process of scaling up; for the relationship between research, policy, and practice; and for the sustainable and long-term improvement of education.

Introduction

"*A subset of creativity, innovation, involves the creation of a new idea but also involves its implementation, adoption, and transfer. Innovation and discovery transform insight and technology into novel products, processes, and services that create value for stakeholders and society*" (Schunn et al. 2006, p. 8). From this perspective on "value creation," we can consider that when teachers implement an intervention in their practice, they are innovating their practice; when an administrator changes aspects of the school's governance to support the teachers' implementation, he or she is, in fact, innovating leadership practice. And it is precisely this innovation

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of practice that enables the sustainability of the innovation in that setting and opens the door to the transformation of education. It is our contention, first, that the successful scaling up of educational innovations requires that we take on an innovation perspective and, second, that the ultimate goal of scaling up is sustainable educational improvement rather than to merely expand the use of a given educational innovation.

Getting an innovation to scale and sustaining that innovation at scale are not trivial matters. Richard Elmore, a prominent educational leader in instructional improvement, has stated in an oft-repeated quote, "*The pathology of American schools is that they know how to change. They know how to change promiscuously and at the drop of a hat. What schools do not know how to do is to improve, to engage in sustained and continuous progress toward a performance goal over time*" (Elmore 2002, p. 8). The existence of a large number of successful innovative practices and the fact that some schools use them do not necessarily imply the ability of these practices to scale up and be of use in many other venues. Similarly, the existence of research-generated knowledge does not imply its usability for policy or in practice. Failure to scale reflects limitations in the models and practices involved in generating research knowledge and in the scaling up process itself. It also reflects a hard reality—that "*monumental effort, unusual resourcefulness, and strong leadership of key individuals or groups*" is often required to implement lasting changes in any site (Hatch 2000, p. 581).

This chapter provides a reflection on scaling up that builds in part on knowledge gained from fields outside education that have been analyzing scaling for some time and to illustrate, with examples, how a framework consistent with such perspectives could inform scaling up research and local policy in education. Although our comments regarding policy have as their immediate goal local (school and district) policymakers (Elmore 2007), how state and federal policymakers regard the use of research-generated knowledge has implications that would require separate treatment (but see, e.g., the underlying assumptions of the What Works Clearinghouse[1]).

An analogy such as scaling up brings to mind mass production and creates unhelpful expectations about the nature of the process. An extensive literature points out the problems and limitations of this approach to scaling up in education (Cohen and Ball 2006; Cuban 1998; Elmore 1996). Rather than start from the premise that the core goal of scaling up is *expanding the use of an educational innovation*, we consider that the core goal of scaling up, despite the name, is *improving education through continuous progress toward a performance goal over time, using a working innovation to accomplish it*. This goal holds true for practitioners and policymakers even more so than for researchers. Taking this goal seriously requires a change of perspective from the implied point of view of a developer or a researcher who developed a successful intervention to that of the education practitioners who will implement the innovation in their different sites. The change has significant implications for the process of research on scaling up, for who owns it, for its influence on education policy and practice,

[1] http://ies.ed.gov/ncee/wwc/

for the long-term improvement of education, and for the relationship between research-generated knowledge and its use in practice.

The crucial role of the implementers' perspective arises from the fact that education has organizational and systemic aspects that go beyond teaching and learning; education frames the context in which classroom teaching and learning take place (see, e.g., Honig and Hatch 2004; Spillane 1998; Fuhrman 1993). *Improving practice, writ large, is different from adapting an innovation to a new context; improving practice requires aligning a number of innovations in practice, even if (or when) the improvement effort starts with scaling up a successful innovation*. Measures of success should differ depending on whether the goal is to scale up an intervention—where fidelity is of interest—or use the intervention to sustainably improve practice, where organizational and/or professional changes are expected (Coburn 2003; McDonald et al. 2006). Since the innovation itself undergoes changes when adaptation and appropriation occur, the number of students/teachers/schools using a particular practice is only one aspect of scaling up: static measures may not be sufficient; after all, a broken watch gives the exact time twice a day.

We do not mean to imply that all scaling up research undertaken from the perspective of a particular intervention is misguided. To wit, *To the contrary, scale-up research is doomed to fail if practitioners and policymakers expect it to generate absolute solutions to the nested, multifaceted, and often mutually reinforcing sets of social problems that contribute to low achievement scores. A context-based approach to scale-up research provides the evidence that educators need to select the interventions that are most likely to work in specific settings* (McDonald et al. 2006). We posit that scaling up a proven intervention is a tool to achieve sustainable, iterative, and evolutionary improvements in learning. And we are concerned with the next step, after a selection has been made, when building the site's capacity for the principled and sustainable implementation of the intervention becomes primary in the site's agenda.

This chapter highlights the importance of considering the perspective of the adopting site and is oriented toward local—and sustainable—improvements in education policy and practice more than to understanding the intervention itself. It also points to a type of research middle ground where the practitioner's and developer's perspectives can both be operative goals that can be advanced simultaneously (Penuel et al. 2013).

An NRC report on *Using Science as Evidence in Public Policy* (NRC 2012, pp. 4–5) points out: "The social sciences offer important knowledge about…how people learn, when they optimize and when they satisfice; why they organize themselves, form institutions, communicate, establish norms, and develop routines; how they assess risks; and how they make decisions, individually and collectively. *This array of scientific specialties has never fully addressed a key issue: when, why, how, even whether science is used in public policy making*" *(Authors' emphasis).*

The point made is glaringly evident in education, where the social organization of research is fragmented and underfunded. Bryk et al. (2011) make the point that education research has produced more useable knowledge than ever, but we have limited capacity to exploit it systematically to improve education. The same situation

is reflected in the NRC report mentioned above: *Although the relatively recent approach known as evidence-based policy and practice, focused on improving understanding of 'what works,' has influenced the production of scientific knowledge, it has made little contribution to understanding the use of that knowledge* (NRC 2012, p. 3).

Background: Perspectives on Scaling up and Improvement Goals

Before engaging in a discussion of scaling up and educational improvement as innovation, it is instructive to consider other perspectives on scaling up improvements. One institution that has been concerned with scaling up improvements in governance is the World Bank,[2] a group of international organizations that provide financial and technical assistance to developing countries. Two priorities of the World Bank are advancing reform and development to improve governance and reduce poverty. In their efforts to support ambitious reform in different regions of the world, they are beginning to consider the importance of local policies to implementation success. Their view, shown in Fig. 2.1, distinguishes between "incremental approaches" that work in the existing reform space and "transformational approaches" that expand the reform space. The later objective, which we believe is needed for

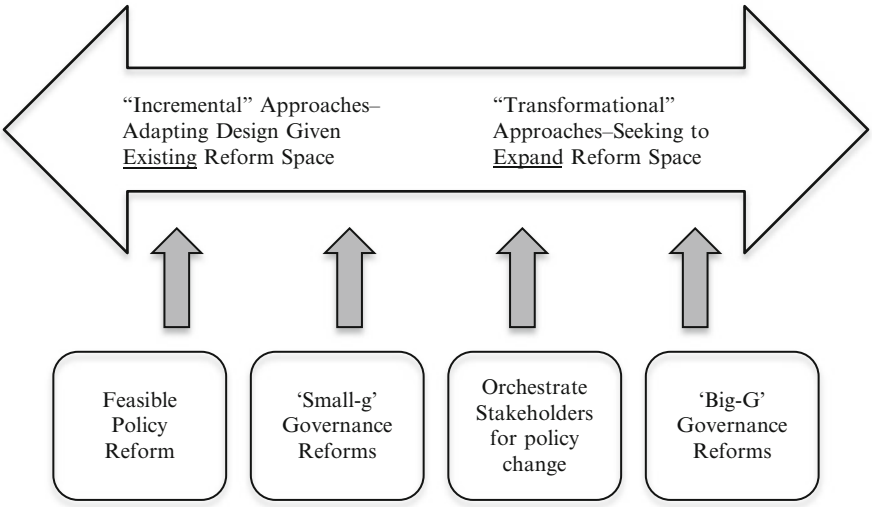

Fig. 2.1 The spectrum of reform space (World Bank 2010)

[2] http://blogs.worldbank.org/governance/moving-the-governance-agenda-forward-a-new-blog-on-development

sustainable improvements to practice, highlights the need to systemically involve local stakeholders in the process.

It should be noted that the World Bank experience indicates that small improvements are more readily attainable than ambitious transformations and may in many cases be the more effective way to start the process of change. Educational experience tends to confirm the observation that incremental approaches are easier to implement but offers few instances of incremental approaches achieving lasting change—as Elmore suggests in his comment at the start of this chapter. Our goal goes beyond *small* improvements; sustainable improvement does not emerge from a series of unrelated changes to practice. Rather, the path to sustainable improvements (transformation) must move through engaging local practitioners in innovating their governance, including the site's internal structural conditions and social relations, as well as their teaching and learning practices.

The policy-driven strategy adopted by the *State Implementation & Scaling up of Evidence-based Practices Center* (SISEP) at the University of North Carolina makes an important distinction that goes to the core of our argument. SISEP's scaling work is based on implementation support frameworks established by the National Implementation Research Network (NIRN; Fixsen et al. 2005, 2009) after an extensive review of the implementation evaluation literature in many different application areas (see Figs. 2.2 and 2.3).

The SISEP strategy distinguishes the practice of teaching and learning—which takes place in the interactions between teacher and student—from the educational

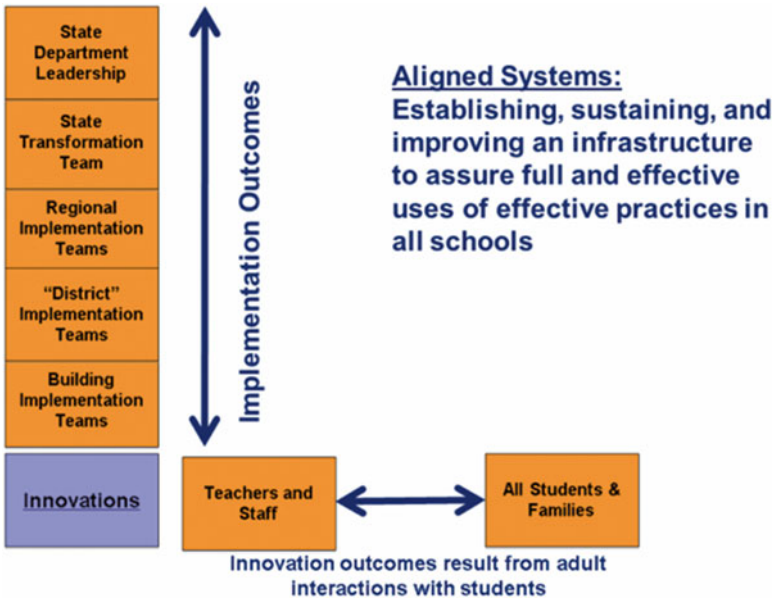

Fig. 2.2 Aligned systems, SISEP. UNC (Fixsen et al. 2009)

Interaction of Intervention Effectiveness and Implementation Effectiveness			
		Effectiveness of *Implementation* Practices	
		Effective	**Ineffective**
Effectiveness of *Intervention* Practices	**Effective**	Good Implementation Outcomes Good Consumer Outcomes	Poor Implementation Outcomes Poor Consumer Outcomes
	Ineffective	Good Implementation Outcomes Poor Consumer Outcomes	Poor Implementation Outcomes Poor Consumer Outcomes

Fig. 2.3 Interaction of intervention and implementation (Fixsen et al. 2009)

organization in which it takes place, that is, the organization that *is necessary to assure that each teacher and staff person is ready, willing, and able to provide best education practices every day for every student. If teachers do not use effective practices, students cannot benefit from them. Thus, implementation capacity is essential to quality education* (see Fig. 2.2, Aligned systems). Their strategy argues for the parallel importance of considering the organization that frames and bounds the teachers' practice and student learning as well as the instructional practice itself when undertaking the process of scaling up or studying an intervention.

Studies of school educational reform (Fishman et al. 2004) provide a useful framework in which to consider the characteristics of an implementation site—assessing its readiness for principled adaptation during the process of scaling up. The Fishman et al. framework encompasses three dimensions—school culture, capability, and policies—that influence the ease or difficulty with which sites can adopt and sustain an innovation and is a useful tool to gauge the innovation readiness of a site; within their framework, developing usable innovations is an iterative process of working to close gaps that exist between the innovation's demands and the system's capacity.

What Is the Innovation When Scaling Up an Innovation? General Considerations

A discussion of what to consider *innovation* itself is important, since what is meant by the word depends on the context in which it is used. We make here a distinction between what can be called *I*nnovation (capital *I*) and what can be called ***i***nnovation (lower case ***i***). We usually use the word to refer to major advances—the invention of the Internet led to the Innovation of e-commerce—and forget that there are multiple processes of innovation involved in attempting to implement a new idea; multiple e-commerce sites have innovated how e-commerce is integrated with their activities and how it is used with their customers. *Learning as a process entails individuals and organizations engaging in innovation in this localized sense*.

The innovation to be scaled up is the result of processes of invention and creativity, leading to products or interventions that, upon research, may merit scaling up. But any new implementation under different conditions, with different actors calls for a *new process of innovation*—a first attempt to carry out into practice something that is already developed by others. Practitioners are indeed innovating when they adapt the intervention being "scaled-up" to their own circumstances, inevitably both modifying it in the process and innovating in their own practice in order to use it. School administrators are also innovating as part of their governance when they change aspects of their policy or infrastructure to support teachers' innovation.

There are two reasons why the process of innovation in scaling up an intervention must be considered a form of innovation in its own right: making this kind of process visible encourages study of the process to understand *scaling up* the ideas embedded in innovative interventions. Highlighting the process of local innovations in practice in order to implement interventions underscores how changes in infrastructure and policies support or inhibit innovation.

An illustrative case in point is the ongoing evaluation of the Project-Based Inquiry Science curriculum, a collaborative effort between learning scientists and a large urban school district to create the best conditions for reaping positive impact from the curricular intervention as it goes to scale (Harris et al. 2015; Penuel et al. 2015). The research team and district stakeholders began working together a year in advance to understand the real-world school and classroom contexts in which the curriculum would be implemented. They studied how best to support the introduction of the curriculum and conduct a rigorous study of its impacts within the district. Rather than treating the ambitious curricular intervention and accompanying empirical study as fixed objects and fitting them rigidly into a large complex urban school system, the researchers and the school district as partners jointly negotiated the implementation. Difficult issues were resolved, leading to modifications to the study design in some instances and, in others, to changes in school and/or district routines to better support both curriculum implementation and the research study. The collaboration process enabled school administrators and researchers to establish shared goals and make explicit to one another their unique goals. Thus, they were better positioned to meet the study team's goals for conducting the study and the district's goals for implementing the curriculum and participating in the research.

A succinct and useful characterization of the types of intellectual work and ownership involved in understanding how research and practice can be integrated is Carlile's concept of "3-Ts" (Carlile 2004), derived from studies in a noneducation (manufacturing) context and based on an analysis of the type of boundary between participants in the exchange. Briefly, *Transfer* from research to practice, *Translation* of research into practice, and *Transformation* of practice based on research *(see Box)* are three approaches corresponding to three different possible goals for scaling up work.

Transfer reflects the traditional one-size-fits-all scale-up model that has not led to sustainable improvements. *Translation* and *Transformation* imply adaptation to actual contexts and policies of knowledge utilization; *Translation* privileges the

perspective of the developer, while *Transformation* privileges the needs of the implementation site. Both benefit from taking place in a neutral middle ground and from the expertise and collaborations brought about by the diverse actors that populate this space, be they individuals or organizations.

Organizational Science Terminology (*From* Carlile 2004)

- *Syntactic boundary: a transfer or information processing approach*: moving ideas, processes, research results, or skills from one organization to another. Knowledge storage and retrieval is adequate. It depends on having a common lexicon to share and assess knowledge at the boundary.
- *Semantic boundary: a translation or interpretive approach*: developing shared meaning across contexts through a process of negotiating and defining common interests. Colocation, cross-functional teams, and knowledge brokers and translators can facilitate the process.
- *Pragmatic boundary: a transformation or political approach*: a process of negotiating in situations where there are different interests between actors that impede sharing and assessing knowledge. It requires practical trade-offs and political effort and can be facilitated by prototyping and other boundary objects that can be jointly transformed.

A parallel, though not identical, construct comes from educational policy research (Datnow and Park 2009) and is based on the theory of action behind the process: technical-rational, mutual adaptation, or sense-making/co-construction. The technical-rational strategy is similar to transfer: change is *uni*directional; designers are active while implementers are passive and pragmatic; fidelity of implementation is valued. The mutual adaption theory has many commonalities with translation research and with Design-Based Implementation Research (DBIR, Penuel et al. 2011): change is viewed as *bi*directional, and policy formation and policy implementation are distinct; it *acknowledges that pressure from the top can serve as a catalyst for change, but [they] argue that policy is actually made at the local level* (Datnow and Park 2009).

Datnow and Park argue that the *bi*directional concept of mutual adaptation fails to capture the complex *multi*directional nature of actual educational practice, and thus they favor the sense-making and co-construction model that considers change arising from actors within education as well as from outside forces and thus is *multi*directional. This internal/external multiplicity of actors aligns this last perspective with transformation: "The sense-making/co-construction perspective not only allows for a greater deal of human agency, but it uses policy instruments such as capacity building and symbolic leverage to change practice."

We will use Carlile's 3-T terminology because it highlights the goals of the process rather than its mechanism; goals are relevant to practice and policy decisions, while mechanisms are of relevance to research.

There are many well-documented reasons why the more traditional linear scaling up (equivalent to *transfer*) strategies usually fail in education, ranging from policy instability to lack of adequate professional buy-in (see, e.g., Fullan 2000; Glennan et al. 2004). Most of the recent scaling up work being conducted can be considered *translation* efforts (Sabelli and Dede 2013), employing different researcher-practitioner collaboration strategies that take into account the need to balance fidelity in implementing a well-researched innovation with adaptation to dynamic local contexts (Sabelli and Dede 2013; Bryk et al. 2011; Dede et al. 2005).

To move from *translation of research* strategies to *transformation of practice* strategies, research must explicitly consider policy and organizational issues, in addition to learning research. It is useful to remember that *Research, when it has something to offer, must be at the policy table. But it shares that table with an array of nonscientific reasons for making a policy choice: personal and political beliefs and values are present, as are lessons from experience, trial and error learning, and reasoning by analogy* (NRC 2012, p. 3).

In what follows, we illustrate our ideas with case studies of successful transfer, translation, and transformation to be used as "boundary objects" for discussion. The three examples chosen have been developed, implemented, and researched over timescales on the order of decades. All three have at their base learning and pedagogy. There are, of course, many other examples that we could have chosen and other success cases that merit acknowledgement, but that are either not well known to us, may not be as illustrative of the process we highlight, may not have been the subject of research, or may not be as long-lasting to the same extent as the ones chosen. A recent article by William Penuel and colleagues (Penuel et al. 2011) discusses in detail a number of relevant DBIR ongoing translation collaborations, including some that are "walking the talk" toward transformation (e.g., Donovan et al. 2013; Scherrer et al. 2013).

Where Is the Innovation in Scaling Up an Innovation? Examples of Transfer, Translation, and Transformation

"Transfer" from Research to Practice and How It Depends on the Selection of Schools: Success for All School Reform as an Example

Perhaps the best example of the transfer approach to scaling up an educational intervention is the comprehensive school reform program, *Success for All* (Slavin and Madden 2001).

> Success for All is a school-based achievement-oriented program for disadvantaged students in grades pre-K through five. This program is designed to prevent or intervene in the development of learning problems in the early years by effectively organizing instructional and family support resources within the regular classroom. In particular, the goal is to

> ensure that virtually every student in a high-poverty school will finish the third grade with grade-level reading skills.[3]

The elementary Success for All program, consisting of a highly specified school-wide curriculum with professional development and other school-wide components, has scaled-up from just a handful of schools to more than 1,600 schools with more than two million students served over the past two decades (Slavin et al. 2008). The developers view going to scale as a process of replication where fidelity of implementation is considered crucial to success. Thus, the curriculum and program components are essentially the same at all schools, with each school receiving the same training, coaching support, and instructional materials.

Teachers at participating schools are expected to change their practices to align with the instructional stance of the program. They are asked to commit to a systematic program of self-study, develop a school improvement plan, and implement the plan. Faculty commitment is considered so important that before adopting, the majority of the teachers in a school must agree to follow the tenets of the program.

Research on the achievement effects of Success for All shows the benefit of high implementation fidelity—the program has consistently demonstrated positive, significant effects on student achievement (e.g., Borman and Hewes 2002; Borman et al. 2007) and schools implementing the curriculum and all program components fare better than do schools implementing the program to a lesser degree (Nunnery et al. 1996).

The Success for All Foundation is the key driver in the expansion of Success for All. The foundation provides the organizational blueprint and a set of supports, including training of school staff, for schools that adopt the program. Through the foundation, Success for All establishes relationships with schools and districts and provides specific guidance in how to replicate the practices used by Success for All schools. For example, the program supports knowledge transfer and implementation via material resources such as manuals and online help that outline structures and routines, professional development that familiarizes staff with practices and norms, and site-based support from trainers who provide guidance for planning and implementation. Routines are considered essential as they provide the replicable step-by-step directions for what to do in particular situations across schools. Once a program is up and running, Success for All evaluators use a rating scheme that describes levels of adoption to determine the extent to which teachers and their school are implementing the program with fidelity.

It is important to note that such a transfer approach to scaling up does not necessarily mean that an intervention is static and impervious to change. In the case of Success for All, the program has evolved over the years in response to new research findings and through collaboration of the developers and foundation with teachers and school leaders (Peurach 2011). In the decades since its' first instantiation in schools, the developers and foundation have drawn from new research to help improve the program to increase effectiveness, added in supports for implementation based on lessons learned from prior implementations, and have strategized with

[3] http://www2.ed.gov/pubs/OR/ConsumerGuides/success.html

schools to ensure sustainability in turbulent environments. Success for All's central approach is to change the school to fit the intervention, rather than change the core of Success for All. The changes it has undergone have been aimed principally at helping schools to better fit with the program and thus make the essential components of the program work better within the school setting. In terms of our framework, the question to ask is what if any Success for All practices have transferred to topics and classrooms not part of the literacy teaching that is core to the Success for All intervention?

"Translation" of Research into Practice and Design for Adaptation to Context: The Scaling Up SimCalc Project

An example of the translation approach to scaling up innovation is the *SimCalc* middle school mathematics program (Kaput and Roschelle 1998; Roschelle et al. 2008a). With the explicit goal of applying principles drawn from learning sciences research, SimCalc integrates teacher professional development, curriculum, and software called SimCalc MathWorlds to support teaching and learning the mathematics of change and variation. Scaling up has been a central goal of the developers and researchers of the SimCalc program since its inception more than two decades ago (Roschelle et al. 2008a, b).

In the early years of the development of the program, the team had teachers implement the SimCalc MathWorlds software and associated learning activities in a wide range of settings—at many grade levels and with many different student populations in many different school contexts. In their approach, they were not aiming to show that one package worked across all settings but to understand the variance in settings and the range of curricular approaches that might work. An important outcome of these explorations is that they were able to build on insights and develop an intervention adaptable to a wide variety of school and classroom circumstances. As the program evolved over a decade, the research shifted to tens of teachers, then tens of schools, and then to an increasing number of districts across a range of geographic settings. During this time, their sustained collaborations with "boutique" or "maverick" teachers who were highly motivated volunteers helped the SimCalc development team better understand patterns of teacher use and begin to articulate features of effective professional development for SimCalc. When the SimCalc Scale-up project began, the configuring of the program for wide-scale use turned toward a more diverse community of teachers and benefitted significantly from the initial volunteer teachers' collaborations.

In the scale-up years, SimCalc researchers established the *Scaling Up SimCalc* project to systematically explore what to try to scale up among the many variations of the program features and materials that had been invented and tried. By this time, the team had a solid understanding of the features that were essential to success across settings and of which of the many ways to organize the software-based lessons, curricula, teachers' professional development, and assessment brought the

most benefit *within existing school constraints*. Yet, they recognized that their program required even greater specification in order to go to scale. In particular, they needed to package the program materials with a very clear scope and place in the standard mathematics curriculum to make it attractive and easier for schools to adopt and for teachers to use. They also needed to create a professional development strategy that would make sense given whatever program configuration was decided upon. To meet these constraints, they decided to package SimCalc as a highly adaptable replacement unit aligned to standards for middle school mathematics. With the curricular package fully specified (i.e., an integrated package of teacher professional development, paper curriculum, and representational software), they then conducted a series of scale-up experiments to examine efficacy with more careful attention to sampling populations.

Their experiments included large samples of teachers with different backgrounds, attitudes, and levels of mathematical knowledge in a variety of middle school instructional settings. Results from the first series of studies show that while the core SimCalc curricular features and technologies were consistent across settings, different teachers configured the available learning resources in quite different ways, suggesting that SimCalc is effective in enabling a wide variety of teachers in a diversity of settings to support student learning of more advanced mathematics (Roschelle et al. 2010).

"Transformation" and How It Extends the Concepts of DBIR and Translation: Boston's Approach to High School Renewal as an Example

The Success For All and SimCalc examples showcase efforts to support change of specific disciplinary pedagogies. Boston's successful urban school reform is also based on changing pedagogy, but not in any one subject area. It illustrates instead the interrelated complexities of transforming the pedagogical practices of an education system and, interestingly, also of how to conceptualize specific drivers for change not in isolation but as components integrated with other parts of the education system so they can become part of the infrastructure. This long-lasting story has been evaluated, researched, and told many times (Neufeld and Woodworth 2001; Neufeld and Guiney 2002; Reville 2007; Childress et al. 2008; Papay et al. 2012), and we will only summarize here how conceiving systemic reform from the system's perspective adds to our understanding of the process and reconceptualizes the critical role that researchers can play in support of transformation, with an emphasis on how this role differs from researchers' role in either Transfer or Translation research (Neufeld and Guiney 2002).

The Boston Public Schools (BPS) designed and implemented an approach to high school renewal to solve the major challenges these schools faced: *low literacy achievement, high absenteeism and dropout rates, and high student alienation from curriculum, instruction, and, too often, school personnel… If the interwoven*

problems of alienation and poor literacy skills are acknowledged as the root problems and addressed intensively, then growth in students' reading comprehension will accelerate, and there will be fundamental changes in the relationships between teachers and students, students and students, and students and the adult world beyond school (Proposal to the Carnegie Corporation, p. 10).[4]

BPS partnered with many local organizations[5] and received significant funding from both the Carnegie Corporation and the Gates Foundation to implement its plan over a number of years. An already established partner, the Boston Plan for Excellence in the Public Schools (BPE), had for many years awarded grants to Boston teachers and schools to improve student achievement and became convinced that this strategy could not lead to sustainable school-wide or district-wide improvement. In response, BPE's Executive Director worked with Boston's new superintendent of schools to develop a model of whole-school change intended to have a sustainable impact on schools *and on the Boston Public Schools (BPS) as a system* (Neufeld and Woodworth 2001). To do so, BPE turned itself into an intermediary organization (Sabelli and Dede 2013) working outside the system but in partnership with it. This arrangement allowed for a research lens to be placed on the process.

BPS' research-based theory of action (see Neufeld et al. 2005) included stability, support from a mayor committed to education, focus on instruction, cooperation from teachers unions, central office reform, unusual partnerships, and a significant source of external funding—this last one reflective of that fact that *reform is always an experimental process that needs to be subjected to ongoing formative evaluation.*

Implementation focused squarely on instruction from the perspective of district goals, which brought to the fore the need for access to quality teachers, which in turn required n the support of teacher unions and of local teacher preparation programs. While its focus on instruction is not unique, the BPS innovation consisted of conceptualizing access to high-quality teachers as a long-term systemic need of the district—its demographics and its outside stakeholders—and therefore went beyond the general calls for better-prepared teachers, teacher credential exams, teacher preparation curricula, and so on. A systems view of the problem implied (a) detailed knowledge about BPS's specific needs, (b) the need to provide BPS support for teachers when they were inducted into the system, (c) the need to support teacher candidates during their period of preparation, and (d) a local infrastructure to integrate the innovation into the BPS modus operandi.

The BPS superintendent saw the pressing need to attract more diverse and talented teachers, especially minority teachers and teachers for hard-to-fill positions such as math, science, and special education[6] and felt that most teacher training institutions focused more on content than on the practice of teaching. Taking the medical approach to *clinical practice* as a model, BPS and BPE developed the *Boston*

[4] Cited in Neufeld et al. (2005).

[5] The Boston Plan for Excellence in the Public Schools (BPE), Jobs for the Future (JFF), the Center for Collaborative Education (CCE), and the Boston Private Industry Council (PIC).

[6] Most of the information in what follows is taken from an NPR interview, *Programs Train Teachers Using Medical School Model*, by Claudio Sanchez. NPR, April 22, 2010, http://www.npr.org/templates/story/story.php?storyId=125854975 and interviews of Payzant and Solomon by one of the authors (NHS).

Teacher Residency (BTR) (Solomon 2009; see also Berry et al. 2008). Note that the model chosen is a *residency*, implying professional status and ability to act independently, rather than the less professional model of an internship.[7] Today, the Boston Teacher Residency program (BTR) is currently a partnership of the Boston Public Schools, its local education foundation, the Massachusetts Service Alliance (MSA, the state-level arm of AmeriCorps), and the University of Massachusetts, Boston.

BTR residents take a full load of courses from area colleges that offer master's degrees in education. The "clinical training" part of the program takes place 4 days a week with an accomplished teacher in a Boston public school where residents experience the context in which they will teach. After an intensive 2-month summer institute, BTR residents spend a clinical year with a mentor teacher while taking related courses and participating in discussions ("grand rounds") that blend theory and practice. They devote one evening and a day (Friday) each week to rigorous courses and seminars related to the specific goals of BPS. During their year-long preparation, BTR provides a $12,100 stipend and eligibility for healthcare benefits.

Residents earn a master's degree from the University of Massachusetts, Boston, with the cost forgiven in exchange for a 3-year commitment to teach in the Boston Public Schools. To date, BTR has been very successful in recruiting and training teachers of color (49 % of graduates fall into this category). Moreover, a high proportion of BTR graduates teach in Boston's highest-need areas, with 55 % of secondary graduates teaching math and science and 37 % of all graduates teaching special education or English as a Second Language.

BTR invested heavily in school-based coaches. Residents consider coaching an opportunity to learn and have time to work on issues of practice in a sustained manner. Coaching also offers a first step toward differentiated career ladders for teachers. Instructional Leadership Teams in each school to distribute leadership, creating additional new roles for classroom teachers. Likewise, the district created a School Leadership Institute to prepare school leaders at a time when district administrators believed that universities were not producing the leaders needed. The program has produced a number of minority principals/headmasters.

The new structures built as part of the BTR—career ladders for teachers, instructional leadership teams to distributed leadership, and programs to develop teachers to serve specific district needs as to demographics and professionalization, plus the origins and leadership of the process—mark BTR as a transformation that created in the district capacity and infrastructure for improvement, rather than as a bidirectional translation of research into educational practice.

[7] http://www.bostonteacherresidency.org/btr-impact/. Other districts have adopted the BTR model. Boston, Chicago, and Denver's Boettcher Teachers Program founded the Urban Teacher Residency Institute. http://www.utrunited.org/the-residency-model

Conclusion

Researchers play different roles in support of scaling up in the three strategies discussed in this chapter. While the boundary between the focus of Transfer and of Translation research is relatively clear and straightforward, the boundary between Translation and Transformation is not so obvious and is one that can become blurred.[8] In fact, such a blurring could be considered a desired and natural outcome of a translation collaboration, as improvements become reflected in the practice partner's infrastructure. The difference between translation and transformation is aptly stated by Datnow and Park (2009): *The sense-making/co-construction not only allows for a greater deal of human agency but it uses policy instruments such as capacity building and symbolic leverage to change practice*. If a transfer-style scale-up relies primarily on a researcher or designer perspective with a more passive role for practitioners in terms of agency, and a translation-style collaboration must be equally owned by researchers and practitioners, *a transformation-style change must be owned and integrated within the complex and multifaceted organizational system, with researchers in a role as intermediaries* (Sabelli and Dede 2013)—a role often performed by good, research-based "evaluators." Behind this transformation view of scaling lies a consideration that what is worth scaling up is more than an artifact, be it a curriculum or an intervention. *It is the set of ideas or principles behind the intervention and the process of implementing those principles* that will allow new implementers to do justice to the intentions of developers and researchers.

The multiplicity of internal and external perspectives is what distinguishes translation from transformation, because under the latter model the outcomes of scaling up must be *both knowledge and people*. If stakeholders are left out of the process, they will not understand its nuances and will not be able to adapt their actions to the new needs—*continuous progress toward a performance goal over time*—and thus support or conduct principled implementations. The learning entity must be the system itself—the organization, through its people, its processes, and its infrastructure—for sustainable improvements to take place. As Marc Tucker, president of the National Center on Education and the Economy, has pointed out, a country such as Finland that excels in STEM international comparisons does not create "STEM-specific" policies but "education policies" and in so doing creates the conditions for STEM excellence throughout the system (Tucker 2011).

In education, goals matter, particularly for policy stakeholders and practitioners.[9] Though many use the language of scaling up, the strategy used for carrying it out is a better reflection of the ultimate goal of the activity. Our aim in this chapter has been to develop an argument that the goal of developing and scaling educational

[8] For example, the work of Lauren Resnick and the Institute for Learning, *ifl.lrdc.pitt.edu/ifl/*

[9] Recall that after the launch of Sputnik, the country and NSF made the preparation of scientists a priority, and succeeded — they created the groundwork for the emergence of scientific leadership that impacted the US for many decades following the launch. But we are still dealing, as a society, with its unintended consequences: "*science is only for the best and the brightest*."

innovations is sustainable educational improvement, rather than to merely spread the use of an innovation, and that this goal should be explicit in scale-up research. We posit that looking at the *process of scaling up* from the standpoint of the ultimate goal will better position researchers to consider the real-world settings in which their interventions will be put into practice. When researchers view scaling up as principally a matter of improving education, the focus shifts from *transfer* of research to practice, where the researcher is primarily concerned with specifying the right conditions for the best fit, toward *transformation* of practice supported by research. Viewed in this way, the role of the researcher in scaling up research is to support practitioners in the broader effort to change their organizations in ways that will support not only the intervention at hand but also future improvement efforts.

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References

Berry, B., Montgomery, D., & Snyder, J. (2008). *Urban teacher residency models and institutes of higher education: Implications for teacher preparation*. Hillsborough: Center for Teaching Quality and National Council for Accreditation of Teacher Excellence.

Borman, G. D., & Hewes, G. M. (2002). The long-term effects and cost-effectiveness of Success for All. *Educational Evaluation and Policy Analysis, 24*, 243–267.

Borman, G. D., Slavin, R. E., Cheung, A., Chamberlain, A., Madden, N. A., & Chambers, B. (2007). Final reading outcomes of the national randomized field trial of Success for All. *American Educational Research Journal, 44*(3), 701–731.

Bryk, A. S., Gomez, L. M., & Grunow, A. (2011). Getting ideas into action: Building networked improvement communities in education. In M. T. Hallinan (Ed.), *Frontiers in sociology of education* (pp. 127–162). New York: Springer.

Carlile, P. R. (2004). Transferring, translating, and transforming: An integrative framework for managing knowledge across boundaries. *Organizational Science, 15*(5), 555–568.

Childress, S., Marietta, G., & Suchman, S. (2008). *Boston teacher residency: Developing a strategy for long-term impact*. Case N9-309-043, Harvard Business School Publishing, Boston, MA 02163.

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

Cohen, D. K., & Ball, D. L. (2006) Educational innovation and the problem of scale. In B. Schneider, & S. K. McDonald (Eds.), *Scale up in education. Volume 1: Ideas in principle*. New York: Rowman & Littlefield Publishers, Inc.

Cuban, L. (1998). How schools change reforms: Redefining reform success and failure. *Teachers College Record, 99*(3), 453–477.

Datnow, A., & Park, V. (2009). Towards the co-construction of educational policy: Large-scale reform in an era of complexity. In D. Plank, B. Schneider, & G. Sykes (Eds.), *Handbook of education policy research* (pp. 348–361). New York: Routledge Publishers.

Dede, C., Honan, J., & Peters, L. (Eds.). (2005). *Scaling up success: Lessons learned from technology-based educational innovation*. New York: Jossey-Bass.

Donovan, M. S., Snow, C., & Daro, P. (2013). The SERP approach to problem-solving research, development, and implementation. In W. R. Penuel, B. Fishman, A. Allen, & B. Cheng (Eds.),

Design-based implementation research (National Society for the Study of Education Yearbook, Vol. 112, pp. 400–425). New York: Teachers College Press.

Elmore, R. (1996). Getting to scale with good educational practice. *Harvard Educational Review, 66*(1), 1–26.

Elmore, R. F. (2002). The limits of change. *Harvard Education Letter, 18*(1), 7–8.

Elmore, R. F. (2007). *School reform from the inside out: Policy, practice, and performance*. Cambridge, MA: Harvard Education Press.

Fishman, B., Marx, R. W., Blumenfeld, P., Krajcik, J., & Soloway, E. (2004). Creating a framework for research on systemic technology innovations. *The Journal of the Learning Sciences, 13*(1), 43–76.

Fixsen, D. L., Naoom, S. F., Blase, K. A., Friedman, R. M., & Wallace, F. (2005). *Implementation research: A synthesis of the literature*. Tampa: University of South Florida, Louis de la Parte Florida Mental Health Institute, The National Implementation Research Network (FMHI Publication #231).

Fixsen, D. L., Blase, K., Horner, R., & Sugai, G. (2009). *Scaling up evidence-based practices in education*. SISEP scaling up brief. Raleigh: OSEP Technical Assistance Center on State Implementation of Scaling Up Evidence-based Practices. See http://sisep.fpg.unc.edu/learning-zone/how/align-systems

Fuhrman, S. (Ed.). (1993). *Designing coherent education policy: Improving the system*. San Francisco: Jossey-Bass Publishers.

Fullan, M. (2000). The three stories of education reform. *Phi Delta Kappan, 81*, 581–584.

Glennan, T. K., Jr., Bodilly, S. J., Galegher, J. R., & Kerr, K. R. (2004). *Expanding the reach of education reforms perspectives from leaders in the scale-up of educational interventions*. Santa Monica: RAND Corporation.

Harris, C. J., Penuel, W. R., DeBarger, A., Moorthy, S., D'Angelo, & Krajcik, J. S. (2015, April). *Supporting next generation science teaching and learning with curriculum materials: Results from an efficacy study*. Paper presented at the annual meeting of the National Association for Research in Science Teaching, Chicago, IL.

Hatch, T. (2000). What does it take to break the mold? Rhetoric and reality in new American schools. *Teachers College Record, 102*, 561–589.

Honig, M. I., & Hatch, T. C. (2004). Crafting coherence: How schools strategically manage multiple, external demands. *Educational Researcher, 33*(8), 16–30.

Kaput, J., & Roschelle, J. (1998). The mathematics of change and variation from a millennial perspective: New content, new context. In C. Hoyles, C. Morgan, & G. Woodhouse (Eds.), *Rethinking the mathematics curriculum* (pp. 155–170). London: Falmer.

McDonald, S. K., Keesler, V. A., Kauffman, N. J., & Schneider, B. (2006). Scaling up exemplary interventions. *Educational Researcher, 35*(3), 15–24.

National Research Council. (2012). In K. Prewitt, T. A. Schwandt, & M. L. Straf (Eds.), *Using science as evidence in public policy* (pp. 4–5). Washington, DC: Committee on the Use of Social Science Knowledge in Public Policy; Center for Education; Division of Behavioral and Social Sciences and Education.

Neufeld, B., & Guiney, E. (2002). Transforming events: A local education fund's efforts to promote large-scale urban school reform. In *The Annenberg Challenge: Lessons and reflections on public school reform*. New York: Carnegie Corporation of New York.

Neufeld, B., & Woodworth, K. (2001). *Taking stock: The status of implementation and the need for further support in the BPE–BAC Cohort I and II schools*. Cambridge, MA: Education Matters, Inc.

Neufeld, B., Levy, A., & Chrismer, S. S. (2005). *High school renewal in the Boston Public Schools: Focus on organization and leadership*. Cambridge, MA: Education Matters, Inc.

Nunnery, J., Slavin, R. E., Ross, S. M., Smith, L. J., Hunter, P., & Stubbs, J. (1996). *An assessment of Success for All program component configuration effects on the reading achievement of at-risk first grade students*. Baltimore: Johns Hopkins University, Center for Research on the Education of Students Placed at Risk.

Papay, P., West, M., Fullerton, J. B., & Kane, T. J. (2012). Does an urban teacher residency increase student achievement? Early evidence from Boston. *Educational Evaluation and Policy Analysis, 34*(4), 413–434.

Penuel, W., Fishman, B., Cheng, B. H., & Sabelli, N. (2011). Organizing research and development at the intersection of learning, implementation, and design. *Educational Researcher, 40*(7), 331–337.

Penuel, W. R., Fishman, B., Allen, A., & Cheng, B. (Eds.). (2013). *Design-based implementation research* (National Society for the Study of Education Yearbook, Vol. 112). New York: Teachers College Press.

Penuel, W. R., Harris, C. J., & DeBarger, A. H. (2015). Implementing the next generation science standards. *Phi Delta Kappan, 49*(6), 45–49.

Peurach, D. J. (2011). *Seeing complexity in public education: Problems, possibilities, and Success for All*. New York: Oxford University Press.

Reville, P. (Ed.). (2007). *A decade of urban school reform: Persistence and progress in the Boston Public Schools*. Cambridge, MA: Harvard Education Press.

Roschelle, J., Tatar, D., & Kaput, J. (2008a). Getting to scale with innovations that deeply restructure how students come to know mathematics. In A. E. Kelly, R. Lesh, & J. Y. Baek (Eds.), *Handbook of design research methods in education* (pp. 369–395). New York: Routledge.

Roschelle, J., Tatar, D., Shechtman, N., & Knudsen, J. (2008b). The role of scaling up research in designing for and evaluating robustness. *Educational Studies in Mathematics, 68*, 149–170.

Roschelle, J., Shechtman, N., Tatar, D., Hegedus, S., Hopkins, B., Empson, S., Knudsen, J., & Gallagher, L. P. (2010). Integration of technology, curriculum, and professional development for advancing middle school mathematics. *American Educational Research Journal, 47*(4), 833–878.

Sabelli, N., & Dede, C. (2013). Empowering DBIR: The need for infrastructure. In W. R. Penuel, B. Fishman, A. Allen, & B. Cheng (Eds.), *Design-based implementation research* (National Society for the Study of Education Yearbook, Vol. 112, pp. 464–480). New York: Teachers College Press.

Scherrer, J., Israel, N., & Resnick, L. B. (2013). Beyond classrooms: Scaling and sustaining instructional innovations. In W. R. Penuel, B. Fishman, A. Allen, & B. Cheng (Eds.), *Design-based implementation research* (National Society for the Study of Education Yearbook, Vol. 112, pp. 426–442). New York: Teachers College Press.

Schunn, C. D., Paulus, P. B., Cagan, J., & Wood, K. (2006). *Final report from the NSF innovation and discovery workshop: The scientific basis of individual and team innovation and discovery*. Washington, DC: National Science Foundation.

Slavin, R. E., & Madden, N. A. (Eds.). (2001). *Success for all: Research and reform in elementary education*. Mahwah: Erlbaum.

Slavin, R. E., Madden, N. A., Chambers, B., & Haxby, B. (2008). *Two million children: Success for All*. Thousand Oaks: Corwin Press.

Solomon, J. (2009). The Boston teacher residency: District-based teacher education. *Journal of Teacher Education, 60*(5), 478–488.

Spillane, J. (1998). State policy and the non-monolithic nature of the local school district: Organizational and professional considerations. *American Educational Research Journal, 35*(1), 33–63.

Tucker, M. (2011, May). *Standing on the shoulders of giants: An American agenda for education reform*. Washington, DC: National Center on Education and the Economy.

Chapter 3
Scaling from the Perspectives of Policymakers and Practitioners from Singapore

David Hung, Shu-Shing Lee, and Laik Woon Teh

Abstract In many countries and regions, education authorities have shown interests in promoting new education initiatives or innovations. With the hefty investments, they are keen to see that their initiatives are well received by the various stakeholders, namely, national leaders, district-level leaders, school leaders, teachers, students and their parents, and can be successfully scaled and improve learning. However, are the perspectives and expectations of policymakers and practitioners with regard to education innovations and their scaling necessarily the same as those of the researchers? Some of these stakeholders may expect a linear model of scaling, i.e. innovations can be translated into ready intervention packages which can be replicated mechanically by all the practitioners and consequently uplifting learning outcomes within the nation. Others may expect extensive adaptation to be allowed for any education innovations accepted for scaling. This chapter describes an ecological model for scaling that allows for a productive tension due to the differences in stakeholder perspectives. Based on scaling practices and considerations that operate in Singapore, the lessons about how scaling can be advanced at the systems level, which may be relevant for school districts, regions or countries similar in size to Singapore, are drawn. The paper also attempts to distil underlying scaling principles that can provide some directions to help analyse or shape scaling strategies across a hierarchy of much larger scale levels.

Introduction

Many high-performing education systems are concerned with a change reform agenda, especially towards student-centred pedagogies and away from conventional teacher-centred models. These efforts aim to reach out to all students in the system rather than just disparate change efforts. The Singapore education system has over the last decade invested in classroom research to transform teacher-centred pedagogies into student-centred practices. Having achieved a new understanding of

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the conditions for how this change occurs, policymakers have been more concerned with how these understandings can be applied to transform the whole system. This chapter describes an ecological model for scaling (Hung et al. 2014) that allows for a productive tension due to the differences in stakeholder perspectives. It also draws on scaling practices and considerations that operate in Singapore from perspectives of Singaporean policymakers and practitioners who are involved in mobilising knowledge, i.e. creating, mediating and utilising knowledge (Hogan 2011; Teh et al. 2013). The underlying scaling principles and heuristics that can provide some directions to help analyse or shape scaling strategies across a hierarchy of much larger scale levels are then surfaced. In the discussion and conclusion sections, we also attempt to delineate the role of research and researchers and that of practice for practitioners and policymakers in this scaling agenda.

Background

Singapore is a small and highly urbanised city state. It has a total population of 5.399 million with a population diversity of 7,540 per sq km in 2013 (Department of Statistics, Singapore 2014). Today, based on the latest official estimates, Chinese, Malays and Indians make up 74, 13 and 9 % of the Singapore resident population, respectively. The remainder is classified as 'others', including 'Eurasians' (those from European and Asian descent). The diversity and size of the Singapore population are mirrored in its education system. Singapore has a small education system with a relatively short history and an ethnically diverse school population. There are about 180 primary schools (grades 1–6), 170 secondary schools (grades 7–10) and about 20 junior colleges, centralised institutes and specialised schools that offer academic preuniversity curriculum (grades 11–12). All these publicly funded schools employ English language as the medium of instruction and cater to almost all Singaporean students of schoolgoing age. Prior to 1978, besides English medium schools, there were vernacular schools where lessons were taught primarily in Chinese, Malay and Tamil. Today, all the publicly funded schools are organised into 28 school clusters, each with 12–14 schools. Each cluster is headed by a cluster superintendent who supervises and advises the school principals. Currently, principals have substantial autonomy in managing the learning programme of the schools within the Ministry of Education (MOE), Singapore guidelines.

Even after three decades of reorganisation, rationalisation, consolidation and reformation, the Singapore education system remains highly centralised and regulated (Gopinathan 1985; Hogan and Gopinathan 2008). Its instructional system has been honed to a level that maximises efficiency and minimises costs. In spite of (or perhaps because of) Singapore's success in international studies such as the Progress in International Reading Literacy Study (PIRLS), the Trends in International Mathematics and Science Study (TIMSS) and the Programme for International Student Assessment (PISA), since the late 1990s, Singapore has stepped up the

refining and reforming of its education system since the late 1990s. In 1997, then Prime Minister Goh Chok Tong announced that:

> The old formulae for success are unlikely to prepare our young for the new circumstances and new problems they will face … we must ensure that that our young can think for themselves, so that the next generation can find their own solutions to whatever new problems they may face. (Goh 1997)

Since the launch of Thinking Schools, Learning Nation (TSLN) in 1997, educational policy in Singapore has been dominated at the broadest level by a vision of 'a nation of thinking and committed citizens capable of meeting the challenges of the future, and an education system geared to the needs of the 21st century' (Dimmock and Goh 2011). In 2011, Singapore Ministry of Education further articulated its vision for education being *values driven and student centric* (Heng 2011). With an increasing shift made towards soft skills, dispositions and student-centred pedagogies, teachers are encouraged to innovate and embrace interventions to meet their students' needs. Nevertheless, this strive for innovations in Singapore is undertaken in a context where there is a more 'tightly coupled' system of instructional governance than many other systems (Hogan and Gopinathan 2008; Hogan 2011).

Scaling and Translation Research: From Medical to Educational Fields

Scaling and translation of a successful laboratory experiment is one of the typical approaches policymakers in all sectors (e.g. public, non-profit, private and commercial) considered first when they wanted to improve practice at the systems level. Most policymakers also typically assumed that a traditional *replication* perspective is an appropriate one to adopt to achieve scaling. For example, it has been a common practice for policymakers in the education sector to attempt to focus on replicating the infrastructure, materials and procedures of interventions which work in one setting to others. The assumption appears to be that translational work can be centrally planned. That is all the permutations of curricular materials and forms of teacher preparation can be tested and planned in a relatively controlled environment. This optimised package can then be organised and subsequently rolled out across the entire school system. Unfortunately many roll-outs have resulted in teachers' lack of agency on the ground in local classrooms and an insufficient emphasis on understanding teachers' own practices in lieu of the centrally advocated programme (Glennan et al. 2004; Peurach and Glazer 2012). The outcomes of traditional replications have been, in most cases, discouraging.

This underlying assumption is aligned to the scaling and translation practice in the natural sciences, including that of the medical field (see Fig. 3.1), where research to everyday practices follows largely a linear and staged process (Woolf 2009). Stage 1 of translational research (T1) focuses on testing in laboratory settings with the aim of developing new methods for diagnosis, therapy and prevention. In T1

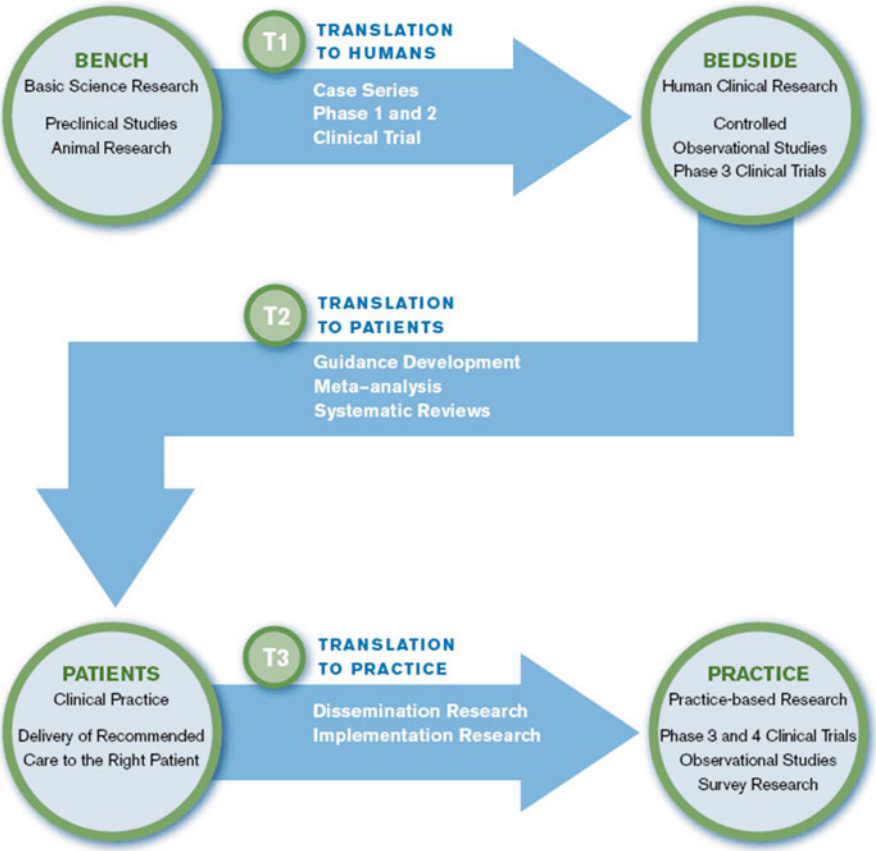

Fig. 3.1 Linear translation model in medical research (University of Miami 2013)

research, clinical and medical scientists are working in laboratories with supportive infrastructures within the institution. This research occurs in community and ambulatory settings. The Institute of Medicine's Clinical Research Roundtable states that stage 2 of translational research (T2) is about translating results from clinical studies into clinical practice and decision-making (Sung et al. 2003). In T2, research moves out of the laboratory into real-world settings. This is the first attempt to bring T1 research to public settings and contexts. T2 research yields knowledge about efficacy of intervention in various controlled real-world settings. It focuses on how infrastructure, resource constraints, human behaviour and organisational issues affect the efficacy of interventions. It begins to recognise that translating interventions is a socially complex phenomenon. Stage 3 of translational research (T3) is about disseminating the intervention from controlled real-world settings to the general population. In T3, researchers explore ways to apply recommendations into everyday practices (Westfall et al. 2007). The focus here is on how interventions work in real-world settings.

Medical research, as described from these stages, moves linearly from laboratory to mass market. Within the T1, T2 or T3 stages, innovations are adjusted and refined, and only those that achieve 'gold standard' can progress to the next stage and to be scaled up subsequently. This dominant thinking is also found in major funding programmes such as the i3 (Innovation through Institutional Integration) model of the National Science Foundation (NSF) (The National Science Foundation 2006).

Although different educational studies have discussed what 'scaling' means and what it entails (e.g. Klinger et al. 2013; Fullan 2000; Coburn 2003; Hargreaves and Fink 2000; Bocconi et al. 2013), we posit that the underlying unstated assumptions which undergird many actual attempts of scaling by many governments remain characterised by a linearity towards diffusing an innovation from one context to the masses (Klinger et al. 2013; Sternberg et al. 2006). Such a construal aligns itself with the 'gold standard' dissemination approach within medical sciences, perceiving continuities and assuming trivial irregularities when diffusing innovations across contexts. In precluding the complex behavioural world of education and its attendant to 'context-dependent interaction effects and insubstantial correlations among events' (Shweder 1980, p. 77), we argue that linear models of scaling remain inadequate in addressing (1) the variability when foregrounding student-centred processes, (2) the dynamic interrelations and social context complexities in education settings and (3) a systemic perspective in making meaning of how the scaling of education innovations may be made more expansive and widespread.

Variability When Foregrounding Student-Centred Processes

In the twenty-first-century learning, much of the focus is on cultivating student-centred process in learning such as inquiry and knowledge building. Student-centred processes thus ensure substantial variability in learning situations, and this makes the adoption of a 'one-size-fits-all' form of instruction untenable. Based on this assumption, we posit that attempts to scale, if consistent to student centeredness, should not be mere replications of the goals, structures and procedures from the original intervention, but substantial and meaningful variations should be allowed to occur based on differences in student profiles, curriculum, teacher dispositions and others. Nevertheless, to maintain the integrity and identity of the innovation, the core design principles or the kernels of the intervention should be upheld.

Dynamic Relations and Context Complexities: Imperative Tacit Knowledge in Education Settings

In the medical field, research starts in laboratories in a context vastly different and abstracted from the real world where a successful product will be consumed. Transfer of innovations to everyday practices is fixed on a set of procedures. In educational science, the social context is more complicated (Clarke and Dede 2009),

characterised by interrelations between not only teachers and students but also researchers, administrators and other stakeholders, at the local, regional and national levels. The education environment is inherently varied and socially messy because learning is a sociocultural process (Beach 1999). Conceptualising the scaling agenda in such dynamic interactions between teachers, students and the situated context where learning and instruction arise necessitates a focus on tacit knowledge (Polanyi 1967; Murnane and Nelson 1984; Nonaka and Takeuchi 1995; Hargreaves 2000; Fullan et al. 2006) that will shift dimensions of abstracted learning akin to abstracted laboratory procedures into contextualising and authenticating knowledge applications to real-world settings. We argue that the linear models of scaling, moving from laboratory to the mass market through T1, T2 and T3 processes, remain perfunctory to the importance of tacit knowledge in education settings. The assumption that figuring out what worked there and then for the others is the best, or perhaps the only, way to find out what is most likely to work for me here and now is probably a lot less valid in the twenty-first-century education setting.

The process of large-scale adoption of innovations is concerned, therefore, not simply about 'rubber stamping' the same programme into multiple contexts but on empowering teachers in the design process of student-centred lessons, fitting and adapting for local circumstances (Barab and Luehmann 2003) and others. There is not just one model for successful implementation – there are probably as many models as there are the unique contexts (Wylie 2008). The articulation of a number of core design principles or kernels, or explicit knowledge, that are relevant in these contexts will nevertheless heighten the likelihood of the teachers internalising these principles into their practice (e.g. tacit knowledge) and successfully designing effective learning experience for their students.

An Expanded Conception of 'Scale'

Considerations of 'scale' are therefore a key challenge for education reform. Definitions have traditionally been focused on an innovation-oriented perspective that emphasises the expanding number of schools or quantitative dimensions reached by an intervention or innovation. There are, however, complex challenges of reaching out broadly while simultaneously cultivating the depth of change necessary to support and sustain consequential change. Coburn (2003), Dede (2006) and Clarke and Dede (2009) contribute to an expanded conception of scale that has five interrelated dimensions: depth, sustainability, spread, shift and evolution in reform ownership to the teacher and school. To elaborate:

- Depth looks at the nature or degree of change, whether change is effected by the organisation's beliefs, whether individual beliefs and thereafter practices have evolved or whether these changes are merely superficial.
- Sustainability is about endurance: how long will the change endure and what strategies are in place to assure sustainability of the change.

- Spread refers to the norms, principles and beliefs understood by greater numbers of people. It asks 'How widespread is the change?', 'Who is involved in the change?', 'Who should be involved?' and 'Who will benefit from the change?'.
- Ownership is the attempt to shift reform ownership in terms of knowledge and authority to implementers, the schools who should ultimately 'own' the process.
- Evolution is about how users' adaptations for the innovation in localised contexts can be learned and used in rethinking the innovation's design model.

We see the first three dimensions of scale as focusing on the explicit spread and reach from an innovation-oriented, local-project instantiation point of view and the next two dimensions as more aligned to a system-wide perspective as it requires a genuine understanding and internalisation of the innovation and the knowledge associated with it, from explicit to tacit, which involves an inherently more complex and non-linear process. Scaling from a system-wide perspective must therefore make considerations about the issue of ownership and evolution as the core of the scaling effort, and not as an afterthought, that is pursued after the first three dimensions of scaling have been secured. We note, however, that all the above criteria are important when considering local-level interventions at respective schools.

An Ecological Model: Non-linear Approach to Educational Scaling

Given the above discussion, we would like to introduce a non-linear scaling model where innovations that are analogous to those conceptualised in medical research, of T1, T2 and T3 stages, can take place without a specific order (see Fig. 3.2). This non-linear model is appropriate because in most of the education interventions, unlike the medical model, the path towards a greater adoption of educational

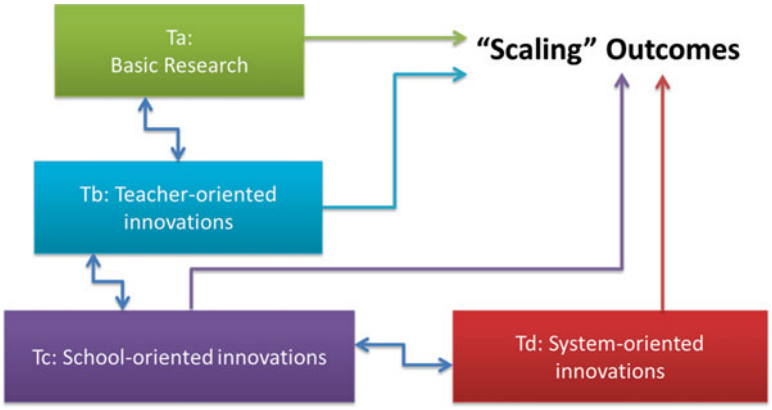

Fig. 3.2 Non-linear model of educational scaling

innovation is complex and cannot be assumed to be linear. The model stresses that educational scaling is not just about scaling the innovation to the masses (explicit knowledge). It is essential to develop school cultures and build teacher capacity (tacit knowledge) to take ownership and sustain the innovations in practice. Educational scaling is an organic evolution, balanced approach where top-down (centralised) structures are available to scale innovations to school-wide and system-wide levels. Yet, structures are loose enough to enable teachers to initiate and adapt innovations for their contexts (i.e. decentralised innovations).

A more detailed description of this model is given in Hung et al. (2014).

The essence of this ecological model is that instead of viewing stages, which are analogous to those conceptualised in medical research, of T1, T2 and T3 as stages to be enacted linearly, we reframe:

- *T1 as Tb – teacher oriented* (innovation units are at the teacher level)
- *T2 as Tc – school oriented* (innovation units are at the school level)
- *T3 as Td – system oriented* (innovation units are at the system level)

Teachers and researchers can also take a theoretical idea (Ta) and work around it in classroom (or equivalent) settings and these become Tb (teacher-oriented) innovations. More importantly, a*ll four types of innovations must happen concurrently for a healthy ecology to occur* in any education landscape. Growth and spread of innovations happen locally, and the state of play can be understood according to Coburn's (2003) and Dede's (2006) frameworks and criteria. See Table 3.1. Consistent to this ecological model, we attempt to describe the roles and levels of innovations to enable a healthy ecology for innovations to be scaled throughout the system.

Table 3.1 Growth of innovations

Role in ecology	Level of innovation	Description of the innovations' spread
'Seeding'/populating bottom-up innovations	Teacher-oriented/ supported innovations	Translating learning theories into classroom practice
		Ownership shifts from researcher to teacher or shared by both
		Innovation is driven by teacher's initiatives, for example, action research
'Spreading'/'growing' innovations from teacher to school level	School-oriented/ supported innovations	Diffusing teacher-led innovations to the school-wide level
		Creation of school's microcultures for sustaining the innovation
'Dispersing' innovations to more schools with system supports	System-oriented/ supported innovations	An innovation that is successfully adopted by several schools to system-wide diffusion
		System structures considering both the innovation's characteristics and school profiles are needed to ascertain support and resources needed
		System-wide dispersals should be kept to a minimal, for example, basic literacies

Teacher-Oriented Innovations (Tb)

There is a need to acknowledge that innovations have varying levels of complexities and therefore 'flourish' under different conditions with various structural supports. Teacher-oriented innovations (Tb) are usually simple interventions that can be easily adopted with available resources. Teachers develop contextualised understandings as they enact the innovations. Those that can more easily spread and scale would be those that have an established and socially accepted core kernel design. When such innovations are implemented in different situations, the resources are well disseminated and the sociality of teachers is built around it, such as professional learning communities (PLCs) or communities of practices (CoPs), we can expect more of such innovations to be taken up by teachers for implementation in their classrooms.

School-Oriented Innovations (Tc)

There are currently a considerable number of *teacher-oriented projects* (with researchers' support) populated throughout the Singapore education system, for example, java simulation design for teaching and learning (eduLab 2010). Some projects have been more successful in spreading across different classrooms and moving towards a school-oriented innovation while others have been less successful. This could be due to the complexity of the innovation and the readiness of teachers. As school-oriented innovations are happening on a larger scale, they require additional support and structures, such as resources, technical expertise, funding and more professional development for teachers. School-oriented structures from school leaders or management are needed to create the school's culture for sustaining innovations (Mulford 2003).

We posit that Singapore (with collaboration between Ministry of Education, MOE, Singapore, and National Institute of Education, NIE, Singapore) stand ready to engage teachers to spread these teacher-led innovations across schools. We envisage that innovations that are less complex would require less support. To a certain extent, if the sociality built around the innovation is strong, the innovation could continue to grow. Of course, if school-based supports are given, the spreading could happen more quickly at the school-wide and across school levels. We refer to these as *school-oriented or school-supported projects* (see Fig. 3.2).

Singapore also recognises that more complex innovations could require higher levels of support to enable it to spread. Such innovations would require the commitment of schools and principals to rally school-based support from more teachers and to make resources available in order to better support such innovations to grow. Likewise, school principals who opt to undertake these more challenging innovations will be supported by MOE and partnered with NIE researchers (in specific instances). Given the more complex nature of these projects, a richer partnership is envisaged.

System-Oriented Innovations (Td)

Another kind of innovation could be for projects that grew from teacher levels or school levels to system-wide levels. This would also include projects or initiatives that MOE initiates which are intended to be implemented *system wide* and/or intended to have *system-wide* impact. Appropriate system structures considering both the innovation's characteristics and school profiles are needed when working towards system-wide diffusion. Ideally, system-oriented supports are provided by MOE because schools may find it difficult to collaborate and tackle complexities of the innovation at the system's level of scale. To ensure teacher ownership, sustainability and evolution, system-oriented innovations must be adaptive so that they can be locally relevant and meet local needs without changing principles underpinning the kernel of the innovations.

With the three types of innovations (teacher-, school- and system-oriented innovations) populated across the system, we envisage that as teachers and schools adopt, adapt and implement innovations (with MOE's continued support and other school-based structures), local cultures of innovation would be nurtured. Due to the complexity of innovations and the nature of support required, it would be reasonable to expect an education landscape that is populated with more teacher-oriented (Tb) and school-oriented (Tc) innovations than of system-oriented (Td) initiatives, especially in the milieu of student-centred pedagogies. The *more radical and complex* and *less well defined* the innovation is compared to conventional practices, the *greater the need for local instantiation and spread* in order to develop and cultivate the tacit knowledge underpinnings of the innovation.

As change, growth and eventual impact of innovations to the community would be gradual, an evolutionary rather than a radical change process should be expected. With this organic approach, teachers and schools can begin the scaling adoption at different starting points. Teacher-oriented innovations relate to experimentations at the local (classroom) level in small instantiations. The focus of these innovations relates to the identification and contextualisation of innovations to meet students' needs and address issues in classrooms, especially of student-centred pedagogies and designs. Teachers work collectively towards refining innovations, identifying the core/kernel principles and building teaching resources that allow innovations to be implemented in classrooms. Through experimentations and consistent dialoguing, teachers may begin to adapt innovations for use with their own students in different classroom contexts. Teacher-oriented (Tb) innovations and experimentations could grow to influence more people in various local situations. In other words, teacher-oriented (Tb) innovations could be *scaled locally* to include more subjects, classes and different student profiles and result in eventual 'promotion' to school-oriented (Tc) status. Spreading from teacher-led to school-supported status, implementation efforts are locally driven and emerged. These innovations could subsequently be taken up by MOE,

and these could be provided with financial and infrastructural supports to ensure innovations' spread and sustenance with greater efficiencies. As such, these efforts could eventually be system-oriented innovations (Td). Examples of these Td innovations could include the levelling up of the base of core literacies in order to bridge achievement gaps or when local growth models may be too slow for certain policy priorities.

In summary, these are the growth trajectories:

Criteria based on the level that the kernel operates at and not who it is led.

1. Ta –> Tb (teacher oriented or supported) – experimentation of theoretical ideas at the local level in a small instantiation.
2. Tb –> Tc (school oriented or supported) – Tb experimentation grows and influences more people and in variant local situations in schools, such as increased number of subjects or with different student profiles. These efforts are 'locally' school driven or emerged.
3. Tc –> Td (system-oriented or supported) – expansions on Tc are encouraged and cultivated further with some structural supports from 'outside' the local community, such as system supports.

In other words, to ascertain the degree through which policymakers can decide whether supports should be given to the above efforts in order to proceed to the next steps, indicators such as evidence of teacher uptake, the availability of infrastructure and whether the kernel core idea has been increasingly moved from tacit to explicit forms of knowledge and understanding as existing amongst the teachers in the community need to be shown (see Table 3.2).

Table 3.2 Supporting criteria for taking projects to the next steps

Level of innovation	Criteria for supporting innovation to the next step
System-oriented/ supported innovations	Innovation is fundamental that all students in the system can benefit
	Tacit knowledge can be translated to explicit knowledge
	Teachers are generally ready
	Infrastructure is available
School-oriented/supported innovations	School supports with infrastructure
	School leadership has provided resources and time for teachers to redesign curriculum
	Trust has been established between school leaders and teachers
	Other teachers from school commit to the innovation
	Teachers from other schools join in community
Teacher/researcher-oriented/supported projects	Translation from theory to classroom has been accomplished
	Learning objectives have been met, such as the twenty-first-century literacies and pedagogies
	Teachers are recognised for their efforts

Discussion

Instead of 'Gold Standard', Scaling Can Begin When Conditions Are 'Sufficing'

One fundamental difference between conceptualising the spreading of innovations in ecological ways and not purely a mechanistic way is that we do not seek to ask if a 'gold standard' has been achieved before allowing for the spread to occur. Instead, besides having established the evidence that the innovation can deliver the learning outcomes that it is designed to achieve at the classroom, school and system level, we also seek to ask if the teachers are enthused, committed and ready about the innovations and if the teachers are able to take innovations to their respective classrooms (or equivalent) and implement the core ideas or kernel of that intervention/innovation. Moreover, are resources to support these subsequent take-ups available, or can they be mobilised at the school, cluster or MOE levels to support the spreading? Are school leaders willing to support these teachers to experiment and permit possible implementation gaps to happen, if any? And are teachers able to collect evidence-based data for their experimentations to exemplify some form of rigour and monitor their experimentations?

We connote the above questions as important to the issues around a *sufficing standard* for spreading of innovations, rather than a gold standard. Some possible indicators of spread could be the adoption of school-led innovations by other schools, an increasing community of teachers involved around an innovation, more dialogue and sharing between schools and others.

To reiterate, the use of 'sufficing' standard as opposed to 'gold' standard is adopted and argued for here to shift the focus away from expecting and deriving a par excellence model which can be considered ripe and optimal as a gold standard to be rolled out to the system at large. This is because, given the substantial varying and evolving environment and context, even if a 'gold standard' can be identified there and then (and many will argue otherwise), it is not likely to be the 'gold standard' for here and now. In this shift towards a sufficing standard, we underscore that the thinking of policymakers should shift closer to that of understanding how to support teacher, school and system innovations (i.e. to build up the tacit knowledge within the system) rather than the conventional notion of focusing solely on achieving a gold standard (i.e. explicit knowledge) and replicating this system wide.

In the next phase of the Singapore education system's focuses on student centeredness, there will be a shift towards enabling teacher-oriented pedagogical innovations and local instantiations in schools to support the spread of education innovations. The Singapore education system will therefore need to deepen the culture of trust that lets teachers engage in pedagogical innovations as well as develop tacit and explicit knowledge of designing and enacting student-centred curriculum.

Supporting local instantiations would also mean enabling school leaders with the autonomy to provide time and resources to teachers, developing a culture of trust that encourages teachers to experiment and do what is of value to students, building

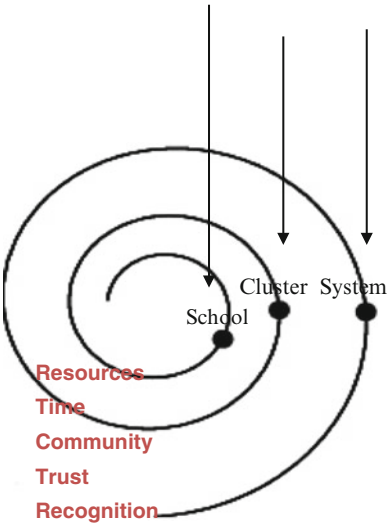

Fig. 3.3 Tenets for supporting teachers

teacher communities to enable professional growth and to initiate and sustain pedagogical innovations and providing recognition to teachers who overcome tensions – such as teaching according to the prescribed syllabus and yet be innovative in their pedagogies. These five critical dimensions (see Fig. 3.3) must be present for an innovation journey to continue.

'Mechanical' and 'Organic' Scaling Can Coexist in an Ecological Model of Scaling

Policymakers usually look at an issue more so from the system's level and less at the individual student, teacher or school levels. They are more likely to ask 'how can innovations be spread throughout my system' and less to ask 'what are the orientations of the innovations that can be spread'. From the perspective of ecological model of scaling, we argue that a system that has a healthy ecology of innovations must have a good spread of teacher-oriented, school-oriented and system-oriented innovations and must support both 'mechanical' and 'organic' scaling.

By 'mechanical scaling', we are referring to the more traditional replication perspective of scaling which was discussed earlier. Such a scaling approach is appropriate when, across all schools in the system, (a) the tacit knowledge to be developed and understood amongst teachers has been or can be readily codified, (b) the readiness of the teachers to enact the innovation has been or can be readily enhanced, (c) the infrastructure that is required to support the innovation has been or can be made available and (d) the innovation is so fundamental that all students in the system can benefit. Given that system-level instantiations of innovation will entail substantial transaction costs, a system is only likely to accommodate a small

number of 'mechanically' scaled innovations, and hence these innovations have to be carefully selected based on benefits and costs considerations.

While the system cannot accommodate too many 'mechanical' scaling efforts, within a system there will always be room for individual or groups of schools, classrooms or teachers to try out new interventions and to spread these intervention 'organically', i.e. without following a centrally prescribed plan. The 'organic' scaling strategy is one that allows teachers the time and space to decide if an innovation is appropriate for his/her classrooms and schools and to develop the skill sets and mind sets to enact the innovation. 'Organic' scaling is therefore appropriate for innovations which are not yet ready for 'mechanical' scaling (i.e. in the absence of all the four above-mentioned criteria), but these innovations may nevertheless be efficacious in addressing classroom or school problems locally. The kernel of an innovation appropriate for 'organic' scaling is therefore less likely to have been clearly explicated, and the support needed for teachers to enact these innovations successful is less readily available. The organic spread of such innovations takes place when teachers or schools share them in network or collaborative learning situations (e.g. PLCs). Besides spreading innovations from one site to another, another important reason why 'organic' scaling should be promoted is because 'organic' scaling is an effective way of fostering teacher agency and professionalism and of preparing them for successful 'mechanical' scaling when the circumstances permit.

The Role of Researchers and Policymakers

If we accept the ecological framework of scaling as discussed above, we begin to recognise that for an education system to be successfully innovative, it must necessarily promote a more organic bottom-up scaling process with appropriate supports, because 'organic' scaling not only encourages teacher-oriented and school-oriented innovations, but it also lays the ground for successful system-oriented innovations and accelerates 'mechanical' scaling.

Researchers therefore play at least three roles in an ecological scaling model. First, as in mechanistic scaling, researchers must engage in research to discover theories, translate the theories into interventions and test them in controlled experimentations. Successful examples can then be 'mechanically' scaled out subsequently to practitioners if the above-mentioned criteria are met. Second, as in organic scaling which is necessarily ground up, the researchers are also expected to engage in equal partnership with practitioners to improve the teacher-oriented and school-oriented interventions in local instantiations and to support practitioners in incorporating innovations into daily practices and deliberately supporting the shifting of ownership of an intervention to more practitioners. This second role is important for an innovation to spread 'organically'. To play the latter role effectively, researchers can be more proactively involved in the professional learning communities (PLCs) and communities of practice (CoPs) existing in the school

system. The third role of the researchers, besides directly involved in designing and spreading innovations, is to study the patterns of growth, spread and implementation of innovations from a systems perspective, so as to improve the effectiveness of scaling. This role is more appropriate for researchers than for practitioners because the former have generally broader exposure to a variety of contexts and innovations, which is opposed to the deep local knowledge that is the definitive strength of practitioners. Research of this nature will not only collect baseline data that provides policymakers with a systems view of the progress made through (the ecological approach of) scaling, it will also develop the models, frameworks and criteria for supporting the various kinds and levels of scaling or for deciding whether an innovation is ready to progress to the next phase.

While the above-mentioned roles played by researchers are important to the successful scaling of an innovation, it is important for policymakers and practitioners to recognise that researchers are usually not in the best position to lead scaling efforts, neither is it normally the mandate of researchers to lead scaling. Of course, there will be exceptions when individual researchers, who are well connected, can mobilise resources from different level, have an intuitive deep understanding of the needs and reality of classrooms and schools, are passionate for ground work and can lead scaling work. However, these are exceptions rather than the norm. Furthermore, once these researchers embrace the scaling of an innovation as their primary mission, it can then be argued that they are no longer playing the role of a researcher.

Regardless of the above, the importance of researchers as members of a cross-functional scaling team cannot be overstated. If the primary role of researchers is to create theories and translate these theories into interventions and the primary role of practitioners is to incorporate these interventions into professional practices to improve learning and teaching, then the role to ensure that interventions are scaled across the system must belong to the 'policymakers'. In this paper, we consider 'policymakers' broadly to include both senior political leaders who direct and chart broad education policies and more junior policy officers who interpret these policies and design and implement programmes based on these policies. To optimise the chance for successful 'organic' scaling, policymakers' role is to provide proscriptively (or loosely) supporting conditions for teacher-oriented and school-oriented innovation to seed, grow and spread. These conditions include engendering a vision amongst all stakeholders to *initiate or catalyse* the momentum for teachers and schools to embrace local innovations, making available resources (e.g. time, materials, manpower) to support and sustain locally instantiated teacher-oriented and school-oriented innovations and playing the important 'boundary spanning' (Tushman 1977) role which includes cushioning and protecting teachers and schools from the unnecessarily external interferences which may disrupt or corrupt the innovation.

In addition to the above, to enact 'mechanic' scaling which requires even more deliberate coordination, policymakers will need to do even more. They will need to facilitate informed dialogue amongst all stakeholders (including researchers, practitioners and the public) to establish a shared understanding of the key problems facing the system so as to mobilise resources to research into and develop innovations and to spread these innovations across the system to resolve these problems.

This dialogue will significantly heighten the likelihood of any new knowledge, and the innovations derived from the knowledge, produced and developed to be meaningfully adopted and used by practitioners across the system through 'mechanical scaling'. This is because such shared understanding is needed to shift the more prevalent supply-driven Mode 1 knowledge production to the demand-driven Mode 2 knowledge production more relevant to practice (Gibbons et al. 1994). Second, the policymakers must put in place a system-wide education knowledge base to capture not only rich and robust baseline data that comprehensively describes the status of teaching and learning in classrooms and schools within the system; this knowledge base must also capture the codification and verification of expert knowledge of teachers who responded to the challenges in classrooms and schools. Finally, with the support of the education knowledge base, the policymakers must identify a shortlist of interventions that can address the key challenges facing the system and have the best chance of being sustained by the system. They must also mobilise the resources and the supports of the various stakeholders to scale/implement them across the system.

Conclusion

Educational settings differ across classrooms and contexts. In the past, when resources were wanting and when teachers were less prepared, Singapore embraced a more traditional 'mechanical' scaling approach to spread innovations across the system. This probably contributed to the substantial improvement in learning and teaching and in student performance in international studies that occurred between the mid- to late-1990s (Teh 2014). As the Singapore education system develops further, more and more attempts are made to more 'organically' scale innovative pedagogies that emphasise student-centric learning and diverse learning outcomes. Singapore's Teach Less, Learn More initiative is one obvious example (MOE 2008). In a natural fashion, not all innovations attempted by the schools will succeed and scale. However, that does not mean these attempts are unproductive because valuable lessons can be learnt by teachers, researchers and policymakers to enable future instantiations. Such initiatives also help develop a culture of trust and experimentation amongst students, parents, teachers, researchers and policymakers that education endeavours which do not yield immediate measureable results can be critical and productive. This also empowers teachers to do what they think is professionally needed to develop students to the fullest potential, and such professionalism is key to any successful adoption and adaptation of student-centric innovations, whether through 'organic' or 'mechanical' scaling.

What we have described above are some experience of and considerations for the scaling of innovations across classrooms and schools of Singapore. We are keenly aware that Singapore is a highly urbanised East Asian city state with a centralised education system that is characterised by its 'tightly coupled' instructional governance. What is sensible for Singapore may therefore not work for other systems which are

contextually different. Nevertheless, we believe that some principles could be distilled from Singapore's experience and these principles could be relevant to other systems.

First, in the milieu of student-centred pedagogies and designs, Singapore has recognised that the celebrations of diversity in student learning and participations are highly desired. If Singapore, which is more centralised, tightly coupled and strategically aligned in terms of policy, research and practice than many other systems, is reasonable in recognising that one-size-fits-all solution for education challenges is hard to come by, then it is the quest for 'silver bullets' of other larger and more loosely coupled jurisdictions ought to be substantially more difficult. Hence, we believe that it is important for education systems which strive to promote and enhance the quality of student-centric learning, and teaching should invest substantially on structures to provide top-down support for bottom-up (i.e. classroom and school) initiatives and innovations to address local problems. Support provided would include opportunities for teacher learning to enhance teacher readiness, empowerment for school leadership to support local initiatives and infrastructural and material support to sustain local innovations. More importantly, while there is celebration of diversity at local levels, the system has to keep tab of the growth and spread of innovations with systems' data in order to identify gaps or concerns where nudging is necessary for some localities and to identify if future work and initiatives are needed.

Second, the experience in Singapore as in other systems shows that the tacit nature and rich interactions of educational settings require time for interventions to take root, for teachers to experiment and change pedagogies, if the interventions are to be deep and sustained, and for the practitioners to take over the ownership. The system must therefore acknowledge that teachers need to believe in what they do, for very good reasons, and hence genuine and meaningful change and reform take time. Even with the trust that teachers and schools are doing what they should, the system should still closely monitor what is happening at each local level before assuming that rolling out interventions will result in change and that change is always for the better. This monitoring must be systematic and as nonintrusive as possible. In Singapore, this is carried through the baseline data collected by NIE's Core Research Programme funded by Singapore Ministry of Education (see Hogan 2007, 2011; Hogan et al. 2013). We would therefore like to argue the merit for the other systems to also invest in the collection of local- and system-level data so that the system, as well as the subunits, can continually and critically reflect on issues related to scaling and spreading of innovations to improve education practice based on rigorous and valid data of what happens in classrooms and schools. The collected data will also allow the unpacking of the sufficing standards at each local instantiation and of the supporting structures necessary for moving an innovation to the next level.

Third, the ecological model, proposed in this chapter, is informed by the need for continuous iteration and responsiveness to the ground, yet envisioned by consensual need for progressive changes in specific directions. This model is largely based on Singapore's experience of experimenting with scaling over the last few decades.

As belaboured before, one of the most distinguishing features of Singapore is its small size and the small number of key actors amongst policymakers, researchers and practitioners. The 'smallness' creates opportunities for these actors to develop a broad understanding of the institutional imperatives and interests of multiple stakeholder groups. This substantially facilitates the alignment of institutional goals and practices. We believe that this strategic alignment is a critical factor of successful scaling efforts, especially of 'mechanical' scaling which requires substantially more system-level transactions, coordination and trusts across multiple parties and multiple stakeholders groups.

Because of our experience (both success and failure, but more the latter) in scaling innovations, we are inclined to believe that it will be significantly more difficult to establish such a level of alignment in a system that is substantially larger than Singapore. Hence, a possible approach of applying the proposed ecological model of scaling to an education system that is larger in size is to consider it as a collective of relatively autonomous sub-ecological systems, say, innovation zones that comprise about a few hundred schools each. The boundary of these innovation zones (e.g. school districts, education authorities) should be co-constructed by the stakeholders (especially the local actors) so that there are geographical, social, historical and educational similarities within the zones, as these similarities are crucial in facilitating the forging of the above-mentioned strategic alignment. Each innovation zone should then be empowered and supported by the higher jurisdiction(s) to enact its own 'mechanical' and 'organic' scaling efforts and to promote a healthy ecology of teacher-oriented, school-oriented and system-oriented innovations within each innovation zone. We hypothesise that allowing these innovation zones, within a larger jurisdiction, to autonomously scale innovations is more likely to be productive than trying to dictate a rigidly defined scaling policy throughout this jurisdiction in the absence of strategic alignment between policy, research and practice.

References

Barab, S. L., & Luehmann, A. L. (2003). Building sustainable science curriculum: Acknowledging and accommodating local adaptation. *Science Education, 87*(4), 454–467.

Beach, K. (1999). Consequential transitions: A sociocultural expedition beyond transfer in education. *Review of Research in Education, 24*, 101–139.

Bocconi, S., Kampylis, P., & Punie, Y. (2013). Framing ICT-enabled innovation for learning: The case of one-to-one learning initiatives in Europe. *European Journal of Education, 48*(1), 113–130.

Clarke, J., & Dede, C. (2009). Design for scalability: A case study of the River City Curriculum. *Journal of Science Education and Technology, 18*(4), 353–365.

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

Dede, C. (2006). Scaling up: Evolving innovations beyond ideal settings to challenging contexts of practice. In R. K. Sawyer (Ed.), *The Cambridge handbook of learning sciences* (pp. 551–566). Cambridge: Cambridge University Press.

Department of Statistics, Singapore (DOS). (2014). *Yearbook of statistics, Singapore, 2014*. Retrieved from http://www.singstat.gov.sg/publications/publications_and_papers/reference/yearbook_2014/yos2014.pdf

Dimmock, C., & Goh, J. W. (2011). Transformative pedagogy, leadership and school organisation for the twenty-first-century knowledge-based economy: The case of Singapore. *School Leadership & Management, 31*(3), 215–234.

eduLab. (2010). *Java simulation design for teaching and learning*. Unpublished proposal. Singapore: National Institute of Education, NTU.

Fullan, M. (2000). The return of large-scale reform. *Journal of Educational Change, 1*(1), 5–27.

Fullan, M., Hill, P., & Crevola, C. (2006). *Breakthrough*. Thousand Oaks: Corwin Press/Sage.

Gibbons, M., Limoges, C., Nowotny, H., Schwartzman, S., Scott, P., & Trow, M. (1994). *The new production of knowledge: The dynamics of science and research in contemporary societies*. London: Sage Publications Limited.

Glennan, T. K. J., Bodilly, S. J., Galegher, J. R., & Kerr, K. A. (2004). *Expanding the reach of educational reforms: Perspectives from leaders in the scale-up of educational interventions*. Santa Monica: RAND Corp.

Goh, C. T. (1997) *Speech by Prime Minister Goh Chok Tong at the opening of the 7th international conference on thinking*. Retrieved February 14, 2014, from http://www.moe.gov.sg/media/speeches/1997/020697.htm

Gopinathan, S. (1985). Education in Singapore: Progress and prospect. In J. S. T. Quah, H. C. Chan, & C. M. Seah (Eds.), *Government and politics in Singapore* (pp. 197–232). Singapore: Oxford Press.

Hargreaves, D. (2000). The production, mediation and use of professional knowledge among teachers and doctors: A comparative analysis. In OECD/CERI (Ed.), *Knowledge management in a learning society* (pp. 219–235). Paris: OECD.

Hargreaves, A., & Fink, D. (2000). The three dimensions of reform. *Educational Leadership, 57*(7), 30–34.

Heng, S. K. (2011). Opening Address by Mr Heng Swee Keat, Minister for Education, at the Ministry of Education (MOE) Work Plan Seminar, on Thursday, 22 September 2011 at 10.00 am at Ngee Ann Polytechnic Convention Centre. Extracted from http://www.moe.gov.sg/media/speeches/2011/09/22/work-plan-seminar-2011.php

Hogan, D. (2007). Policy-driven research and evidence-based educational innovation in Singapore. In OECD/CERI (Ed.), *Evidence in education – Linking policy and research* (pp. 131–144). Paris: OECD.

Hogan, D. (2011). *Interim Core 2 report on classroom pedagogy*. Unpublished Report, National Institute of Education, Singapore.

Hogan, D., & Gopinathan, S. (2008). Knowledge management, sustainable innovation, and pre-service teacher education in Singapore. *Teachers and Teaching: Theory and Practice, 14*(4), 369–384.

Hogan, D., Chan, M., Rahim, R., Kwek, D., Aye, K. M., Loo, S. C., Sheng, Y. Z., & Luo, W. (2013). Assessment and the logic of instructional practice in Secondary 3 English and mathematics classrooms in Singapore. *Review of Education, 1*(1), 57–106.

Hung, D., Lee, S. S., Teh, L. W., Kwan, Y. M., Vishnumahanti, S., & Widiastuti, A. (2014). An ecological perspective on scaling: Balancing structural and individual adaptivities. In D. Hung, K. Y. T. Lim, & S. Lee (Eds.), *Adaptivity as a transformative disposition: For learning in the 21st century* (pp. 267–285). Singapore: Springer.

Klinger, J. K., Boardman, A. G., & McMaster, K. L. (2013). What does it take to scale up and sustain evidence-based practices? *Exceptional Children, 79*(2), 195–211.

Ministry of Education, Singapore. (2008). *More support for school's "Teach less, learn more" initiatives*. Extracted from http://www.moe.gov.sg/media/press/2008/01/more-support-for-schools-teach.php, on 23rd Feb 2014.

Mulford, B. (2003). *School leaders: Challenging roles and impact on teacher and school effectiveness* (OECD Commissioned Paper). Retrieved March 11, 2013, from http://www.oecd.org/edu/school/37133393.pdf

Murnane, R. J., & Nelson, R. R. (1984). Production and innovation when techniques are tacit: The case of education. *Journal of Economic Behavior and Organization, 5*(1984), 353–373.

Nonaka, I., & Takeuchi, H. (1995). *The knowledge creating company: How Japanese companies create the dynamics of innovation*. New York: Oxford University Press.

Peurach, D. J., & Glazer, J. L. (2012). Reconsidering replication: New perspectives on large-scale school improvement. *Journal of Educational Change, 13*(2), 155–190.

Polanyi, M. (1967). *The tacit dimension*. London: Routledge & Kegan Paul.

Shweder, R. A. (1980). Rethinking culture and personality theory: From genesis and typology to hermeneutics and dynamics. *Ethos, 8*, 60–94.

Sternberg, R. J., Birney, D., Jarvin, L., Kirlik, A., Stemler, S., & Grigorenko, E. L. (2006). From molehill to mountain: The process of scaling up educational interventions (First hand experience upscaling the theory of successful intelligence). In M. A. Constas & R. J. Sternberg (Eds.), *Translating theory and research into educational practice – Developments in content domains, large-scale reform, and intellectual capacity* (pp. 205–222). Mahwah: Routledge.

Sung, N. S., Crowley, W. F., Genel, M., Salber, P., Sandy, L., Sherwood, L. M., Johnson, S. B., Catanese, V., Tilson, H., Getz, K., Larson, E. L., Scheinberg, D., Reece, E. A., Slavkin, H., Dobs, A., Grebb, J., Martinez, R. A., Korn, A., & Rimoin, D. (2003). Central challenges facing the national clinical research enterprise. *The Journal of the American Medical Association, 289*(10), 1278–1287.

Teh, L. W. (2014). Singapore's performance in PISA: Levelling up the long tail. In S. K. Lee, W. O. Lee, & E. L. Low (Eds.), *Educational policy innovations – Levelling up and sustaining educational achievement* (pp. 71–83). Singapore: Springer.

Teh, L. W., Hogan, D., & Dimmock, C. (2013). Knowledge mobilisation and utilisation in the Singapore Education System: The nexus between researchers, policy makers and practitioners. In B. Levin, J. Qi, H. Edelstein, & J. Sohn (Eds.), *The impact of research in education: An international perspective* (pp. 41–63). Bristol: The Policy Press.

The National Science Foundation. (2006). *Innovative technology experiences for students and teachers (ITEST)*. Retrieved March 22, 2013, from http://www.nsf.gov/pubs/2009/nsf09506/nsf09506.htm

Tushman, M. L. (1977). Special boundary roles in the innovation process. *Administrative Science Quarterly, 22*(4), 587–605.

University of Miami. (2013). *University of Miami healthcare system*. Retrieved from http://mscti.med.miami.edu/program/what-is-translational-research/

Westfall, J. M., Mold, J., & Fagnan, L. (2007). Practice-based research – "blue highways" on the NIH roadmap. *The Journal of the American Medical Association, 297*(4), 403–406.

Woolf, S. H. (2009). The meaning of translational research and why it matters. *The Journal of the American Medical Association, 299*(2), 211–213.

Wylie, E. C. (2008). *Tight but loose: Scaling up teacher professional development in diverse contexts*. Princeton: Educational Testing Service.

Chapter 4
Increasing the Scale and Adoption of Health Innovations: Practice Models for Public Health

Andrew J. Milat and Adrian E. Bauman

Abstract The expansion and institutionalisation of effective health interventions is essential to improving population health outcomes, and hence, the study of factors that can assist in scaling up health interventions from small projects or controlled trials into wider policy and practice is important. Sharing lessons learned about scaling up innovative programmes across health has the potential to advance thinking in the field. This chapter describes a 'scalability framework' that can be used to guide the scaling-up of health interventions that is divided into four stages: (1) scalability assessment, involves assessing the suitability of the intervention(s) for scaling-up; (2) develop a scaling-up plan, involves creating a vision of what scaling-up will look like and a compelling case for action; (3) prepare for scale-up, describes how to secure resources and build a foundation of legitimacy and support for scale-up; and (4) scale up the intervention, describes the main tasks that should be addressed during the practice of scaling-up to reach many more people or settings. The framework provides a useful tool to assist health policymakers and practitioners in their efforts to scale up health interventions. Consideration of factors identified in the framework can assist policymakers, practitioners and researchers with cues and processes that may facilitate widespread adoption and maintenance of policies and programmes. Key lessons from the framework are of relevance to scale-up efforts in the educational field, including (1) understanding the nature of the intervention and its effectiveness, (2) understanding the context within which interventions operate, (3) determining the acceptability of the intervention for stakeholders, (4) considering workforce training and capacity building requirements and (5) establishing robust evaluation and monitoring systems.

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Introduction

Clinical and Public Health 'Evidence': Different Histories and Differences in the Potential for Scaling Up Interventions

Understanding the history of 'evidence' for interventions in the health setting is a useful first step in defining the need for health sector programme scalability. How did the clinical health sector develop and understand 'evidence', and what does it mean in practice? This will be considered first from the clinical perspective, briefly examining how evidence developed in medicine and how clinical therapies are scaled up. This is followed by a discussion of the challenges in understanding evidence in population-focused health programmes (public health).

The concept of evidence for treatment efficacy is relatively recent in the history of medicine (Smith and Rennie 2014). Although physicians started to question which of their treatments worked, they did so by observation only and not using scientific methods. Examples of generating evidence were sparse; an early case study was the clinical observation that lemon/lime juice prevented the chronic disease, scurvy, noticed by a British naval physician, James Lind, in 1747 (Wyatt 1976); however, it took many years before this was seen as acceptable 'evidence' and turned into policy in the British Navy.

In the nineteenth century, physicians started to make epidemiological observations about the causes of disease, including John Snow's observations linking cholera epidemics to contaminated water supply in London, leading to policy decisions to shut down the infected water suppliers (Tulodziecki 2012). This was an interesting public health action, as the 'germ theory' linking microbiological causes to cholera had not yet been developed.

Evidence accrued rapidly following the introduction of specific treatments for disease, such as antibiotics in the late 1930s, but still 'evidence' was mostly empirical. Only in the past 50 years has the science of clinical trials evolved, using randomised and controlled experimental designs to determine the efficacy of therapy; did a particular drug or surgical procedure or investigative procedure work compared to placebo controls, usual care or typical practice. By the 1980s, the science of 'evidence-based medicine' (EBM) was emerging, led by clinician-epidemiologists at McMaster University in Canada (Claridge and Fabian 2005). EBM started to synthesise the best practice, based on summarising evidence to date for particular clinical treatments; they identified when treatments were effective or ineffective or when effectiveness was still uncertain.

The principles of EBM were endorsed by policymakers, looking to deliver optimal and efficient health care; even the pharmaceutical industry, instead of driving and marketing only their own medications, started to develop therapies that were optimally effective. Efficacious and proven therapies could be specified, economists could carry out cost-effectiveness studies, and then affordable approaches could be offered to the health sector for wider dissemination. Given the ways in which

universal health coverage or private health insurance systems operate, this approach made economic sense, and where evidence-based cost-effective therapies were available, they were communicated to physicians, and most were eventually adopted. Ineffective treatments were slowly phased out, as the health system would not pay for them. Nonetheless, adoption of evidence-based approaches has not been universal (Timmermans and Mauck 2005). The 'grey area' in the middle, treatments which were of uncertain or unproven effectiveness, remains a resourcing challenge to the health system, fuelling efforts to understand EBM better in all branches of clinical care.

The development of clinical EBM provided an approach to define and then 'scale up' effective therapies as defined in 'clinical guidelines'; this permeated medicine, physiotherapy, nursing and other health professions (Grol 2001). Although this process is not always rapid, it is more straightforward than efforts in public health, the discipline associated with population-wide approaches to prevention.

Public health is concerned with health promotion, preventive health and health protection delivered to whole communities and populations, but does not include treatment by individual health-care providers to individual patients (Detels 2009). The science of public health defines and characterises health risk and then can develop a range of alternate solutions to reduce that risk. For example, the links between tobacco smoking and cancer/heart disease were well established by the 1960s, but a wide range of potential solutions were proposed. Some solutions could be tested using small-scale controlled trial designs, for example, testing the effectiveness of nicotine replacement therapy for smokers (Stead et al. 2012). Other public health problems required much larger investment and could not be tested in randomised trials. These included mass media campaigns to inform the population about the risks of smoking, increasing taxation on cigarettes and implementing regulatory policies to restrict access to tobacco and reduce the environments in which people could smoke. The consensus on 'evidence-based public health' could not be based on single interventions, and a multi-strategy approach seemed necessary to reduce smoking rates across the population (Brownson et al. 2010). This made it more difficult for policymakers to determine what to do first. Overall, the tasks of disseminating public health interventions are more challenging than for clinical treatment, as there may be no single approach deemed 'effective', and the public health interventions suggested may be expensive to implement at scale.

Thus, there are important differences in the approach to scale up or implement public health programmes or sets of interventions, compared to health-related interventions that target individual patients. This creates complexity in the decisions to scale up prevention efforts and challenges policymakers to consider what is acceptable as 'evidence' for prevention, what levels of investment are feasible as solutions and what vehicles or system conduits are available for scaling up programmes. Both clinical and public health interventions need scaling-up in order to have an impact on health, but this section has defined the differences between them, so that the concept of health intervention scalability can be tailored to each setting and to address different kinds of health problems.

The Move to Scaling Up Effective Interventions in Health

The transfer of new knowledge from research into any health practice still remains a slow process (Productivity Commission 2010). Even in clinical areas of research, it may take at least 6 years for research evidence to reach reviews, papers and textbooks, and on average, it then takes an additional 9.3 years to implement evidence from reviews, papers and textbooks into health practice (Balas and Boren 2000). A contributing factor to the slow transfer of evidence into practice is that much research conducted by health scientists is not immediately useful to health policymakers, particularly the shortage of evidence regarding feasible and effective interventions (Hawe and Potvin 2009; Milat et al. 2011a). Unfortunately, the majority of published public health research remains focussed on describing patterns of risk and disease, rather than providing evidence of the effectiveness of interventions (Milat et al. 2011a).

An increasing number of policymakers, research funders and researchers now contend there is a need for high-quality studies assessing the mechanisms through which more widespread adoption of effective interventions can be achieved (Catford 2009; National Institutes of Health 2013; Rubenstein and Pugh 2006). This expansion and institutionalisation of effective public health interventions is essential to improving population health outcomes (Milat et al. 2011b, c). In light of this, the study of how to effectively scale up interventions from small-scale feasibility studies to wider state, national or international roll-out is increasingly important.

Defining Scale-Up and Scalability

While the scale of an intervention may seem an obvious concept, the terms 'scaling-up' and 'scalability' are increasingly being applied in different ways and contexts with little consistency or rigour in the health literature (Milat et al. 2011b). The terms 'scaling-up' and 'scalability' have been applied in the literature to describe (1) the dissemination of a new technique, prototype product or process innovation (Edouard and Edouard 2012; Larson et al. 2012; Pearson and Ljungqvist 2011; Pérez-Escamilla et al. 2012; Underhill et al. 2010); (2) epidemiological and economic forecasting (Johns and Baltussen 2004; Maher et al. 2007; Morel et al. 2005; Winfrey et al. 2011; Zhang et al. 2012); (3) 'growing' an organisational or system capacity to implement to a new level (de Silva-Sanigorski et al. 2010; Merson et al. 2012; Pearson and Ljungqvist 2011; Rani et al. 2012); and (4) translating a small-scale initiative into a government policy (Aldinger et al. 2008; Marrero 2009; Nankunda et al. 2010).

In order to have a clear understanding of the field, specific definitions are needed for the terms 'scaling-up' and 'scalability'. Scaling-up is '…deliberate efforts to increase the impact of successfully tested health interventions so as to benefit more people and to foster policy and program development on a lasting basis'(World

Health Organization and ExpandNet 2010, p. 2), while scalability is 'the ability of a health intervention shown to be efficacious on a small scale and or under controlled conditions to be expanded under real world conditions to reach a greater proportion of the eligible population, while retaining effectiveness' (Milat et al. 2012, p. 1). Scaling-up is a process of increasing the scale of a successfully tested health intervention, while scalability denotes the capacity of an individual intervention to be scaled up.

Models for Scaling Up Health Interventions

Theories, models and frameworks attempt to organise what is known and can assist in understanding causal relationships, growing the knowledge base in an organised way and predicting the outcome of interventions or events (Eccles et al. 2005; Gregor 2002; Kuhn 1962; Popper 2013; Rycroft-Malone and Bucknall 2010). The issue of how to describe scaling up health interventions is receiving greater attention in the health literature (Kohl and Cooley 2003; Milat et al. 2011b, 2012; Norton and Mittman 2010; World Health Organization and ExpandNet 2010), and there are now a number of frameworks to assist those tasked with scaling up health interventions.

The Scaling-Up Management (SUM) Framework (Kohl and Cooley 2003) by Kohl and colleagues proposes three key steps. The first step involves developing a scaling-up plan and creating a vision of what scaling-up will look like if successfully implemented. Step 2 involves establishing the preconditions for scaling-up, comprising building the legitimacy of the intervention, constituency building and realigning and mobilising resources. In the final step, the scaling-up process is implemented based on the identification of factors that can promote extension and sustainability. Key tasks involve modifying organisational structures, coordinating action and monitoring performance.

The World Health Organization and ExpandNet model (World Health Organization and ExpandNet 2010) offers a model comprised of four strategic choice areas (dissemination and advocacy, organisational process, cost and resource mobilisation, monitoring and evaluation). The framework proposes nine steps for developing a scaling-up strategy that involves:

1. Planning actions to increase the scalability of the innovation
2. Increasing the capacity of the user organisation to implement scaling-up
3. Assessing the environment and planning actions to increase the potential for scaling-up success
4. Increasing the capacity of the resource team to support scaling-up
5. Making strategic choices to support vertical scaling-up (policy, political, regulatory, resourcing or other health system changes needed to institutionalise the innovation)
6. Making strategic choices to support horizontal scaling-up (replicating innovations in different geographic sites or extending them to serve larger or different population groups)

7. Determining the role of diversification
8. Planning actions to address spontaneous scaling-up
9. Finalising the scaling-up strategy and identifying next steps

Though providing a comprehensive guide for the scaling-up, its length and complexity may be a barrier for use for some policymakers and practitioners.

Taking a broader approach, Yamey (2011) describes key success factors for scaling up global health initiatives based on interviews with 'thought leaders' ($n = 14$). Yamey's framework divides the scaling-up process into six categories: attributes of the specific tool or service being scaled up, attributes of the implementers, the chosen delivery strategy, attributes of the 'adopting' community, the sociopolitical context and the research context. The Yamey model is less prescriptive than other models and importantly reflects on the experience of people who have scaled up global health initiatives.

Our research using a two-stage Delphi process with senior population health policymakers and researchers (Milat et al. 2011b, 2012) suggests that scaling-up can be aided by giving particular attention to issues of effectiveness, reach and adoption; human, technical and organisational resources; costs; intervention delivery; contextual factors; and appropriate evaluation approaches. Our study concludes that if these 'scalability considerations' are addressed in the funding, design and reporting of intervention research, the quality and usability of research for decision-makers could be advanced and by doing so improve uptake and expansion of promising programmes into practice (Milat et al. 2012).

Though all of these frameworks (Milat et al. 2012; World Health Organization and ExpandNet 2010; Yamey 2011) describe important considerations when scaling up health interventions, they have not been informed by empirical examination of how scaling up decision-making occurs in the real world from the perspectives of policymakers, practitioners and researchers. In addition, none of these frameworks have been systematically tested with a sample of respondents actively involved in scaling up processes in high-income countries. This is addressed in our scalability framework, which considers differing incentives for researchers, policymakers and practitioners in the scaling-up processes, hypothesised in our previous research and in the broader literature (Brownson et al. 2006; Milat 2014; Milat et al. 2014a, b) to facilitate the systematic transfer of research evidence into broader policy and practice. The framework was developed using previous research (Milat et al. 2014a), a systematic review of scaling-up models (Milat 2014) and two-round Delphi process (de Meyrick 2003) with a sample of senior policymakers, practitioners and researchers actively involved in scaling-up processes. The framework was specifically developed as a practice tool for the New South Wales Ministry of Health in Australia to assist health policymakers and practitioners in their efforts to take a systematic approach in developing scaling-up strategies for major public health investments (Milat et al. 2014b).

Scalability Framework

The Milat et al.'s (2014b) scalability framework provides a practical guide for scaling up health policy and programmes and is primarily designed to be used by practitioners, policymakers and others, with responsibility for scaling up evidence-based population health interventions. The framework can also be used by researchers to assist in the design of research studies that are potentially suitable for scaling up, particularly in circumstances where research-practice collaborations are encouraged. The framework is divided into four steps (see Fig. 4.1). Step 1 is a scalability assessment which involves assessing the suitability of the intervention(s) for scaling-up. The outcome of this assessment will determine whether the remaining steps in the framework should be followed. Step 2 describes how to develop a scaling-up plan which should create a vision of what scaling-up will look like and a compelling case

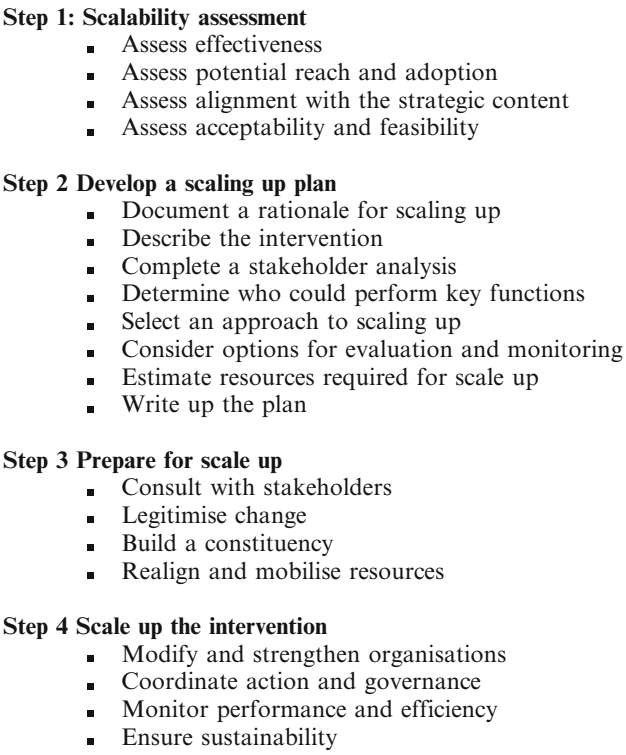

Fig. 4.1 Scalability framework (Milat et al. 2014b)

for action. Step 3 describes how to prepare for scale by securing resources and building a foundation of legitimacy and support for scale-up. Finally, step 4 describes some of the main tasks that should be addressed during scale-up:

- Modify and strengthen organisations
- Coordinate action and governance
- Monitor performance and efficiency
- Ensure sustainability

While the framework is written as if the user is starting from the point of assessing the scalability of an intervention, the latter steps can be used by those already involved in scaling up interventions to review current implementation processes. Each step in the framework and associated sub-steps are now examined in more detail.

Step 1. Scalability Assessment

The aim of this step is to determine if the intervention is scalable. In this process, published research, grey literature, expert advice and practice-based knowledge should all be considered. This step can gather information about the scalability of a particular intervention or to compare and contrast different interventions that are being considered for scale-up as part of a planning process. This step could also be used as a tool to identify gaps in knowledge around the scalability of an intervention which could then be used to build a case for further research to address these gaps. This step is made up of four sub-steps.

1.1 Assess Effectiveness

The key prerequisite for scaling up a population health intervention is that it has been demonstrated to be effective (Kohl and Cooley 2003; Milat et al. 2012; World Health Organization and ExpandNet 2010). Ideally, evidence of effectiveness should be provided from randomised controlled research trials (RCTs), however, it is increasingly acknowledged that evidence of effectiveness, especially for public health interventions, can be derived from a broader range of research designs including quasi-experimental studies, cluster randomised trials and the relatively new 'step wedge design' (Sanson-Fisher et al. 2007). In a stepped wedge design, the intervention is implemented sequentially. The concept is similar to a crossover RCT, but at the start of the trial, all clusters are in the control phase, and by the end of the study, all clusters are in the intervention phase (Sanson-Fisher et al. 2014). In this design, the outcomes are measured at the start of the study prior to implementing the intervention in any of the sites and then measured again at the end of each intervention period and before implementation in the next site(s) (Sanson-Fisher et al. 2014). Rolling recruitment also characterises multiple baseline designs, which require fewer participants than classic experimental designs; these are often used in educational settings (Cooper 1982).

It is also important to consider whether the size of the effect of the intervention is known and whether this is likely to be of policy significance. In addition, intervention effects are likely to be smaller as they are scaled up, and therefore, relatively large effect sizes should be demonstrated in the efficacy stage if an acceptable level of effect is to be maintained when interventions are scaled up (Milat et al. 2012). For example, a recent meta-analysis of RCTs concluded that lifestyle-based diabetes prevention programmes were effective in reducing progression to type 2 diabetes (Gillies et al. 2007). However, subsequent less intensive, 'real-world' intervention replication trials targeting different populations yielded smaller effect sizes for lifestyle outcomes (Absetz et al. 2007; Laatikainen et al. 2007). This reduction in the size of intervention effect is in part due to difficulties maintaining the dose and fidelity of the original intervention in real-world settings. It is rare for interventions to remain unchanged as they are scaled up due to the need to adapt interventions to suit the local context and the organisational, financial and human resources available for scaling-up (Kohl and Cooley 2003; Milat et al. 2012). Whether the dose and fidelity of the intervention could be maintained within acceptable costs when the intervention is scaled up should form part of the scalability assessment. It may also be possible that the intervention is flexible enough that it can be modified while still remaining effective.

The scalability assessment should also determine whether differential effectiveness across target groups and socio-economic status (SES) has been shown (Milat et al. 2012; Thomas et al. 2008). This is important as interventions can be highly effective amongst target groups that need them least (e.g. high SES populations with low-risk profiles) and ineffective in those that need them most (e.g. low socio-economic populations with high-risk profiles) (Halfon and Newacheck 1993). Unfortunately, such differential effects are often not reported in the literature, and calls have been made for this to be a standard practice in reporting of intervention studies (Macintyre 2003). The final part of the effectiveness assessment is an examination of any unintended consequences and adverse outcomes. Interventions should aim to minimise adverse outcomes before being scaled up and in extreme instances may be abandoned altogether if outcomes are adverse (Milat et al. 2012).

1.2 Assess Potential Reach and Adoption

Reach refers to the level of individual participation of an intended target population in an intervention (Glasgow et al. 1999), while *adoption* is the proportion of settings, practices or organisations that adopt an intervention (Glasgow et al. 1999). Both reach and adoption are at the heart of scalability (Milat et al. 2012). What is important is that interventions reach as large a proportion of those eligible to receive them as possible when they are scaled up. Similarly, it is important that interventions are adopted by as large a proportion of eligible settings as possible. When assessing scalability, it is also important to determine whether an intervention has differential rates of reach and adoption across target populations and settings.

1.3 Assess Alignment with the Strategic Context

For interventions to have the best chance of being scaled up into policy and practice, it is important that they are aligned with policy priorities and the broader strategic context (Bhandari et al. 2008; Pearson and Ljungqvist 2011; Pérez-Escamilla et al. 2012). Even highly effective interventions may struggle to obtain funding if they are not aligned with the current priority areas of funding agencies (Kohl and Cooley 2003; Milat et al. 2012). It is also important that the intervention is compatible with or complements existing interventions in the same setting (Milat et al. 2012).

1.4 Assess Acceptability and Feasibility

Another important consideration for scalability is a broad assessment of the feasibility of the intervention. A judgement is required about whether the intervention could realistically be scaled up given what is known about its costs, workforce requirements, time required, infrastructure requirements and acceptability to stakeholders.

Step 2. Develop a Scaling-Up Plan

The aim of this step is to develop a practical and workable scaling-up plan that can be used to convince stakeholders that there is a compelling case for action. This step is made up of eight sub-steps.

2.1 Provide a Rationale for Scale-Up

The rationale for scaling up the intervention should be drawn from the information gathered in step 1, although further investigation and analysis may be necessary to provide a more comprehensive case for action.

2.2 Describe the Intervention

This is a description of 'what' successful characteristics and components from 'original intervention' will be scaled up. Where possible, the original intervention should be simplified and streamlined and costed 'at scale'. For example, the key to 'rapid and massive scale-up' of antiretroviral therapy (ART) for people living with AIDS/HIV infection was to '…keep the principles and practices of ART delivery as simple as possible' (Harries et al. 2009). It is usually also necessary to adapt the original intervention to suit the context(s) within which it will now be implemented.

2.3 Complete a Stakeholder Analysis

A stakeholder is an individual or an organisation with an interest in scaling up the intervention. Stakeholders can be internal or external to the organisation that is commissioning or developing the scaling-up plan. Stakeholders can be mapped according to their importance to scaling up the intervention, influence/power over the outcomes and interest in participating in scaling up the intervention. This step is related to step 1.3, but requires a more comprehensive analysis of the contextual issues that have a potential impact on the proposed scaling-up model. For example, in the Australian state of New South Wales (NSW), the Get Healthy Information and Coaching Service is a free telephone-based physical activity, nutrition and healthy weight coaching service offered by the NSW Government. It was based on evidence of effectiveness in telephone-based health counselling from numerous small-scale selected studies. An important step in the development of the scaled-up service model was a comprehensive mapping of the sociopolitical context to identify potential barriers and enablers to the scaled-up implementation of the service (O'Hara et al. 2013).

2.4 Determine Who Could Perform Key Functions

The next step is to consider who might perform key functions (e.g. performance and fund management; formative research; evaluation and monitoring; workforce development and training; development of content, materials and technologies; marketing and media management; workforce management) when the intervention is scaled up. Mapping key functions and matching them to those who may be involved will assist with this task. During this process, the degree to which the organisation's core business, culture, values, organisational systems and capacities are compatible with the intervention and the plan for scaling it up should be considered (Kohl and Cooley 2003; World Health Organization and ExpandNet 2010).

Determining who will perform key functions is more complex when scaling-up requires action from multiple players within and outside the health system or when several partners are involved and their roles during scaling up are unclear (World Health Organization and ExpandNet 2010). To simplify this process, it is helpful to think of the agencies involved in scaling up interventions as having two main possible roles, that of the *originating organisation* and that of the *delivery organisation* (Kohl and Cooley 2003). The originating organisation is responsible for commissioning and/or developing the scaling-up plan, and the delivery organisation takes up the implementation of the plan. Delivery organisations may be newly created for the purpose of scaling-up or they may already exist.

2.5 Select an Approach to Scaling-Up

There are two main approaches to scaling up health interventions – vertical and horizontal (World Health Organization and ExpandNet 2010). Scaling-up using a vertical approach involves the introduction of an intervention simultaneously across a whole system and results in institutionalisation of a change through policy, regulation, financing or health system change. Examples of successful 'vertically scaled-up' interventions include the introduction of mandatory seat belt legislation (Wagenaar et al. 1988), smoking bans in outdoor eating areas (Brennan et al. 2010) and the introduction of new health system financing models (Eagar 2011). This is usually managed by a central agency (e.g. national, state or regional government) rather than at a local level. The advantages of vertical approaches are that compliance is generally mandatory and such efforts are often accompanied by commitment from the government and resources to support implementation. This means that implementation can occur fairly rapidly and can cover a large area quickly. However, this approach may limit opportunities to adapt intervention delivery to the local context or respond to local issues during implementation. There may also be limited opportunities to change or reverse the intervention overall if it is not working.

Scaling-up using a horizontal approach involves the introduction of an intervention across different sites or groups in a phased manner, often beginning with a pilot programme, followed by stepwise expansion, learning lessons along the way to help refine further expansion. Case studies of successful 'horizontally scaled-up' interventions include the stepwise expansion of the effective fall prevention in older people intervention Stepping On (Clemson et al. 2004) in local health districts across New South Wales, Australia and the expansion of lifestyle-based diabetes prevention programmes in community settings in the United States using a YMCA model (Ackermann and Marrero 2007). This type of scaling-up is sometimes referred to as *expansion* or *replication*. Rather than being managed by a central agency, interventions that are scaled up using this approach tend to be managed by various agencies and/or at a local level. This type of approach is useful when there is some uncertainty about the scalability of an intervention. However, the success of the approach is dependent on the ability of those delivering the intervention to resource and implement the necessary internal changes for scaling up. These skills and resources are not always available at a local level.

These approaches are not mutually exclusive, and often, a combination of approaches is used to scale up interventions. Strategic choices about how scaling-up is organised and how resources are mobilised need to be made that best suit the intervention and the agencies involved in scaling it up.

2.6 Consider Options for Evaluation and Monitoring

It is important that an appropriate evaluation framework is built into intervention delivery from the outset (Milat et al. 2012). Formative evaluation prior to scale-up will be required to test the appropriateness and acceptability of the scaled-up

intervention with the target audience and other stakeholders (see step 3.1). Subsequent evaluation and monitoring efforts during scale-up should focus on measuring effectiveness over time, rates of reach and adoption, acceptability, compatibility with existing interventions and costs.

The emphasis placed on measuring each of these aspects during scale-up will depend on what is already known about the intervention (gaps in evidence identified in step 1) and the approach to scaling up the intervention that has been selected. For example, if a horizontal approach is chosen, there may be greater focus on the practicalities of implementation as well as the acceptability and effectiveness of the intervention as it is scaled up more widely. For vertical approaches, the emphasis may be on measuring the processes and factors that lead to widespread reach and adoption across the target population or setting.

2.7 Estimate Resources Required for Scale-Up

It is necessary to estimate the human (e.g. workforce requirements), technical (e.g. materials, technologies, infrastructure, systems) and financial (e.g. money) resources that will be needed to scale up the intervention in order to provide as much information as possible about the potential cost of scaling up the intervention to decision-makers and to determine whether it is likely that the intervention can be implemented within the budget that may be available.

2.8 Write Up the Plan

The scaling-up plan should summarise the thinking and analysis that took place during the previous steps. It should present a clear and concise case for scaling up the intervention as well as an overview of how this will be brought about. Ultimately the plan should create a vision of what scaling-up will look like if successfully completed. Audiences for the plan can be both internal (e.g. decision-makers within the originating organisation) and external (potential delivery organisations, champions and other stakeholders). It should be written with this in mind. In some cases, more than one version of the plan may be necessary.

Step 3. Prepare for Scale-Up

The aim of this step is to secure resources needed for going to scale and operating at scale and to build a foundation of legitimacy and support that can help sustain the scaling-up effort through the implementation stage.

3.1 Consult with Stakeholders

It is important that the appropriateness and acceptability of the intervention and the scaling-up plan to key stakeholders (including target group for the intervention) are assessed before scaling-up begins. Measuring appropriateness and acceptability will identify problems with the scaling-up plan, potential barriers and enablers to scaling up the intervention and is central to the design of effective advocacy and communication strategies. Often scaling-up plans must be adapted to meet concerns raised by stakeholders through a process of negotiation (Kohl and Cooley 2003).

3.2 Legitimise Change

Legitimising change begins with gaining the support of decision-makers. They must be convinced that scaling up the intervention is a credible and superior solution to a pressing problem, for a population that is a priority and that it is affordable (World Health Organization and ExpandNet 2010). The plan developed during step 2 is important for this purpose. Potential advocacy strategies include policy briefs, engaging the support of champions to act as spokespersons for scaling up the intervention, input into policy and budgetary processes and establishing 'commissions' and advisory boards made up of key influencers. The need for change will be legitimised further once decision-makers come to believe and assert publicly that change is necessary (Kohl and Cooley 2003; Milat et al. 2012).

3.3 Build a Constituency

Constituency building complements and amplifies the efforts to build legitimacy by going beyond engaging leaders and champions to mobilising the broader 'community of practice' required to successfully scale up an intervention. The aim here is to not only move from passive acceptance of the need for change to action in favour of implementing the intervention. This can be a challenging process because it can be difficult to change the status quo (Kohl and Cooley 2003; Milat et al. 2012; World Health Organization and ExpandNet 2010). Opposition generally comes from those that perceive that they may be impacted adversely by the introduction of an intervention due to a reallocation of resources (Kohl and Cooley 2003). To overcome this resistance, stakeholders must believe the change is legitimate, imperative and the best solution to the problem even if it requires the realignment of existing services and priorities. This can be done by organising stakeholder dialogues; working through peak bodies, nongovernment organisations or social institutions; and mobilising grass roots campaigns. Tailored stakeholder engagement, social marketing and public relations campaigns targeting these audiences can also be used to build support for change, as can the use of 'champions' to add weight to these efforts.

3.4 Realign and Mobilise Resources

Funding for scaling-up and for operating at scale is rarely in place at the start of scaling-up efforts. These funds need to be mobilised through existing channels or through new funding streams (Kohl and Cooley 2003). In addition, the resource problem is not simply financial (Kohl and Cooley 2003; Milat et al. 2012). Often the organisations charged with implementing change lack the needed organisational skills and systems to successfully scale up an intervention (Milat et al. 2014a). Therefore, mechanisms to improve skills and develop systems to support implementation need to be developed. There is also a need to consider lateral responses, for example, alternative workforces, to overcome human resource capacity constraints and high workforce costs. For example, many fall prevention exercise interventions originally tested in randomised controlled trials to be delivered by allied health professionals (Campbell et al. 1997; Robertson et al. 2001) have subsequently successfully been delivered by alternate workforces meeting appropriate competency standards at substantially reduced costs. In addition, it is rare for a single organisation to have all of necessary capabilities for scaling up an intervention so partnerships between organisations with complementary resources and strengths can be a synergistic way to provide the resources needed for the scaling-up process (Kohl and Cooley 2003; Milat et al. 2012; Norton and Mittman 2010).

Step 4. Scale Up the Intervention

4.1 Modify and Strengthen Organisations

Most organisations need to adapt to scaling-up interventions (Kohl and Cooley 2003). For example, one challenge is handing over responsibility for delivery of the intervention to others or expanding internally to accommodate increased programme delivery. Newly formed delivery organisations may need new systems and structures and coordination with other participating agencies. This organisational change can be supported through processes such as staff retraining, mentoring, leadership development and coaching (Kohl and Cooley 2003).

4.2 Coordinate Action and Governance

When implementing a scaling-up process, concrete and detailed agreements about how, when, where and by whom resources are to be utilised must be implemented (Kohl and Cooley 2003; Norton and Mittman 2010; Rani et al. 2012; World Health Organization and ExpandNet 2010; Yamey 2011). This requires managing across organisational boundaries so transparent and clear governance structures are put in place to allocate roles, responsibilities and ownership. In addition, these structures should be used to overcome resistance to change and resolve any disputes that arise.

The establishment of networks and coalitions to support those responsible for delivering the intervention is another mechanism that can be used to coordinate action.

4.3 Monitor Performance and Efficiency

It is important to track the implementation of the intervention and make adjustments if it is not reaching required groups or producing intended results (Kohl and Cooley 2003; Milat et al. 2012; World Health Organization and ExpandNet 2010). Monitoring systems should have an ongoing focus on measuring effectiveness, reach, fidelity, fit within the context, acceptability and costs, with a particular focus at this stage on the efficiency of the delivery of an intervention.

Such monitoring systems should be established early in the implementation of the scaling-up process and must be credible and transparent. Also of critical importance is that performance monitoring systems include processes for feeding information back to key influencers, decision-makers, key stakeholders and the public (Kohl and Cooley 2003; Milat et al. 2012; World Health Organization and ExpandNet 2010).

4.4 Ensure Sustainability

The ultimate aim of most scaling-up processes is a sustained change in policy and practice (Milat et al. 2012; Swerissen and Crisp 2004). Most commonly this is achieved through implementing organisational changes to institutionalise an intervention so it becomes part of routine practice (Swerissen and Crisp 2004). This can be difficult to achieve using horizontal scaling-up processes alone (Kohl and Cooley 2003). Expansion and replication ultimately need to be supported by vertical approaches such as policy support and wide-scale realignment of budgets and resources.

Once the scaling-up process has been fully implemented, efforts must turn to greater efficiency in programme delivery and to maintaining stakeholder engagement and political support for the policy or practice changes (Milat et al. 2014a, b). Even initially effective, scaled-up interventions may change in their effects over time. Therefore, interventions must adapt to changing circumstances and contexts over time to continue to be effective and relevant to stakeholders and intended target groups (Milat et al. 2012; Milat et al. 2014a, b).

Health and Educational Interventions: Similar Challenges in Scaling-Up

The issue of scaling-up interventions is receiving greater attention in both the health and educational literature (Constas and Sternberg 2006; Milat et al. 2012; Yamey 2011). A review of educational interventions shows many similar features and problems in scaling-up that are in common with scaling up health programmes.

An 'intervention' in an educational context is defined as a planned modification of the environment made for the purpose of changing behaviour in a prespecified way (Tilly 2008). In school settings, educational interventions change the way education is designed and delivered and can include programmes, policies and systems. Generally interventions involve a broad range of stakeholders including school teachers, principals, school administrators and policymakers.

Similar scalability factors and considerations to those described in the Milat et al.'s (2014a, b) 'scalability framework' have the potential to provide educational policymakers, practitioners and researchers with cues and processes that may facilitate widespread adoption and maintenance of educational policies and programmes. The first factor common to both health and educational interventions is the importance of policy or programme itself, in that it must be effective. The intervention should have identifiable and measurable outcomes distinctly illustrating the impact of the intervention as compared to other interventions or usual educational practice (Sternberg et al. 2006).

The linear processes of scaling-up that might occur following the demonstration of efficacy of medical technologies or clinical therapies (Woolf 2009) are less true of public health interventions. Unlike medical research, the evidence base for public health is based on a range of study designs, including experimental and quasi-experimental research (Sanson-Fisher et al. 2007; 2014), that may provide more contextually relevant, but less definitive evidence base for action than that which is derived from summarising clinical trials. The latter test quite specific interventions (single, specific pharmacological treatments or surgical approaches), whereas public health interventions may be testing a wide range of concurrent interventions applied to a community, so it is difficult to disentangle the efficacy of each intervention component. This makes scalability more complicated and more context-defined in a population health environment. This has an analogue relationship with the education field, where generalising interventions to scale must take account of the school system, school level and school teacher and pupil factors.

In education as in health, the fidelity of the intervention and its relationship with effectiveness is vital and at the heart of scalability. Programme fidelity is the extent to which the implementation of the intervention is consistent with intervention protocols previously found to be effective (Mowbray et al. 2003). The counteracting pressure of programme adaptation involves adjusting a programme for different target populations, localities and organisational factors (Shen et al. 2008).

A key lesson from health scale-up framework is the necessity of finding the right balance between fidelity and adaption when an innovation is scaled up. Lessons from educational innovations that have been successfully scaled up from small trials to programmes that reach millions of students in the United States highlight the importance of maintaining intervention fidelity to programme success (Borman and Hewes 2002; Borman et al. 2007; Slavin et al. 2008). While it is acknowledged that adaption to local contexts is important, maintaining the fidelity of 'core' elements of innovations has been found to be a key contributor to maintaining intervention effectiveness as innovations are scaled up (Slavin et al. 2008). Maintaining fidelity can be difficult in educational settings, where local districts may have different

school boards that implement central curricula differently; in more centralised systems of education, greater standardisation may occur, but local context still matters, in terms of differences in student literacy, cultural diversity and socio-economic factors. Central Education Departments need to understand these differences at the local level and provide differential funding and training to implement new educational programmes in diverse settings.

It is now widely acknowledged across sectors that understanding and accommodating the context within which innovations are implemented are central to uptake (Cohen and Ball 2007; Glennan et al. 2004; Milat et al. 2014a, b; Norton and Mittman 2010; Sternberg et al. 2006). Based on their experience in scaling up educational interventions in schools across the United States, Sternberg et al. (2006) observed that the degree of success varied in school districts based on five contextual factors: available resources, working environments in the districts, commitment of the district leadership to the innovation, readiness to change and the level of organisation experience amongst both teachers and administrators. Given the variability in educational standards at state and local district levels, it is important to determine the correspondence between the objectives of the programme and educational policies and standards prior to scaling-up (Glennan et al. 2004; Sternberg et al. 2006). Not surprisingly, it has been reported that (Glennan et al. 2004; Sternberg et al. 2006) the better is the fit, the more successful will be the scale-up. These contextual factors have much in common with those that have been identified in the health literature, including resourcing, organisational factors, leadership and workforce capacity.

One similarity between education and health is that the perspectives of both policymakers and coal-face practitioners should be sought as part of the scaling-up process. This is seldom done in public health, in terms of the acceptability, flexibility and trialability of the proposed innovation (Glasgow et al. 1999; Rogers 2002; Milat et al. 2014a, b). Little research has been carried out in the public health environment to explore the feasibility of scaling up interventions, and even less research has identified what factors could help policymakers to support intervention scaling up decisions (Milat et al. 2012; Milat et al. 2014a, b).

It is often assumed that a good programme or a great idea will ‘sell itself’ (Sternberg et al. 2006). The health scaling-up literature (Milat 2014) and our ‘scalability framework’ highlight the importance of what we term ‘constituency building’ as a way of building legitimacy and community mobilisation prior to scaling-up. In the context of education, this means that well-crafted cases for the introduction of innovations must be constructed for implementers at the classroom level, but also for stakeholders (local school boards, superintendents, principals, curriculum specialists) who make the critical decisions with regard to bringing innovations to the school in the first place and keeping them there (Constas and Sternberg 2006; Glennan et al. 2004; Quint et al. 2005).

As in health, workforce training and the development of teacher training and support tools is an essential scalability factor to support widespread practice change (Borman et al. 2007; Constas and Sternberg 2006; Glennan et al. 2004; Sternberg et al. 2006). In health-care settings, incentives and feedback have also been identified

as playing an important role in increasing workforce compliance with practice change (Milat et al. 2014a, b), with these factors similarly identified as important issues in the scale-up of education reforms in the United States (Glennan et al. 2004).

Evaluation and performance monitoring frameworks are also essential in both health and education settings to track implementation and make adjustments if scaled-up programmes are not producing the intended results (Glennan et al. 2004; Kohl and Cooley 2003; Milat et al. 2012; World Health Organization and ExpandNet 2010). Scaled-up public health and system-based interventions need evaluation, but the randomised controlled trial (RCT) research design has significant limitations when applied to the complexity of many public health system-based interventions (Sanson-Fisher et al. 2007). After some years of being largely dismissed in the ranking of evidence in medicine, alternatives to the RCT have been debated recently in public health and social service fields and now include study designs such as multiple baseline designs (Hawkins et al. 2007; Sanson-Fisher et al. 2007). As described earlier in this chapter, like RCTs, the multiple baseline design can demonstrate that a change in behaviour has occurred, the change is a result of the intervention, and the change is significant. Especially important practical advantages over the RCT are that this design requires fewer population groups and communities may act as their own controls (Hawkins et al. 2007). These innovations in research design are important tools to test scaled-up interventions and system changes in both health and educational settings as they can be applied to a wide range of contexts when randomisation is impractical or unethical (Sanson-Fisher et al. 2007).

In public health, it has been suggested that scaled-up intervention monitoring systems should measure effectiveness, reach, fidelity and costs, with a particular focus on the efficiency of the delivery of the innovation (Milat et al. 2012). Options for monitoring should be developed at the planning stage. It has also been observed that successfully scaled-up educational programmes use performance monitoring systems and systematically use research findings and input from stakeholders to reshape and improve programmes over time (Constas and Sternberg 2006; Glennan et al. 2004; Penuel et al. 2011; Peurach 2011).

In recent years many education systems have considered scaling up student- or pupil-centred education rather than teacher-driven curricula (Hung et al. 2014). The analogue of this in health services is the concept of patient-centred care, especially around chronic disease management (Bauman et al. 2003). The challenges are greater in scaling up public health or population health interventions (compared to health services), and the counterpart to student-led or patient-centred programme in public health is to influence 'community-led health intervention choices' (Israel et al. 2001). The challenge here is that many of these choices are value driven, and yet public health is guided by evidence-based guidelines, based mostly on the scientific distillation of intervention evidence (Rychetnik et al. 2004). For that reason, the methods for 'community-led population health decisions' are still in their infancy and remain an area of exploration for further investigation by public health researchers (Kohatsu et al. 2004).

One difference between education and health is in the nature of evidence that is sometimes used to define innovation and to describe the potential for scalability.

As some academics construe education as a social science, a scalable intervention can be one which demonstrates creativity or innovation alone (Cohen and Ball 2007). As the origins of public health are in biomedical sciences, it is much more tied to rigorous experimental evidence-based standards in the generation of evidence that is suitable for scalability (Wright et al. 2003; Rychetnik et al. 2012). This means it is arguably more difficult for an intervention to provide the level of evidence required for scalability in a public health context, compared to interventions that might be considered in an educational or other social science context.

In the health setting, the concept of a 'system approach' is as important as it is in an educational setting (Trochim et al. 2006; Sugai and Horner 2009). Taking a 'health system approach' ensures that new interventions are adopted in hospital settings, in private practices and in primary health care. This concept of scalability in public health is difficult, as the contexts are varied and adaptation almost infinite in their complexity across the different settings in which public health practitioners work (Milat et al. 2014a, b). To illustrate, in public health, the implementers of action are likely to be located in multiple and often different sectors (e.g. in regional public health units, in the sports sector, in urban planning, in agriculture, in education or in other government or nongovernment instrumentalities). This has implications for both workforce and public health system capacity. In public health, it means that when a new intervention needs to be considered, it is usually to be added to the outputs already expected of the public health workforce (Milat et al. 2014a, b; Norton and Mittman 2010). It is clear that public health needs to consider scalability across multiple levels, at the level of the public health system which is centralised and region-wide or national, at the level of public health regions and at the level of public health practice. These parallel the ecological levels of influence in the education sector, namely, interventions that are pupil oriented, teacher oriented, school oriented or education system level in their focus (Hung et al. 2014).

Roles of Policymakers, Practitioners and Researchers in Scale-Up

Health and education policymakers, practitioners and researchers face similar challenges when scaling up interventions. According to Klingner et al. (2013), the problem of scale in education has historically been considered by a few intervention researchers independent of the broader community of innovators, administrators and practitioners. As observed by Coburn and Stein (2010), these different stakeholders tend not to share the same goals, resulting in a pronounced gap between research and practice. Though there have been concerted efforts in both education and health sectors to close this gap, a significant divide remains (National Institutes of Health 2013; Klingner et al. 2013; NRC 2012).

A better understanding of the roles and motivations of key players in the policy, practice and research nexus can provide important insights to inform efforts to scale up interventions. In both sectors, policymakers, practitioners and researchers play

different, but complementary, roles in the process of scaling up interventions (Klingner et al. 2013; Milat et al. 2014a). To address this in the health context, we investigated the role that health policymakers, practitioners and researchers play in this process of scaling interventions. We interviewed a sample ($n=21$) of senior health policymakers, practitioners and implementation researchers from Australia, the United Kingdom and the United States and with substantial scaling-up experience (Milat et al. 2014a, b). They opined that researchers play an important role in bringing independent and expert opinion and advocacy for evidence to policymakers. This influences the way that policymakers and practitioners think about evidence in both health and education settings (Brownson et al. 2009; Milat et al. 2014a; Klingner et al. 2013; McDonald et al. 2006). The role of policymakers was seen as determining priorities, securing resources, providing leadership and increasing stakeholder support for scaled-up actions, which were roles similar to education policymakers and district administrators (Klingner et al. 2013). Policymakers make the decisions about what to implement based on a variety of factors including the available evidence, of which research was only one component (Brownson et al. 2006; Brownson et al. 2009; Klingner et al. 2013).

Our study found that researchers, policymakers and practitioners had different needs, interests and value systems that impact on scaling-up processes (Yamey 2011; Milat et al. 2014a). Policymakers aim to identify tools to improve population health and were influenced by the political implications of action and by stakeholders needs. Practitioners had a greater focus on meeting local community and stakeholder needs. Researchers identified funding and publishing papers as core motivators for engaging in scaling-up processes, a finding mirrored across academic settings including education (Taylor 2008). It seems that effective scaled-up research requires recognition of the different needs and values of stakeholders, with an optimal process engaging with policymakers and practitioners being involved from the inception through to the interpretation and dissemination of findings (Milat et al. 2014a, b).

Similarly, education researchers and practitioners have been described as operating in different worlds, with distinct cultures, expectations, motivations and hierarchies (Klingner et al. 2013). As in public health, stakeholder groups have different priorities and interpret evidence in different ways (Klingner et al. 2013; Milat et al. 2014a), reinforcing the importance of effective communication when planning, implementing and evaluating scaled-up interventions.

As described by Sabelli and Dede (2013), change must be owned and integrated within the complex and multifaceted organisational system, with researchers in a role as intermediaries. Thus, researchers need to be aware of policymakers' concerns and windows of opportunity to influence policy and practice, through active involvement and interchange of ideas (Brownson et al. 2006). Similarly in educational settings, Cobb and Smith suggest that researchers should learn about the decision-making processes of policymakers, district leaders and teachers in order to foster better engagement with and uptake of research in scaling-up processes. This requires a conscious effort to better understand each other's perspective and motivations in the scaling-up processes (Cobb and Smith 2008).

Conclusion

In order to achieve population-wide outcomes, promising health or educational innovations must be scaled up for widespread implementation. The Milat et al. (2014b) 'scalability framework' describes a step-by-step process for scaling up health interventions divided into four steps: (1) scalability assessment, (2) develop a scaling-up plan, (3) prepare for scale-up and (4) scale up the intervention. Despite the unpredictability of scaling-up processes, a clear plan can guide the scaling-up process. Moreover, learning requires systematic use of evidence. Our framework argues that plans for scaling-up need to consider a broad range of factors and balance what is desirable with what is feasible. Such strategic thinking must continue as the process moves from planning to implementation to sustainability.

In the health sector, the process of scaling up interventions differs in the clinical setting, compared to scaling up public health interventions to influence population health. The former has a relatively standardised set of health-care institutions [hospitals], fixed funding allocations in which decisions can be made and clear rules about 'evidence-based medicine' that allow for clarity in determining scalable therapeutic priorities. By contrast, public health interventions provide less clear 'evidence', as public health change usually requires multiple component community-wide interventions to prevent or reduce smoking, improve healthy diet or even disseminate immunisation programmes across a large region. This makes the challenges greater for scaling up population-level prevention, exacerbated by differences in local settings and sites that might implement recommended new interventions or approaches. In terms of timescale, it may take several attempts to scale up public health interventions and have them adopted in similar ways across a large system; the length of time to adoption may vary across settings or regions, leading to or exacerbating health inequalities.

Similar scalability factors and challenges in implementation to those described in the Milat et al. (2014b) 'scalability framework' have the potential to provide educational policymakers, practitioners and researchers with important cues and processes to inform their scaling-up efforts. Again, these will vary according to the educational system in which scaling-up is attempted and the capacity for differential resourcing and training being provided for the scale-up of interventions in hard-to-reach educational settings. Sharing of lessons learned about scaling up innovations across health and education disciplines has the potential to advancing thinking in both fields. As with health interventions, educational innovations should have robust evidence of effectiveness prior to scale-up, have the potential to be substantially expanded to reach eligible populations, should be acceptable to the target groups and settings and delivered at an acceptable cost and wherever possible be sustainable. Again, it is vital to understand the context within which interventions operate; and contextually appropriate evaluative and performance monitoring systems should be built into intervention delivery from the outset, with these systems producing reliable information to inform intervention development and scaling-up processes.

Of note, policymakers, practitioners and researchers play different, but complementary, roles in the process of scaling up interventions in broader health and education practice. A better understanding of needs and motivations of key stakeholders in scaling-up processes can inform future intervention research design, intervention development and scaling-up decisions more broadly.

In conclusion, scaling-up is the central tenet of achieving population-wide change; the rhetoric of improved health or educational outcomes will not occur without concerted and focused efforts at identifying evidence-based innovations and implementing them 'at scale' across a system or population. The planning required, resource costs and time and personnel investments required for scaling-up should not be underestimated and should form an ongoing dialogue in policy and service delivery agencies. Culture change in organisations towards an understanding and support of scaling-up is a necessary precursor to improved outcomes in education and in health.

References

Absetz, P., Valve, R., Oldenburg, B., Heinonen, H., Nissinen, A., Fogelholm, M., & Uutela, A. (2007). Type 2 diabetes prevention in the "real world" one-year results of the GOAL implementation trial. *Diabetes Care, 30*(10), 2465–2470.

Ackermann, R. T., & Marrero, D. G. (2007). Adapting the diabetes prevention program lifestyle intervention for delivery in the community the YMCA model. *The Diabetes Educator, 33*(1), 69–78.

Aldinger, C., Zhang, X.-W., Liu, L.-Q., Guo, J.-X., Hai, Y. S., & Jones, J. (2008). Strategies for implementing Health-Promoting Schools in a province in China. *Promotion & Education, 15*(1), 24–29.

Balas, E. A., & Boren, S. A. (2000). Yearbook of medical informatics. *Amsterdam: Schattauer, 384*, 1419–1431.

Bauman, A. E., Fardy, H. J., & Harris, P. G. (2003). Getting it right: Why bother with patient centred care? *Medical Journal of Australia, 179*(5), 253–256.

Bhandari, N., Kabir, A., & Salam, M. A. (2008). Mainstreaming nutrition into maternal and child health programmes: Scaling up of exclusive breastfeeding. *Maternal & Child Nutrition, 4*(s1), 5–23.

Borman, G. D., & Hewes, G. M. (2002). The long-term effects and cost-effectiveness of Success for All. *Educational Evaluation and Policy Analysis, 24*(4), 243–266.

Borman, G. D., Slavin, R. E., Cheung, A. C. K., Chamberlain, A. M., Madden, N. A., & Chambers, B. (2007). Final reading outcomes of the national randomized field trial of Success for All. *American Educational Research Journal, 44*(3), 701–731.

Brennan, E., Cameron, M., Warne, C., Durkin, S., Borland, R., Travers, M. J., & Wakefield, M. A. (2010). Second hand smoke drift: Examining the influence of indoor smoking bans on indoor and outdoor air quality at pubs and bars. *Nicotine & Tobacco Research, 12*(3), 271–277.

Brownson, R. C., Fielding, J. E., & Maylahn, C. M. (2009). Evidenced – Based public health: A fundamental concept for public heath practice. *Annual Review of Public Health, 30*, 175–201.

Brownson, R. C., Royer, C., Ewing, R., & McBride, T. D. (2006). Researchers and policymakers: Travelers in parallel universes. *American Journal of Preventive Medicine, 30*(2), 164–172.

Brownson, R. C., Baker, E. A., Leet, T. L., Gillespie, K. N., & True, W. R. (2010). *Evidence-based public health*. Oxford: Oxford University Press.

Campbell, A. J., Robertson, M. C., Gardner, M. M., Norton, R. N., Tilyard, M. W., & Buchner, D. M. (1997). Randomised controlled trial of a general practice programme of home based exercise to prevent falls in elderly women. *BMJ [British Medical Journal], 315*(7115), 1065.

Catford, J. (2009). Advancing the 'science of delivery' of health promotion: Not just the 'science of discovery'. *Health Promotion International, 24*, 1–5.

Claridge, J. A., & Fabian, T. C. (2005). History and development of evidence-based medicine. *World Journal of Surgery, 29*(5), 547–553.

Clemson, L., Cumming, R. G., Kendig, H., Swann, M., Heard, R., & Taylor, K. (2004). The effectiveness of a community-based program for reducing the incidence of falls in the elderly: A randomized trial. *Journal of the American Geriatrics Society, 52*(9), 1487–1494.

Cobb, P., & Smith, T. (2008). The challenge of scale: Designing schools and districts as learning organizations for instructional improvement in mathematics. In *International handbook of mathematics teacher education* (Vol. 3, pp. 231–254). Rotterdam : Sense

Coburn, C. E., & Stein, M. K. (2010). *Research and practice in education: Building alliances, bridging the divide*. Lanham: Rowman & Littlefield Publishers.

Cohen, D. K., & Ball, D. L. (2007). Educational innovation and the problem of scale. In *Scale-up in Education: Ideas and Principles* (pp. 19–36). Lanham : Rowman & Littlefield Publishers.

Constas, M. A., & Sternberg, R. J. (Eds.). (2006). *Translating theory and research into educational practice: Developments in content domains, large scale reform, and intellectual capacity*. Mahwah: Psychology Press.

Cooper, J. O. (1982). Applied behavior analysis in education. *Theory Into Practice, 21*(2), 114–118.

de Meyrick, J. (2003). The Delphi method and health research. *Health Education, 103*(1), 7–16.

de Silva-Sanigorski, A. M., Bolton, K., Haby, M., Kremer, P., Gibbs, L., Waters, E., & Swinburn, B. (2010). Scaling up community-based obesity prevention in Australia: Background and evaluation design of the Health Promoting Communities: Being Active Eating Well initiative. *BMC Public Health, 10*(65).

Detels, R. (2009). The scope and concerns of public health. In: *Oxford textbook of public health* (Vol. 1, p. 392). Oxford: Oxford University Press.

Eagar, K. M. (2011). *What is activity-based funding?* ABF Information Series No. 1.

Eccles, M., Grimshaw, J., Walker, A., Johnston, M., & Pitts, N. (2005). Changing the behavior of healthcare professionals: The use of theory in promoting the uptake of research findings. *Journal of Clinical Epidemiology, 58*(2), 107–112.

Edouard, E., & Edouard, L. (2012). Application of information and communication technology for scaling up youth sexual and reproductive health. *African Journal of Reproductive Health, 16*(2), 197–206.

Gillies, C. L., Abrams, K. R., Lambert, P. C., Cooper, N. J., Sutton, A. J., Hsu, R. T., & Khunti, K. (2007). Pharmacological and lifestyle interventions to prevent or delay type 2 diabetes in people with impaired glucose tolerance: Systematic review and meta-analysis. *BMJ, 334*(7588), 299.

Glasgow, R. E., Vogt, T. M., & Boles, S. M. (1999). Evaluating the public health impact of health promotion interventions: The RE-AIM framework. *American Journal of Public Health, 89*(9), 1322–1327.

Glennan, T. K. J., Bodilly, S. J., Galegher, J. R., & Kerr, K. A. (2004). *Expanding the reach of educational reforms: Perspectives from leaders in the scale-up of educational interventions*. Santa Monica: RAND Corp.

Gregor, S. (2002). A theory of theories in information systems. In *Information systems foundations: Building the Theoretical Base* (pp. 1–20). Canberra : Australian National University.

Grol, R. (2001). Successes and failures in the implementation of evidence-based guidelines for clinical practice. *Medical Care, 39*(8), II-46–II-54.

Halfon, N., & Newacheck, P. W. (1993). Childhood asthma and poverty: Differential impacts and utilization of health services. *Pediatrics, 91*(1), 56–61.

Harries, A. D., Zachariah, R., Jahn, A., Schouten, E. J., & Kamoto, K. (2009). Scaling up antiretroviral therapy in Malawi-implications for managing other chronic diseases in resource-limited countries. *JAIDS Journal of Acquired Immune Deficiency Syndromes, 52*, S14–S16.

Hawe, P., & Potvin, L. (2009). What is population health intervention research? *Canadian Journal of Public Health, 100*(1), I8–I14.

Hawkins, N. G., Sanson-Fisher, R. W., Shakeshaft, A., D'Este, C., & Green, L. W. (2007). The multiple baseline design for evaluating population-based research. *American Journal of Preventive Medicine, 33*(2), 162–168.

Hung, D., Lee, S. S., Teh, L. W., Kwan, Y. M., Vishnumahanti, S., & Widiastuti, A. (2014). An ecological perspective on scaling: Balancing structural and individual adaptivities. In D. Hung, K. Y. T. Lim, & S. S. Lee (Eds.), *Adaptivity as a transformative disposition: For learning in the 21st century* (pp. 267–285). Singapore: Springer.

Israel, B. A., Schulz, A., Parker, E. A., & Becker, A. B. (2001). Community-based participatory research: Policy recommendations for promoting a partnership approach in health research. *Education for Health, 14*(2), 182–197.

Johns, B., & Baltussen, R. (2004). Accounting for the cost of scaling up health interventions. *Health Economics, 13*(11), 1117–1124.

Klingner, J. K., Boardman, A. G., & McMaster, K. L. (2013, Winter). What does it take to scale up and sustain evidencebased practices? *Exceptional Children, 79*(2), 195–211.

Kohatsu, N. D., Robinson, J. G., & Torner, J. C. (2004). Evidence-based public health: An evolving concept. *American Journal of Preventive Medicine, 27*(5), 417–421.

Kohl, R., & Cooley, L. (2003). *Scaling up: a conceptual and operational framework*. Washington, DC: Management Systems International.

Kuhn, T. (1962). *The structure of scientific revolutions* (50th Anniversary Edition ed.). Chicago: The University of Chicago Press.

Laatikainen, T., Dunbar, J. A., Chapman, A., Kilkkinen, A., Vartiainen, E., Heistaro, S., & O'Neil, A. (2007). Prevention of type 2 diabetes by lifestyle intervention in an Australian primary health care setting: Greater Green Triangle (GGT) Diabetes Prevention Project. *BMC Public Health, 7*(1), 249.

Larson, C. P., Koehlmoos, T. P., & Sack, D. A. (2012). Scaling up zinc treatment of childhood diarrhoea in Bangladesh: Theoretical and practical considerations guiding the SUZY Project. *Health Policy and Planning, 27*(2), 102–114.

Macintyre, S. (2003). Evidence based policy making: Impact on health inequalities still needs to be assessed. *BMJ [British Medical Journal], 326*(7379), 5.

Maher, D., Dye, C., Floyd, K., Pantoja, A., Lonnroth, K., Reid, A., & Cunningham, J. (2007). Planning to improve global health: The next decade of tuberculosis control. *Bulletin of the World Health Organization, 85*(5), 341–347.

Marrero, D. (2009). The prevention of type 2 diabetes: An overview. *Journal of Diabetes Science & Technology, 3*(4), 756–760.

McDonald, S.-K., Keesler, V. A., Kauffman, N. J., & Schneider, B. (2006). Scaling-up exemplary interventions. *Educational Researcher, 35*(3), 15–24.

Merson, M. H., Curran, J. W., Griffith, C. H., & Ragunanthan, B. (2012). The President's Emergency Plan for AIDS Relief: From successes of the emergency response to challenges of sustainable action. *Health Affairs, 31*(7), 1380–1388.

Milat, A. J., Bauman, A., Redman, S., & Curac, N. (2011a). Public health research outputs from efficacy to dissemination: A bibliometric analysis. *BMC Public Health, 11*, doi:10.1186/1471-2458-1111-1934, 10.1186/1471-2458-11-934.

Milat, A. J., King, L., Bauman, A., & Redman, S. (2011b). Scaling up health promotion interventions: An emerging concept in implementation science. *Health Promotion Journal of Australia, 22*, 238.

Milat, A., Monger, C., Smith, J., Bauman, A., Redman, S., & Goodger, B. (2011c). The strategic development of the NSW Health Plan for Prevention of Falls and Harm from Falls Among Older People: 2011–2015; translating research into policy and practice. *NSW Public Health Bulletin, 22*(4).

Milat, A. J., King, L., Bauman, A., & Redman, S. (2012). The concept of scalability: Increasing the scale and potential adoption of health promotion interventions into policy and practice. *Health Promotion International*. doi:10.1093/heapro/dar1097.

Milat, A. J. (2014). *Increasing the use of intervention research evidence in policy and practice: Roles of policy makers, practioners, researchers and funders in research generation and utilization*. PhD thesis, Faculty of medicine, University of Sydney.

Milat, A. J., King, L., Wolfenden, L., Rissel, C., Newson, R., Bauman, A. E., & Redman, S. (2014a). Increasing the scale and adoption of population health interventions: Experiences and perspectives of policy makers, practitioners and researchers. *Health Research Policy and Systems, 12*(18).

Milat, A. J., Newson, R., & King, L. (2014b). *Increasing the scale and adoption of public health interventions: A guide*. North Sydney: NSW Ministry of Health.

Morel, C. M., Lauer, J. A., & Evans, D. B. (2005). Cost effectiveness analysis of strategies to combat malaria in developing countries. *BMJ, 331*(7528), 1299.

Mowbray, C. T., Holter, M. C., Teague, G. B., & Bybee, D. (2003). Fidelity criteria: Development, measurement, and validation. *American Journal of Evaluation, 24*, 315–340.

Nankunda, J., Tylleskär, T., Ndeezi, G., Semiyaga, N., & Tumwine, J. K. (2010). Establishing individual peer counselling for exclusive breastfeeding in Uganda: Implications for scaling-up. *Maternal & Child Nutrition, 6*(1), 53–66.

National Institutes of Health. (2013, June 17). *Dissemination and implementation research in mental health PA-02-131*, from http://grants.nih.gov/grants/guide/pa-files/pa-02-131.html

National Research Council. (2012). Using science as evidence in public policy. In K. Prewitt, T. A. Schwandt, & M. L. Straf (Eds.), *Committee on the use of social science knowledge in public policy* (pp. 4–5). Washington, DC: Center for Education; Division of Behavioral and Social Sciences and Education.

Norton, W., & Mittman, B. (2010). *Scaling-up health promotion/disease prevention programs in community settings: Barriers, facilitators, and initial recommendations*. Report Submitted to Patrick and Catherine Weldon Donaghue Medical Research Foundation.

O'Hara, B. J., Bauman, A. E., Eakin, E. G., King, L., Haas, M., Allman-Farinelli, M., & Milat, A. J. (2013). Evaluation framework for translational research case study of Australia's get healthy information and coaching service®. *Health Promotion Practice, 14*(3), 380–389.

Pearson, B. L., & Ljungqvist, B. (2011). REACH: An effective catalyst for scaling up priority nutrition interventions at the country level. *Food & Nutrition Bulletin, 32*((Supplement 2)), 115S–127S.

Penuel, W. R., Fishman, B. J., Cheng, B. H., & Sabelli, N. (2011). Organizing research and development at the intersection of learning, implementation, and design. *Educational Researcher, 40*(7), 331–337.

Pérez-Escamilla, R., Curry, L., Minhas, D., Taylor, L., & Bradley, E. (2012). Scaling up of breastfeeding promotion programs in low-and middle-income countries: The "breastfeeding gear" model. *Advances in Nutrition: An International Review Journal, 3*(6), 790–800.

Peurach, D. (2011). *Seeing complexity in public education: Problems, possibilities, and Success for All*. Oxford: Oxford University Press.

Popper, K. (2013). *Realism and the aim of science: From the postscript to the logic of scientific discovery*. London: Routledge.

Productivity Commission. (2010). *Strengthening evidence-based policy in the Australian Federation. Vol. 2: Background paper* (Productivity Commission, Ed.). Canberra: Productivity Commission.

Quint, J, Bloom, H. S., Black, A. R., Stephens, L., & Akey, T. M. (2005). *The challenge of scaling up educational reform. Findings and lessons from first things first*. Final Report. MDRC.

Rani, M., Nusrat, S., & Hawken, L. (2012). A qualitative study of governance of evolving response to non-communicable diseases in low-and middle-income countries: Current status, risks and options. *BMC Public Health, 12*(1), 877.

Robertson, M. C., Gardner, M. M., Devlin, N., McGee, R., & Campbell, A. J. (2001). Effectiveness and economic evaluation of a nurse delivered home exercise programme to prevent falls. 2: Controlled trial in multiple centres. *BMJ, 322*(7288), 701.

Rogers, E. M. (2002). Diffusion of preventive innovations. *Addictive Behaviors, 27*(6), 989–993.

Rubenstein, L. V., & Pugh, J. (2006). Strategies for promoting organizational and practice change by advancing implementation research. *Journal of General Internal Medicine, 21*, S58–S64.

Rychetnik, L., Hawe, P., Waters, E., Barratt, A., & Frommer, M. (2004). A glossary for evidence based public health. *Journal of Epidemiology and Community Health, 58*(7), 538–545.

Rychetnik, L., Bauman, A., Laws, R., King, L., Rissel, C., Nutbeam, D., & Caterson, I. (2012). Translating research for evidence-based public health: Key concepts and future directions. *Journal of Epidemiology and Community Health, 66*(12), 1187–1192.

Rycroft-Malone, J., & Bucknall, T. (2010). Using theory and frameworks to facilitate the implementation of evidence into practice. *Worldviews on Evidence-Based Nursing, 7*(2), 57–58. doi :10.1111/j.1741-6787.2010.00194.

Sabelli, N., & Dede, C. (2013). Empowering DBIR: The need for infrastructure. In W. R. Penuel, B. Fishman, A. Allen, & B. Cheng (Eds.), *Design-based implementation research* (National Society for the Study of Education Yearbook, Vol. 112, pp. 464–480). New York: Teachers College Press.

Sanson-Fisher, R. W., Bonevski, B., Green, L. W., & D'Este, C. (2007). Limitations of the randomized controlled trial in evaluating population-based health interventions. *American Journal of Preventive Medicine, 33*(2), 155–161.

Sanson-Fisher, R. W., D'Este, C. A., Carey, M. L., Noble, N., & Paul, C. L. (2014). Evaluation of systems-oriented public health interventions: Alternative research designs. *Annual Review of Public Health, 35*, 9–27.

Shen, J., Yang, H., Cao, H., & Warfield, C. (2008). The fidelity adaptation relationship in non-evidence-based programs and its implications for program evaluation. *Evaluation, 14*, 467–481.

Slavin, R. E., Madden, N. A., Chambers, M. E., Chambers, B., & Haxby, B. (2008). *2 million children: Success for all*. Thousand Oaks: Corwin Press.

Smith, R., & Rennie, D. (2014). Evidence-based medicine—An oral history. *JAMA, 311*(4), 365–367.

Stead, L. F., Perera, R., Bullen, C., Mant, D., & Lancaster, T. (2012). Nicotine replacement therapy for smoking cessation. *Cochrane Database of Systematic Reviews, 1*(1).

Sternberg, R. J., Birney, D., Jarvin, L., Kirlik, A., Stemler, S., & Grigorenko, E. L. (2006). Scaling up educational interventions. *Translating educational theory and research into practice: Developments in content domains, large scale reform, and intellectual capacity*.

Sugai, G., & Horner, R. H. (2009). Responsiveness-to-intervention and school-wide positive behavior supports: Integration of multi-tiered system approaches. *Exceptionality, 17*(4), 223–237.

Swerissen, H., & Crisp, B. R. (2004). The sustainability of health promotion interventions for different levels of social organization. *Health Promotion International, 19*(1), 123–130.

Taylor, J. (2008). The impact of performance indicators on the work of university academics: Evidence from Australian universities. *Higher Education Quarterly, 55*, 42–61.

Thomas, S., Fayter, D., Misso, K., Ogilvie, D., Petticrew, M., Sowden, A., & Worthy, G. (2008). Population tobacco control interventions and their effects on social inequalities in smoking: Systematic review. *Tobacco Control, 17*(4), 230–237.

Tilly, W. D. (2008). The evolution of school psychology to science-based practice: Problem solving and the three-tiered model. In *Best practices in school psychology, v* (1, pp. 17–36). Bethesda: National Association of School Psychologists.

Timmermans, S., & Mauck, A. (2005). The promises and pitfalls of evidence-based medicine. *Health Affairs, 24*(1), 18–28.

Trochim, W. M., Cabrera, D. A., Milstein, B., Gallagher, R. S., & Leischow, S. J. (2006). Practical challenges of systems thinking and modeling in public health. *American Journal of Public Health, 96*(3), 538.

Tulodziecki, D. (2012). Principles of reasoning in historical epidemiology. *Journal of Evaluation in Clinical Practice, 18*(5), 968–973.

Underhill, K., Operario, D., Mimiaga, M. J., Skeer, M. R., & Mayer, K. H. (2010). Implementation science of pre-exposure prophylaxis: Preparing for public use. *Current HIV/AIDS Reports, 7*(4), 210–219.

Wagenaar, A. C., Maybee, R. G., & Sullivan, K. P. (1988). Mandatory seat belt laws in eight states: A time-series evaluation. *Journal of Safety Research, 19*(2), 51–70.

Winfrey, W., McKinnon, R., & Stover, J. (2011). Methods used in the lives saved tool (LiST). *BMC Public Health, 11*(Suppl 3), S32.

Woolf, S. H. (2009). The meaning of translational research and why it matters. *The Journal of the American Medical Association, 299*(2), 211–213.

World Health Organization. (2010). *Health systems financing: The path to universal financing*. Geneva: WHO.

World Health Organization, & ExpandNet. (2010). *Nine steps for developing a scaling-up strategy*. Geneva: WHO.

Wright, J. G., Swiontkowski, M. F., & Heckman, J. D. (2003). Introducing levels of evidence to the journal. *The Journal of Bone & Joint Surgery, 85*(1), 1–3.

Wyatt, H. V. (1976). James Lind and the prevention of scurvy. *Medical History, 20*(4), 433.

Yamey, G. (2011). Scaling up global health interventions: A proposed framework for success. *PLoS Medicine, 8*(6), e1001049.

Zhang, L., Gray, R. T., & Wilson, D. P. (2012). Modelling the epidemiological impact of scaling up HIV testing and antiretroviral treatment in China. *Sexual Health, 9*(3), 261–271.

Part II
Case Studies of Scaling

Chapter 5
How Educational Innovators Apply Diffusion and Scale-Up Concepts

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Abstract The challenge of how to diffuse and scale up effective educational interventions has received increasing attention from researchers in recent years, though achievement of this objective has confounded policy makers, practitioners, and the scholarly community at least since the 1970s. This chapter presents three case studies of efforts at US community college STEM centers to apply diffusion and scale-up concepts to their educational innovations to advance student learning. Ours is an analysis of knowledge use. These community college innovators participated in a series of meetings and activities over 3 years to familiarize themselves with concepts and strategies about diffusion and scale-up and were encouraged to apply these concepts in practice. Case study results show that teams of innovators did try to use these concepts, some more than others, and worked to resolve the combined use of concepts to best suit their own objectives. Innovators found some concepts to be overlapping or redundant, some too complex to apply, and some in

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contradiction. We conclude that teams acted in creative ways to implement diffusion and scale-up concepts. Recommendations for future efforts to spread educational interventions are made.

This chapter describes the work of three centers funded by the US National Science Foundation (NSF) Advanced Technological Education (ATE) Program that voluntarily joined the Synergy Collaboratory, an effort among 13 ATE centers to learn and apply a set of concepts and strategies about diffusing and scaling up innovative projects of their creation. On the advice of Synergy leadership, we selected these projects because of their active involvement with applying the concepts and strategies of this initiative. The three projects we describe were not chosen because of their success, though each did experience success; they were selected because through participation, they gained confidence and became "frequent triers" in applying the concepts to which they were introduced. Their charge was an explicit call to use knowledge of a certain type to help achieve their diffusion and scale-up objectives.

Our work was designed to answer the following questions:

1. When a set of grantees is introduced to concepts and strategies about how to diffuse and scale up the products of their work, how long does it take them to try out those concepts?
2. Which concepts get tried, and how?
3. Are concepts tried together or one by one?
4. Why do grantees try certain concepts and not others?
5. Do grantees add value to concepts by putting them to use?

We answer these questions through case study descriptions of the experiences of faculty and staff of these three Synergy projects. We then summarize our observations by addressing the above questions. We believe that these results are applicable to the diffusion and scale-up objectives of other educational innovators, especially those with similar types of innovations.

Advanced Technological Education and the Synergy Collaboratory

ATE is a granting program and portfolio within the Division of Undergraduate Education at NSF. The program focuses on 2-year community colleges in the USA, and its goal is to improve the education of science, technology, engineering, and mathematics (STEM) professionals for the high-technology fields that affect the nation's economy. The program fosters partnerships between academic institutions and employers to promote improvement in the education of science and engineering technicians at the undergraduate and secondary school levels. ATE supports projects

that are designed to improve curriculum, the professional development of college faculty and secondary school teachers, and career pathways to 2-year colleges from secondary schools and from 2-year colleges to 4-year institutions and/or into gainful employment.

History of Synergy

Synergy began as a conference series that was grounded in research. Using an innovative problem-based challenge cycle as the format, the conferences purposefully intertwined call-to-action keynotes with highly interactive breakout sessions to allow participants to reflect on the innovation strategies presented and to work through processes that culminate in action planning. Synergy 2004 meshed research on learning reviewed by Bransford et al. (2000) with ideas on design by Wiggins and McTighe (2005) and with the realities of the workplace as depicted by people employed in private industry. These perspectives illustrated the importance of adaptive expertise and design in both education and the private sector. Synergy 2006 engaged participants as they experienced new tools and approaches that could help students develop and practice the skills required for success in technology-intensive workplaces. Synergy speakers challenged faculty to design problem-based instructional modalities that drew on sophisticated technologies and to work productively with industry to provide real-world learning experiences for students.

Synergy 2008 focused on achieving scale and was closely aligned with making innovative pedagogical models common practice in technical classrooms across the nation. Implicit in this task was the need to develop big-picture thinking among conference participants and to help attendees to think about ways to develop and execute projects with diffusion (the adoption of innovations by faculty at many more colleges for the benefit of students) and scale-up (the transference of responsibility and ownership of innovative activity to subsequent adopting colleges) as a major outcome. Research on diffusion theory (Dearing 2009) and the dimensions of scale (Dede et al. 2005) were combined with learning theory to provide a knowledge base for addressing some of the key meta-issues of the NSF ATE Program, including efficacy of educational interventions, external validity testing of efficacious interventions, replication and adaptation of successful programs and practices, supporting attempts at implementation, encouraging adopters to adapt innovations to best suit their needs and thus "own" them, sustainability of effective interventions with continual improvement, and return on investment.

Synergy and Scale/Diffusion

Based on this sequence of conferences, a subsequent grant in 2009 funded the Synergy Collaboratory for Research, Practice, and Transformation. This effort, led by three of us (Boisvert, Johnson, and McNeel), built explicitly on the diffusion and scale-up research

by two of us (Dede and Dearing) by inviting 13 ATE centers across the country to work as a national network for sharing knowledge and skills. This effort brought together leaders and staff of these ATE centers in two meetings each year for 3 years. Between meetings, stakeholders from each center, supported by Synergy evaluators and by innovation coaches, worked through challenges of understanding and then using scale and diffusion concepts. The implementation work was largely facilitated by each center's innovation coach, a designated staff person with partial FTE support to participate in Synergy. Innovation coaches organized the work of their respective center team and then shared their experiences with innovation coaches at the other centers.

The first Collaboratory year was expert centered. Leaders from each of the centers committed to scaling and diffusion work as a condition of their involvement in Synergy. The second year emphasized application of those expert ideas by ATE participants to their own projects. In effect, the scaling and diffusion experts in year 1 became listeners and learners in year 2, while the leaders and staff at the 13 ATE centers became experimenters and teachers about what worked and why. In year three, the leaders and staff at the ATE centers recognized that they themselves were now experts through the process of grounded application. This article reports on the results of this strategy for producing trial attempts at using diffusion and scale concepts in practice.

ATE Centers Involved in the Synergy Collaboratory

Thirteen ATE centers participated in the Synergy Collaboratory. Each selected one project (Table 5.1) to which it would apply scale and diffusion concepts. Each of these centers is somewhat an anomaly on its campus because, while community and technical colleges are developing the ability to accept large federally funded centers and projects, this is far from the norm.

Without exception, ATE principal investigators (center directors) are entrepreneurial compared to their faculty colleagues on their campuses. For prospective students and business people in their communities, ATE centers function as windows into the college: a way in through a career-centered curriculum. For students and others on campus, ATE centers function in reverse, as conduits through which they can learn of the needs and opportunities of employers in the industry in which the ATE center specializes. This bridging function is also true of similar centers on 4-year campuses: They are entrepreneurial places and topically specific windows into, and out of, the college or university (Ikenberry and Friedman 1972; Birnbaum 1991).

Prior Research About Diffusion and Scale-Up of Educational Innovations

Early research about spreading and expanding educational innovations documented the importance of time and interpersonal networks to diffusion. Studies led by Paul Mort and his colleagues at Teachers College at Columbia University showed that

Table 5.1 Thirteen ATE centers and their selected projects comprise the Synergy Collaboratory

1.	BATEC (*Boston Area Advanced Technological Education Connections*)	Synergy project: Tech Apprentice Program
2.	Bio-Link (*Center of Excellence for Biotechnology and Life Sciences*)	Synergy project: Bridge to Biotech Program
3.	CREATE (*Renewable Energy Center*)	Synergy project: Teaching Skills Workshop
4.	CSSIA (*National Resource Center for Systems Security and Information Assurance*)	Synergy program: Cyber Security Competitions for All
5.	CTC (*Convergence Technology Center*)	Synergy project: Mentored College Program
6.	GeoTech (*National GeoTech Center*)	Synergy project: Remote Desktop Access and Remote Application Access for Geospatial Programs
7.	ICT (*Information and Communication Technology Center*)	Synergy project: Replicable New Media to Aid Centers and Projects in Enhanced Dissemination
8.	MatEd (*National Resource Center for Materials Technology Education*)	Synergy program: National Educators Workshop
9.	MPICT (*Mid-Pacific Information and Communication Technologies Center*)	Synergy project: Hybrid/Distributed ICT Education
10.	Nano-Link (*Nanotechnology Resources for Educators*)	Synergy project: Getting Nanotechnology into High Schools
11.	RCNGM (*Regional Center for Next Generation Manufacturing*)	Synergy project: Advanced Manufacturing Expo Expansion
12.	SC ATE (*South Carolina Advanced Technological Education Center of Excellence*)	Synergy project: Technology Gateway Curriculum
13.	SCME (*Southwest Center for Microsystems Education*)	Synergy project: Leaning SCME's Pressure Sensor Workshop

educational innovations could take 25 years to be adopted in schools (Mort 1953). The Pittsburgh school system study of mathematics curriculum showed the importance of informal opinion leading school superintendents in accelerating spread across schools (Carlson 1965). Efforts to use the lessons from these and other early studies conceptualized the achievement of scale and diffusion as one-way, emanating from a centralized expert source, with the receivers of new practices and programs being passive consumers (Havelock 1969). NSF, through its teacher institutes and partnerships with commercial publishers, and the US Department of Education, with its investments in demonstration projects, embedded this linear research, development, diffusion, and evaluation (RDDE) approach to knowledge transfer. A great deal of content was developed and organized, but little of it was taken up and used in practice (Hutchinson and Huberman 1993).

Within a decade, researchers were calling for modifications to this rational model so that it better accounted for the knowledge, skills, and practice-based expertise held by the users of innovations, such as teachers and students in classroom settings (Berman and McLaughlin 1978). Empirical studies of knowledge use were clearly indicating that considerable constructivist sensemaking occurred as implementers

of educational innovations applied their own needs and situational demands to what an innovation might do for them. This change in perspective repositioned practitioners not only as active agents in making innovations work but also as innovators themselves (Dunn and Holzner 1988). This acknowledgment of the nonlinearity of social change was an affirmation of the importance of linking agents, paraprofessionals, and informal opinion leaders that figured so prominently in the agricultural extension model (Rogers 2003) and a corrective to the education community's overreliance on simple transmission or dissemination of information as a basis for lasting change (Hutchinson and Huberman 1993).

Cohen and Ball (1990) argued that a basis for rejection by teachers of packaged new practices and programs was their normative sense of themselves as autonomous professionals who were accustomed to applying their own expertise to customize content to best fit the exigencies of their students and classrooms. Logically, this high degree of agency by teachers made them co-creators of the original innovations, perhaps to the point of contributing the most critical aspects of the innovation if use is to be a key outcome. Critical studies such as these suggest the importance of implementation when organizations are the settings for learning about, trying, adopting, implementing, and sustaining innovations. Teachers were learners, teachers were researchers, and teachers taught researchers how to understand implementation (Hutchinson and Huberman 1993).

This user-centric perspective on what adopters did with innovations in their everyday practice represented a reconceptualization of the meaning of diffusion and scale. Whereas a source perspective on spread leads to conceptualizing diffusion and scale as the number of adopters and the number of settings such as schools or districts that adopt a philosophy, program, or practice, a user perspective leads to a focus on the depth achieved in each adopting site, i.e., the quality of implementation and sustained use rather than the quantity of adopting units (Coburn 2003).

This implementation emphasis in educational scale-up characterizes much current educational research that is classroom based, focused on what teachers and students actually do with and contribute to innovations, and often conducted through anthropological qualitative observation (Fullan 1991). It is an approach to scale that is decentralized and interactive and inductively based in experience (Bodilly et al. 2004). We suggest that, even when the educational innovation in question is not intended for classroom use, the same insights about the importance of what users do with innovations in practice and, as a precondition, the elaboration or "scaffolding" that designers include for the benefit of practitioners are key to effective diffusion and scale-up (Cohen and Ball 2007).

Modern Concepts of Scale and Diffusion

This collective experience by researchers and faculty about how to spread and utilize knowledge helped to form a basis for the Synergy Collaboratory. While no easy answers are available for the challenges of scale-up and diffusion, nevertheless,

certain principles and concepts can guide research and practice about the scale and diffusion of educational innovations (Baker 2007; Pellegrino 2007). To what concepts were ATE center principal investigators and staff exposed in repeated group meetings? What strategies were they expected to master through a series of presentations, workgroups, and planning sessions and then adapt to their own projects through teamwork, conference calls, one-on-one consultations, and report backs?

Two interrelated sets of processes were introduced to participants. One set is Dede's framework for designing successful educational innovations that can scale, which builds on a foundational framework by Coburn (2003). This scaling framework includes five concepts (Dede 2006; Clarke and Dede 2009):

- *Depth* concerns the quality or effectiveness of the innovation. An educational innovation has depth to the extent that its implementation and use lead to changes that are desired by the innovation designer.
- *Sustainability* concerns the extent to which the innovation is maintained in ongoing use. An educational innovation is sustained if those persons who implemented the innovation continue to use it.
- *Spread* is the extent to which large numbers of people or organizations adopt an innovation. Spread is the sum of each adoption decision, which can be measured by adopters trying an educational innovation, going through training or licensing it, or buying it.
- *Shift* is a decentralization of ownership over the creation of an innovation. Adopters, through adaptation behavior, can significantly change an innovation or come to share in representing it to other, later potential adopters.
- *Evolution* concerns learning from adopters by the original creators of an innovation. When creators change their own practice or work as a result of others' good ideas, they evolve.

A second set of concepts comes from diffusion of innovation theory as articulated by Rogers (2003) and then Dearing (2008, 2009) and with his colleagues (Dearing et al. 2006; Dearing and Kreuter 2010; Scheirer and Dearing 2011; Dearing and Kee 2012). Participants were taught these diffusion concepts:

- *Opinion leadership* is the extent to which an individual regularly influences the thoughts and actions of others. Opinion leadership is an informal trait, commonly contrasted with positional authority, and can be assessed through sociometric analysis.
- *Guided adaptation* is advice provided to implementers of an innovation so that their changes to a program or practice can demonstrate positive rather than negative outcomes.
- *Effectiveness* is the degree to which an innovation works regularly in the ways desired by its creators. Data about effectiveness is commonly considered evidence of effect.
- *Compatibility* is the extent to which an innovation fits with the norms, beliefs, and past practices that characterize those persons who adopt it. Innovations higher in perceived compatibility spread faster than innovations that are not very compatible.

- *Simplicity* is the extent to which an innovation is easy to understand and use. The more complex an innovation is perceived, the lower the likelihood that it will diffuse.
- *Cost* is the perception by potential adopters concerning an innovation's resource requirements. Innovations perceived to be higher cost – most commonly in time or money – spread more slowly.
- *Trialability* is the extent to which an innovation can be tried incrementally or without a loss of resources. Diffusion is more likely of trialable innovations.
- *Observability* is the extent to which the results of using an innovation are visible. Frequently, seeing is believing for individuals who are weighing the pros and cons of an innovation.

Because they derive from different streams of research, the concepts about scale and diffusion are not mutually exclusive. Rather, they overlap, reinforce, and sometimes in practice contradict one another.

Projects Within Synergy Centers as Opportunities for Scale and Diffusion

Each ATE center involved in Synergy is organized around a variety of projects. ATE centers create training programs, internship programs, revise curricula for technology classes, and host career days and expos that bring area employers into discussions with students. Center leaders and staff members create and demonstrate new ways of reaching out to high schools, unemployed residents who need skills retraining, and minority students who are at high risk of dropping out of science, engineering, and technology classes and academic majors. The centers play roles in supporting the matriculation potential and plans of community college students for transfer to 4-year colleges. Each of these functions can take the form of a distinct project that is tried, refined, and tried again by ATE center staff. For projects that work well, center staff may seek to scale up or diffuse the project so that it can benefit more people in their catchment area or to reach people in other catchment areas through institutional partnerships or to convince leaders and staff at other colleges to adopt the project and implement it themselves.

Methods

Early in the Synergy effort, participating ATE center leaders and staff were encouraged to select one of their projects to which they would apply and test the ideas about scaling up and diffusion of innovations that they had learned (Table 5.1). Working in teams, participants used logic models (Kellogg Foundation 2004) to identify and logically link together the objectives of their chosen project to specific

activities, objectives, intermediate outcomes, and more distal outcomes. In most instances, this process of specifying a logic model helped center personnel to better understand their project, to see how certain activities were supposed to relate to other activities, and to identify planned activities that did not build toward project objectives.

We selected 3 of the 13 Synergy projects for data collection and analysis based on their degree of active involvement with applying the concepts and strategies of this initiative. The three projects selected were not chosen because of their success, although each did experience success; they were selected because through participation, members of those community college centers gained confidence in understanding the concepts, saw ways that they could try them, and did so repeatedly.

We conducted case study research about the use of diffusion and scale-up concepts in the three projects at the host community colleges. Case studies are advantageous methods for organizing data when the object of the study – the *case* – is difficult to disentangle from its organizational context. We define projects housed within centers as our cases; each case is embedded within its ATE center. As is common with education research based on case studies (Stake 1995; Yin 2014), we relied on multi-method data collection, including repeated semi-structured in-person and telephone-based interviews with project leaders and staff, in-person discussions, document reviews, and reports and presentations by ATE center faculty and staff.

Results

Case 1: Bridge to Biotech in California

The City College of San Francisco had long recognized the problem of poorly prepared and disadvantaged students dropping out of the sciences. Many would begin, but very few would complete their science coursework. The language, symbols, principles, and concepts of biology and chemistry seemed esoteric and far removed from their daily lives. Many did not have consistent backgrounds in being students, with underdeveloped study habits, individualized and often marginalized learning, and poor grades. In response to these challenges, and with a hope that the booming biotechnology industry in the Bay Area might employ some of these students, City College initiated biotech certificates in 1991 to help students. But by 2002, the faculty realized that the majority of at-risk students were still dropping out.

That's when the faculty, with administrative support, started the Bridge, revamping and integrating the content of the introductory courses. The Bridge to Biotech is a project of Bio-Link, a National ATE Center for Biotechnology, directed by Elaine Johnson and administratively based at the City College of San Francisco. The Bridge is an intensive semester-long experience consisting of three linked for-credit simultaneous courses in introductory science (the content of which includes biology and chemistry), math, and English. The project targets underprepared,

economically disadvantaged, and minority students to increase their enrollment in the sciences, supports their continued progress, retains them in community college science courses, and moves them toward certificates, associates of science degrees, and or transfer to 4-year colleges. The introductory science, math, and English courses that comprise the Bridge are taught in contextualized fashion; that is, the same biotechnology topics and problems are introduced and worked by teams of students in all three courses so that students come to appreciate the interdisciplinary nature of biotech work.

Cohorts of 25 students enter and progress through the Bridge together as teammates. Instructors organize the courses as team-based, inquiry-based, and problem-based learning experiences for students. A fourth course, the Bridge to Biotech internship preparation course, for internships in biotechnology companies and research laboratories, is a popular capstone. Students complete the Bridge with a 13-credit Laboratory Assistant Certificate.

The Bio-Link National ATE Center of Excellence for Biotechnology recognized the value of the Bridge to Biotechnology as one project worthy of supporting and expanding to other colleges.

Although the Bridge has proven popular and successful for (in particular, at-risk students) and has provided a pipeline for local companies to find and hire employees, it also has been controversial with some faculty. The popularity of the internship and the fact that it can transition students directly into the workforce means that some students chose work over further education. Will they return later to complete their degree? The Bridge may be more effective in sending students to work rather than to degree completion and 4-year universities. Still, according to students themselves, the Bridge has helped them. Moreover, it has done so successively, with cohort after cohort, moving students toward jobs and degrees.

Scaling and Diffusing the Bridge to Biotech

The Bridge to Biotech became a Synergy program in 2008. Becoming a Synergy program meant that Bridge personnel began attending briefings and participating in active learning workshops to understand the perspectives, concepts, and methods of scale and diffusion. Then they would apply them to the Bridge.

While Elaine Johnson had been part of the development of the Bridge, multiple faculty members are involved in teaching the linked courses and in working to develop and refine the program. Laurence Clement, a City College faculty member, oversees the internship and is the project leader for applying Synergy concepts to the Bridge. Laurence and Elaine work closely with John Carrese, the Innovation Coach for applying Synergy concepts to the Bridge. John also directs the San Francisco Bay Center of Excellence at City College, which provides a further conduit to the regional business community.

The scaling and diffusion presentations and discussions during Synergy meetings introduced many concepts. Which Synergy concepts have been applied to the Bridge

program? How did Bridge personnel approach the challenge of scaling or diffusing the Bridge?

- Laurence, John, and Elaine recognized that the national network Bio-Link was not just a means for faculty to communicate among themselves; it could also function as a *distribution system* for diffusing an innovation such as the Bridge. Bio-Link could be the mechanism by which the Bridge would replicate from campus to campus, as various faculty involved in biotech education across the nation learned about it, inquired with questions, attended information sessions or trainings, and then tried the Bridge on their own campuses. Identifying a means by which an innovation can move from place to place is an important step in a diffusion strategy. Ideally, such a mechanism already links potential adopters together and is an actively used means of communication and learning through which the types of people who logically might adopt such an innovation already participate. Bio-Link fulfilled this condition.
- "Initially, we felt it was our model and that others should adopt it," said Laurence. "It's our curriculum, we put it together, here it is, 'take it, or leave it.' Then we went to the San Francisco Synergy meeting and it just hit us. Adaptation was okay! Adaptation by others would help to spread the model. They had to do the key things but we could change our message," said Laurence. This is an application of the scale concept of *shift*, in which potential adopters are encouraged to add to or customize an innovation so that it is made more compatible with their own context. Encouraging shift can make adopters feel that the innovation is really theirs. Encouraging shift or a broadening of ownership also ensures that adopters will implement versions of the innovation that are highly *compatible* with their community colleges, their courses, and their students; in the scale framework, this is the concept of *sustainability*.

In this case, applying the concepts of shift and sustainability to achieve the ideal of a compatible innovation has been critical to achieving a broadening of interest in the Bridge. "We do this in our Summer Fellows Forum," said John. "We're bringing in people from five colleges this summer. Every summer we'll add five more. Our hope is that the first cohort will mentor the next cohort, etc. So shift will occur just as a result of others training and helping. That'll make the program compatible. We won't have to be so strict about things, but there will be quality control."

- One of the difficult lessons for innovators to learn is that the best innovation you can create isn't necessarily the best innovation to scale or diffuse. Indeed, the creators of innovations such as new pedagogies – especially if they are research-oriented faculty – frequently test, retest, tweak, retest, and customize their innovations so that they are maximally effective, a development process which can also make an innovation too expensive, too complex, and too specialized for most potential adopters. "We talk a lot about avoiding the *trap of perfection*, another concept related to scale. We weren't thinking this way prior to Synergy," said John. "But now we are." An innovation that's only "good enough" can be

better for scale and diffusion than a technically superior (i.e., more effective) innovation.

- Bridge leaders and staff have had many meetings about the Summer Fellows program, which is held on the UC Berkeley campus. "One of the big challenges has been to try to simplify how we present and describe the Bridge," said Laurence. "We can easily overload them. We can't describe every little detail about what we've tried and learned and all the mistakes we've made and how we've revised it. We have done all these things but it's too much to present and we will just confuse them." Laurence, Elaine, and John all talked about the importance of simplifying the Bridge and how they describe it. This is the concept of *spread* in the scale framework.

Complexity is, in a sense, the enemy. Of course some innovations are extremely complex, but complexity can be shielded when an innovation is explained to potential adopters so that they will become interested enough to want to understand the details. The masking of the complexity of an innovation demonstrates an appreciation of this concept and also reflects use of the diffusion concept of trialiability. What potential adopters need to know about an innovation is different from all that they could know about it. "It's hard to simplify the story we tell," said Laurence. "I'm better at it now but it's still hard."

- At the June 2010 Synergy meeting in San Francisco, Laurence and John realized that they could identify *opinion leading* faculty and deans from other community colleges and invite them to the Summer Fellows training so that these opinion leaders would in turn interact with faculty and deans from other colleges. This would spread the Bridge by word of mouth. Laurence and John talked about purposively seeking out influential faculty so that others would naturally become interested. Laurence and John also realized immediately that Elaine, by virtue of her extensive work and social networks, was already applying criteria of opinion leadership when she talked about the Bridge to Biotech and when she decided whom to meet and who to invite. Indeed, her structuring of the Bio-Link network was an application of opinion leadership; it was the basis for building the regional hubs of colleges. Now that the Summer Fellows training is including colleges from outside Bio-Link, Laurence and John realize that sociometric identification of influence can be applied outside as well as inside the network (Dearing et al. 2006).
- "We're really into evolution, learning from those who've adopted," said John. "We're thinking about how better to organize our toolkit, incorporating more interactive online tools, in order to gather valuable knowledge and insights from our adopters about how our model has been adapted to their circumstances." *Evolution* is the concept from the scaling framework that the original creators of an innovation have much to learn from subsequent adopters who may productively adapt, update, and improve the innovation. "We've got people coming onboard at other colleges who have the energy to develop new content for classrooms and that's really great. Some of those things we'll be able to use here, too. And I'm beginning to think about scale applications in my other center."

Overall, Bridge to Biotech has applied many concepts/processes for scale and diffusion. "Our larger team of six or seven people across the nation combined with those of us here is critical in reminding ourselves of these ideas," said John. "We have these discussions and find ourselves saying things like "Hey, that's depth! Or, "that's too much depth; that's the trap of perfection! We really say these things. And we have critical discussions about trade-offs. Depth versus shift: Too much of one can decrease the other. These are concepts we really use, scale and spread. And here's where we're going: We have these 60 community college biotech programs in Bio-Link. What if we communicated the Bridge to all of their contacts?"

Case 2: Technology Gateway in South Carolina

The Technology Gateway is a project of SC ATE, the South Carolina Advanced Technological Education Center of Excellence, directed by Elaine Craft at Florence-Darlington Technical College in Florence, South Carolina. SC ATE funding from NSF began in 1994; NSF designated SC ATE as a center of excellence in 1996; in 2000, SC ATE broadened its mission from engineering technology programs to the improvement of technician education across multiple disciplines; and in 2002, SC ATE became an NSF National Resource Center.

The Technology Gateway began in 1996. Its purpose is to expand the supply of well-trained technicians in South Carolina by helping more students enter and succeed in engineering technology courses and programs. The Gateway is designed to improve mathematics skills in the context of solving industry-style problems and has an emphasis on increasing participation of female and minority students, as well as enhancing the involvement of industry in community college technical programs. The Gateway was originally a "ramp-on" preparatory course to an associates' degree in engineering technology (ET) for underprepared students who often otherwise drop out of technical associates' degree programs.

In South Carolina, ET graduation rates were low, and most graduates were White males. Science, technology, engineering, and math instructors didn't share, let alone coordinate their course content. Students were getting lost at the less-involving, general education beginning of the math to physics to engineering and technology continuum. At first, SC ATE staff and campus instructors restructured a core curriculum sequence that required four instructors to work together across disciplines to make learning relevant. The core sequence lasted three semesters over the students' first year. The model achieved the desired result: Retention, diversity, and student success increased significantly.

Yet, a restructured first year of study in ET was not enough. Too few students were entering the college with the necessary prerequisite skills and knowledge to be placed in an ET curriculum. Underprepared students were being enrolled in traditional developmental studies or prerequisite courses, getting lost in the seemingly irrelevant courses, and dropping out. These results led SC ATE staff to create three linked, preparatory first semester courses, the Technology Gateway, to better

prepare students to enter and be successful in the first year ET core sequence. The Gateway was cross-listed as English 104, Math 104, and Engineering 104.

As with many innovations, unintended consequences occurred. The nondegree credit Gateway course, it turns out, has had more support on the Florence campus and has been more widely adopted/adapted than the core sequence for which it was created as a supplement. It has "taken on a life of its own," said Elaine, and been adopted by other campuses, where the core course sequence innovation has not. The Gateway is organized around cross-discipline scenarios that require the acquisition and application of knowledge in mathematics, science/technology, and communications (i.e., problem-based learning); has students working in long-running teams; is offered in spaces that more resemble workplaces than classrooms; and is taught by instructors who come to the teams' "workplaces" rather than having the students move among classrooms. As in a real workplace, all problems have multiple possible solutions; student teams present their solutions to the entire class and are expected to demonstrate why their solution is best.

Since the Gateway doesn't alter courses in a degree curriculum, faculty and curriculum committees perceive less threat from it. It has an added advantage in that nondegree credit courses can be taught by differently trained instructors or even by a single instructor. The scenario problems all involve math and have communication, science, and technology aspects to them. Now the SC ATE staff is spinning off the Gateway. "We're just learning how to un-tether this curriculum jewel from our SC ATE nest so that it can strengthen its wings, grow new feathers, and fly to places we never conceived when we first developed it many years ago," said Elaine.

Scaling and Diffusing the Technology Gateway

SC ATE was a mature ATE center and had years of experience with developing innovations and growing them as well as a leader in Elaine Craft with strong relationships built up over the course of her career. For SC ATE, being involved in Synergy and learning about scale and diffusion concepts was not exactly new. It was, however, reaffirming, and involvement helped the team understand why strict fidelity implementation of a model can work against diffusion of an innovation and prevent effective scale-up. So which concepts have Elaine and her team of coinvestigator Joshua Phiri and project manager Tressa Gardner tried?

- "We sponsored a Roots & Wings Instructional Leadership Institute as a finale to our ownership of the Gateway," said Elaine. "We knew we had a powerful model – it really worked. We had the data. Students benefitted, and others in North Carolina and Georgia and even in Massachusetts were using it and having success themselves. We entered the Synergy project still preaching the gospel, looking for more disciples. We wanted everyone to do what we were doing. We were afraid that if they didn't, the same positive outcomes would not occur. That's when this whole Synergy thing really changed our thinking. Things just

opened up. We were approached about implementing the Gateway as a drop-out prevention strategy in high schools. We said 'well, why not?' And, you know? It worked! Instead of thinking of faculty at other colleges as followers, we started listening to them, and did they have ideas! Smart ideas. The model of the Gateway evolved right then because we realized these other people were our lifeline for scaling up this innovation. They were energetic. They were smart. They weren't satisfied just to learn from us. For them, that was a starting point. It wasn't an ending. It was a beginning! So they became co-leaders with us in the Technology Gateway model." Learning to give away or share control over an innovation – a *shift* toward co-ownership – can bring fresh ideas to an innovation and help to make it more robust.

- The more people who are allowed not only to implement an innovation but also to contribute to its evolving nature, the more likely that the result will be effective in a variety of user contexts because of heightened *compatibility*. "We came to realize that we could emphasize the core concepts and not insist on everything. Then it could have a new life," said Joshua. "A group in Wyoming wrote to us and said 'We want to lead a workshop based on your model and we want you to come and join us as experts.' Well, we thought, why not? They have changed some things with the Gateway but, you know, our original model wasn't perfect anyway. We've had stops and starts on our own campus. So why wouldn't we think that another group might do just as well as us in making things work on their campus?"
- "A big reason why the single Gateway course has become more popular than the three course sequence is cost," said Joshua. *Cost* has long been appreciated as a critical attribute of innovations and can explain a lot of variance in adoption decisions. High cost usually equals low diffusion. Cost is measured in terms of money but also in terms of resources such as time. "If you want something to spread or be used, you've got to be low-cost," said Joshua. "This is a business mentality but it applies to community colleges. I mean, why did we ever expect three courses all redesigned with coordination among faculty in different fields to work? It was very costly in terms of time and in terms of money. The faculty, they liked it, but they had to meet together several times every week to plan things. Pretty soon they wanted a course release in order to do it right. That's three course releases per year since it's three faculty. What dean is going to do that in a time of cost-cutting? There's no way. Our associate vice-president told us it couldn't be sustained. Not even on our own campus. The Synergy conferences combined with our own Roots & Wings event made us relax the structure of the three courses, and just focus on the learning objectives and the content. At the Albuquerque Synergy meeting we asked ourselves, 'Could we do this all with a single instructor? Why not?' That would dramatically decrease the cost of the program." Reducing cost is part of the *spread* dimension in the scale framework.
- The concepts of effectiveness and depth are about the same. *Effectiveness* means that your innovation achieves its objectives under real-world circumstances.

Depth means that the strength of the innovation is powerful, that as a result of experiencing a program, participants learn what they are supposed to learn or do what the program developers expect them to do. "One of the great things about inviting others in to help us grow the Gateway is that they've done things like put in the hours to create new teaching scenarios. Ours were really old. We had one about VCRs! Students didn't even know what a VCR was. Having new scenarios makes the Gateway materials a lot better. Students can relate to them. They get interested because it's real to them. That's being more effective," said Joshua. Elaine agrees and says, "Developing new synergistic partnerships is also part of being more effective. SC ATE now works with other project-based learning-focused projects to engage and develop more faculty in the use of this teaching methodology. So, while we have a shared vision with our new partners, we take different approaches to implementation. Now we get that our differences are our strengths in scaling. We're not competitors; we're co-leaders in reform of technician education."

- One of the results of the curricular reform process that the SC ATE staff has led and worked through on their own campus has been a streamlining of the model. A complex three-course yearlong reformed curriculum that required coordination and frequent meetings among several instructors has been collapsed into a single course with a single instructor. And while the Gateway course is not a substitute for the more intensive three-course core sequence, the longer sequence was not sustainable. It was too complex, too costly, and was not compatible with departmental and college faculty scheduling, curricular standards, and policies. It generated political opposition on campus as department heads struggled with space allocation and scarce faculty resources. Not so with the pared down Gateway course. It was nondegree credit and thus nonthreatening to degree programs. It prepared many underprepared students so that they could see the relevance of math, communication, and science to their lives and careers and do well in those courses. *Simpler* solutions can be the best solution, as emphasized in the *spread* dimension of the scale framework.

The Technology Gateway is being replicated. The SC ATE staff is working with high schools and community and technical colleges to introduce the Gateway to women and students who are at risk of dropping out of school. Co-leaders are now building new curricula with Gateway-style project-based learning as the starting point, not as an add-on. Schools in several states are using the Gateway, and other schools have sent representatives to attend training events to learn about the model, what it does for students, and how it works in practice. And faculty members at a few colleges are taking on leadership positions themselves with the Gateway. For example, in Massachusetts, the Benjamin Franklin Institute of Technology has offered Gateway train-the-trainer workshops, assisted by SC ATE staff, for attendees from Pennsylvania, Massachusetts, and South Carolina.

Case 3: Pressure Sensors in New Mexico

The Pressure Sensor Workshop is a project of the Southwest Center for Microsystems Education (SCME), housed in the University of New Mexico's Manufacturing Training and Technology Center in Albuquerque, New Mexico. This ATE Regional Center of Excellence is led by Matthias (Matt) Pleil, Research Associate Professor of Mechanical Engineering with the University of New Mexico and Principal Investigator (PI) for the SCME grant. In early 2010, Matt contracted with James (Jim) Hyder to serve as SCME's Innovation Coach. Between the two, they have over 25 years of semiconductor/microelectromechanical systems (MEMS) manufacturing experience.

SCME has a goal of facilitating the production of more technicians for research, development, and production of MEMS. These extremely small systems enhance very popular consumer devices, including Apple's iPad and other 3G tablets, as well as the general cell phone market. In recent years, sales of devices that rely on MEMS have increased about 25 % per year. MEMS are also used in gaming devices, remote controls, and cameras as well as biomedical and chemical sensor applications; in fact, the BioMEMS market is almost doubling every year and is the fastest growing MEMS segment.

SCME produces educational materials for instructors and students, sponsors workshops, offers laboratory and fabrication experiences, and provides instructional kits that bring the fabrication concepts and experiences to the classroom. To date, the lack of a standardized and readily available microsystems curriculum, as well as limited understanding of both the general public and educator populations, has hampered secondary and postsecondary education and, thus, the supply of a well-trained workforce. By asking industry representatives to serve on advisory boards and on a National Visiting Committee for the center, the ATE center has worked closely with regional businesses to improve educational material design and market penetration for its dozens of learning modules and classroom teaching kits. Also, having both the innovation coach and principal investigator coming from semiconductor manufacturing provides a strong understanding of these related hi-tech industries and what successful technicians need as knowledge and skills.

The Pressure Sensor Workshop is one of SCME's primary educational offerings. It is a group-based training meant to illustrate microsystems wafer manufacturing and associated STEM concepts. The Workshop includes information as to how a pressure sensor is made and functions and how it can be simulated for teaching and learning purposes. This is done in the classroom by the use of a pressure sensor macro-model, consisting of a small paint can with a balloon membrane and piezo-resistive Wheatstone bridge circuit applied. This graphene and rubber cement-based layout is connected to an external battery and volt meter to complete the circuit. This MEMS model can be built and used with high school and community college students to teach them basic sensor transduction concepts. There are several additional kits and modules covered in this 4-day workshop related to MEMS fabrica-

tion, including crystallography, etching, liftoff, and even one based on a MEMS film *Making Micro Machines*.

Most participants in the Pressure Sensor Workshop are electronics, chemistry, science, technology, and engineering instructors. Prior to Synergy, the Workshop consisted of a 3-day pressure sensor fabrication experience followed by 1 day of *demonstrations* of the kit designed to bring micro-concepts into the classroom from a macro-perspective (i.e., after building a pressure sensor at the microlevel, participants build a macro-level paint can model). According to limited survey responses, only 15 % of participants utilized Workshop materials in their classroom.

SCME's goal is to enhance the capability of emerging technology to produce technicians for research and the production of hi-tech products. Matt says, "This has been part of SCME's mantra even prior to Synergy – we have designed our materials in a modular format and encourage users to use what makes sense for their situation." SCME not only produces educational materials but disseminates them to secondary and postsecondary educators. In order to spread these materials to other institutions, SCME decided to create an innovation that would formalize a training methodology to achieve three outputs: (1) train the educators so they can better utilize the materials (referred to as Sharable Content Objectives), (2) support educators in their efforts to better educate their students, and (3) provide a vehicle for educators to scale, shift, and evolve SCME's materials via train-the-trainer sessions. Increasing the utilization of these materials and contents became the focus of SCME's Synergy effort.

The innovation that SCME decided to scale was the application of "lean" manufacturing methods that focus on "leaning educational experiences" to eliminate what SCME's Innovation Coach considers "educational waste." Based loosely upon the application of the Training Within Industry method called "Job Instruction" (a precursor to lean manufacturing concepts) and through numerous small improvements, SCME has improved the dissemination and utilization of their materials and educational offerings. This approach is based on the Toyota Production System.

The Pressure Sensor Workshop has been redesigned through the integration of lean concepts. By eliminating primarily "waiting waste," the fabrication experience was reduced down to a 2-day offering without negatively impacting the learning outcomes. This allowed the saved time (a whole day) to be redistributed to focus not only on demonstrating the kits but also on ensuring participants built the kits themselves and left with a higher degree of confidence to use the kits in their classrooms. Most STEM instructors have not had formal training in lean, yet lean has become so ubiquitous in MEMS production that it is a critical perspective and skill set for instructors to communicate to students. Although not a specific goal in the Workshop, introducing lean concepts has become a serendipitous learning outcome for participants.

Scaling and Diffusing the Pressure Sensor Workshop

Which scale and diffusion concepts have staff involved in the Pressure Sensor Workshop tried to apply, and how have they tried to use these concepts?

- Scaling, the use of common scaling vocabulary, and using dimensions of scale to measure the degree of scaling are evident at SCME. Each time Matt and Jim discuss their offerings being utilized by past participants, they try to determine to what degree it might *shift* or *evolve*. The College of Science at North Dakota State is an example. Although SCME never intended to transfer the whole workshop at the outset of the grant, North Dakota State is adopting the workshop as is. North Dakota State faculty may still adapt the workshop, and SCME staff look to learn from what is done and observed at North Dakota State.
- Involvement in Synergy meetings and working sessions led Matt and Jim to redesign the activities of participants in the Pressure Sensor Workshop. Prior to Synergy, attendees were mostly passive learners who observed. Since Synergy, attendees are hands-on participants, demonstrating ability to use Workshop materials. Practice builds confidence that they can implement the workshop back home. Greater participation was planned by Matt and Jim as a trialability strategy. *Trialability* is the extent to which potential adopters of an innovation can experiment with the innovation either a little at a time or without incurring a loss of resources. Matt said, "We saw that some participants didn't use the materials. They didn't think they could." Matt and Jim reasoned that Workshop participants would be much more likely to use the ideas and kits that were introduced to them if they could try them. This way, participants would be more likely to think through the challenges and solutions of applying this new content in their own courses. They would also have experience of building and using the kits themselves which they would also have to do later on. "Active learning was such a key," said Jim. "Even though our sample size is still small, through my contacts with past participants since the redesign, I know that the majority of them are using the Workshop content. This is a big change pre-Synergy."
- Anticipating the probability that adopters will not just use but very frequently *adapt* an innovation so that one can actively guide and shape adaptation decisions is positively related to diffusion. "We've had a teacher take our can and balloon simulation and try it with Tupperware. Although we are exploring if we want to adopt this (thus evolving our offering), it absolutely was a shift that works well enough for his classroom demonstrations. We try to stay open to what they want to do, knowing that if they get some skin in the game they're more likely to use the concepts. And we are more likely to evolve and continuously improve our products, too," said Matt.
- Workshop staff are exploring the extent to which reach and depth must be trade-offs. *Reach* is the extent to which you can communicate about an innovation to a large number of potential adopters. *Depth* means that the strength of the innovation is powerful; as a result of experiencing a program, participants learn what they are supposed to learn. SCME is a niche group since MEMS does not have the same market pull (population of potential adopters) as other technical education. "We discuss this trade-off. It's so key to what we're about: Helping the most people we reasonably can, but needing to do so in a quality manner that ensures the most depth too. It's the same mindset we brought to the workshop redesign; we look at things through the lens of reach and depth, not reach or

depth, in our value propositions," said Jim. He surmises that, if they can successfully involve other instructors in becoming leaders themselves of pressure sensor and related workshops, reach can be attained and depth retained. Matt added, "I prefer to help a few really good adopters – they in turn can help more. We want to have a cadre of folks educated in MEMS and leveraging our materials to impact an increasing number of students ultimately resulting in an adequate number of skilled and knowledgeable technologists in the workforce."

- "We interlock scale concepts with diffusion concepts and tie both to the content of the Pressure Sensor Workshop," said Jim. Rather than pursuing one concept now and other concepts later, Jim takes a more holistic perspective on scale and diffusion. "They affect each other. Cost affects effectiveness, for example. And it's not always a negative trade-off. Making something like a workshop more *observable* can make it more *trialable*. That's a win-win. We haven't been doing this very long yet, but it's the thinking through of consequences that we try to do. 'If we maximize this how will it affect that?'" Matt said, "One example is that, when we started the Pressure Sensor Workshops several years back, it was mostly about the cleanroom experience. Half of the time was spent on preparing the participants for what they will experience in the cleanroom, and the other half they were actually in the cleanroom. So much of the cleanroom time was spent waiting around. As we added our kits to our portfolio, we squeezed these into the same experience, cutting some of the lecture materials to make time. Most of the earlier sessions were show & tell. Now, having Synergy as a catalyst, we have progressed to having a well-honed system, leaner processes, more time for hands-on – and we are seeing a higher implementation rate."

The Southwest Center for Microsystems Education is a good example of how readily staff with less background in scaling or spreading educational innovations can nevertheless learn about concepts and try to apply them in practice.

Insights from Trying Out Concepts of Scale and Diffusion

We have presented an account of how leaders and staff members at three centers at US community colleges have experimented with the use of concepts that they were exposed to as participants in the Synergy Collaboratory, a participative learning experience involving 13 ATE projects funded by the National Science Foundation. The three ATE centers studied here are (1) Bio-Link, a National Advanced Technological Education Center for Biotechnology, (2) the South Carolina Advanced Technological Education Center of Excellence, and (3) the Southwest Center for Microsystems Education.

The three project teams portrayed in this chapter did not hesitate to try using concepts of scale and diffusion. This may be due in part to the experience that certain of the team members brought to the Synergy Collaboratory; they'd tried some of this before. But clearly it was not necessary for much time to pass before

these teams applied these concepts to improving, mapping, defining, and planning for scale-up and spread. What are common themes across the three cases?

As these cases document, concepts and strategies are being used so that potential adopters – primarily other faculty – can feel engaged and invested in these educational innovations (shift, compatibility, adaptation). Engagement accomplishes a couple of important objectives. First, it increases the likelihood that an innovation will best suit a new context such as another community college. Second, it leads the adopting faculty to feel that the innovation is at least partly theirs. The shifting of ownership, the making of an innovation as more compatible, and the encouragement of appropriate adaptations so that the best fit between the innovation and its new organizational context is achieved are prominent in what leaders and particularly staff members have done in these three cases.

Center personnel exhibit sophistication in realizing that adaptation, shift, and compatibility can go too far. Changes to an innovation ought not harm the achievement of beneficial outcomes. In these cases of concept use, center personnel see depth and effectiveness as the flip sides of adaptation, shift, and compatibility. Staff actively discuss with each other the inherent trade-offs between encouraging spread, on the one hand, and encouraging fidelity and quality, on the other. Our interviews showed staff at all three centers having learned that just aiming for high fidelity and high quality runs the risk of falling into the trap of perfecting an innovation, which in turn limits diffusion potential.

Center personnel readily discussed the issue of cost and how they had tried to lower the cost of use by making their innovations easier to use, require fewer resources, and need less deviation from current practices in community colleges, where resources are usually constrained. Emphasizing benefit while reducing costs of use is a means for improving the odds that one can increase the numbers of potential adopters reached who will then give an innovation a try.

Personnel at two of the three centers were strategizing about reaching potential adopters by first identifying informal opinion leaders who could then influence others to pay attention to innovations. Leaders and staff members talked about influential persons as constituting a distribution system with built-in reach and the ability to draw others' attention.

Both leaders and staff members described ways in which they are trying to learn from their innovation adopters at other colleges. Whereas center personnel began their participation in the Synergy Collaboratory thinking that they had a very good innovation that others should hear about and adopt for themselves, they have moved to an appreciation of the contribution that faculty at other campuses can make: evolving second- and third-generation versions of their innovations that are most robust and more applicable in a diversity of organizational settings.

Have these teams added value to the concepts to which they were introduced? If adding value means tailoring and exploring scale and diffusion concepts for their applicability and utility to the real problems of Synergy centers – a form of validity testing – then these teams have brought value to concepts through their practical exploration of how they could use the concepts of scale and diffusion. The value added in these experiences is not only in the teams' learning for themselves how to

make an innovation more compatible or simpler or less costly, etc.; value may also accrue to the theoreticians and researchers who advocate the use of these concepts if they pay attention to which concepts are of utility to practitioners and which are not.

Lessons Learned

ATE center teams involved in the Synergy Collaboratory have invested considerable time in learning the concepts of scale-up and diffusion of innovations. They began as listeners and progressed, sometimes with prodding, into active learners who then began to implement the concepts.

Part of what concepts such as depth and effectiveness require if one is to use them is critical thinking, trial and error, and reflection. The Bridge to Biotech, Technology Gateway, and Pressure Sensor Workshop team members went forward with stops and starts. In each case, they appear to have made decisions about scale and diffusion based on their real-time analyses of what was working and what was not, and they adjusted developmental courses accordingly. In each case, it appears that team members stayed the course; they didn't quit or lose interest or become disenchanted. They did jerry rig, streamline, and, when confronted with seemingly insurmountable obstacles, broaden the scope of the stakeholders attached to their project as a means of bringing in fresh ideas and new resources.

Team members regularly use and have a working understanding of the terminology of scale and diffusion. They are now conversant in this language, bolstered by their own more recent experiences of trying to use the concepts in guiding their work. Application has emboldened them to be critical about the concepts and have opinions about where the concepts are helpful and where they are not.

Would these project teams have done some of these same things and learned some of the same lessons without the Synergy Collaboratory? No doubt, yes. Yet it almost certainly would have taken them longer, with more stops and fewer starts. They would not have learned as much because there would not have been a central organizing team that was focusing their attention, bringing them together, and stimulating scholarly reflection. Ultimately, and in keeping with the idea of a collaboratory, it is the network of teams from all 13 ATE centers –whether funded as a collective or not – that will have to keep this conversation alive if their rate of sharing, learning, and course corrections is to maintain.

Generalizing This Model for Scale and Diffusion

The findings from these case studies and from the Synergy experience overall are consistent with other scale and diffusion work. In several innovations implemented in the Milwaukee Public Schools (Dede and Nelson 2005), technology provided

valuable leverage for increasing *depth* and *spread*, parallel to the strategies used by the Synergy centers. In work with eight innovative K-12 educational projects funded by Microsoft to achieve scale (Dede et al. 2007), technology was also valuable in this respect. Moreover, the Microsoft project strategies used for *sustainability* and *shift* were similar to those used by Bio-Link, SCATE, and SCME as well as other centers in the Synergy Collaboratory.

Diffusion concepts of the attributes of innovations (Rogers 2003) including trialability, simplicity, cost, and compatibility were shown to be important to the faculty and staff we studied. This is consistent with much published literature about the factors responsible for diffusion. Clearly, too, these three cases demonstrate the importance of not only allowing for reinvention by later adopters and users but encouraging their responsible adaptation or reinvention (Dearing 2009) of innovations. We conclude that first-generation creators of these innovations learned a great deal from their second-generation implementers who found new and productive ways to adapt these three innovations so that they would be more compatible with new settings.

Overall, this provides some confidence that the findings from the Synergy experience are representative of what other educational groups may encounter in seeking to attain scale and diffusion. Even though their niche in the education sector and their innovations may be dissimilar from the discipline and other ATE centers, the same fundamental issues and dynamics apply. The one major difference with K-12 attempts to scale and diffuse may be higher barriers to innovation because of the increased oversight that rigid accountability measures impose, making change more difficult and time consuming.

References

Baker, E. L. (2007). Principles for scaling up: Choosing, measuring effects, and promoting the widespread use of educational innovation. In B. Schneider & S. K. McDonald (Eds.), *Scale-up in education: Ideas in principle* (Vol. I, pp. 37–54). Plymouth: Rowman & Littlefield.

Berman, P., & McLaughlin, M. (1978). *Federal programs supporting educational change* (Vol. 3). Santa Monica: Rand Corporation.

Birnbaum, R. (1991). *How colleges work: The cybernetics of academic organization and leadership*. San Francisco: Jossey-Bass.

Bodilly, S. J., Glennan, T. K., Kerr, K. A., & Galegher, J. R. (2004). Introduction: Framing the problem. In T. K. Glennan, S. J. Bodilly, J. R. Galegher, & K. A. Kerr (Eds.), *Expanding the research of education reforms: Perspectives from leaders in the scale-up of educational interventions* (pp. 1–39). Santa Monica: RAND Corporation.

Bransford, J. D., Brown, A. L., & Cocking, R. R. (Eds.). (2000). *How people learn: Brain, mind, experience, and school*. Washington, DC: National Research Council.

Carlson, R. O. (1965). *Adoption of educational innovations*. Eugene: University of Oregon, Center for the Advanced Study of Educational Administration.

Clarke, J., & Dede, C. (2009). Design for scalability: A case study of the River City curriculum. *Journal of Science Education and Technology, 18*(4), 353–365.

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

Cohen, D. K., & Ball, D. L. (1990). Relations between policy and practice: A commentary. *Educational Evaluation and Policy Analysis, 12*(3), 249–256.

Cohen, D. K., & Ball, D. L. (2007). Educational innovation and the problem of scale. In B. Schneider & S. K. McDonald (Eds.), *Scale-up in education: Ideas in principle* (Vol. I, pp. 19–36). Plymouth: Rowman & Littlefield.

Dearing, J. W. (2008). Evolution of dissemination and diffusion theory. *Journal of Public Health Management and Practice, 14*(2), 99–108.

Dearing, J. W. (2009). Applying diffusion of innovation theory to intervention development. *Research on Social Work Practice, 19*, 503–518.

Dearing, J. W., & Kee, K. F. (2012). Historical roots of dissemination and implementation science. In R. Brownson, G. Colditz, & E. Proctor (Eds.), *Dissemination and implementation research in health: Translating science to practice* (pp. 55–71). New York: Oxford University Press.

Dearing, J. W., & Kreuter, M. W. (2010). Designing for diffusion: How can we increase uptake of cancer communication innovations? *Patient Education and Counseling, 81S*, 100–110.

Dearing, J. W., Maibach, E., & Buller, D. (2006). A convergent diffusion and social marketing approach for disseminating proven approaches to physical activity promotion. *American Journal of Preventive Medicine, 31*(4S), S11–S23.

Dede, C. (2006). Scaling up: Evolving innovations beyond ideal settings to challenging contexts of practice. In R. K. Sawyer (Ed.), *Cambridge handbook of the learning sciences* (pp. 551–566). Cambridge, UK: Cambridge University Press.

Dede, C., & Nelson, R. (2005). Technology as proteus: Digital infrastructures that empower scaling up. In C. Dede, J. Honan, & L. Peters (Eds.), *Scaling up success: Lessons learned from technology-based educational improvement* (pp. 110–132). New York: Jossey-Bass.

Dede, C., Honan, J. P., & Peters, L. C. (2005). *Scaling up success: Lessons from technology-based educational improvement*. San Francisco: Jossey-Bass.

Dede, C., Rockman, S., & Knox, A. (2007). Lessons learned from studying how innovations can achieve scale. *Threshold, 5*(1), 4–10.

Dunn, W. N., & Holzner, B. (1988, Spring). Knowledge in society: Anatomy of an emergent field. *Knowledge in Society, 1*(1), 3–26.

Fullan, M. G. (1991). *The new meaning of educational change* (2nd ed.). New York: Teachers College Press.

Havelock, R. G. (1969). *Planning for innovation through dissemination and utilization of knowledge*. Ann Arbor: Institute for Social Research.

Hutchinson, J., & Huberman, M. (1993). *Knowledge dissemination and use in science and mathematics education: A literature review. NSF EHR/RED Report 93-75*. Arlington: U.S. National Science Foundation.

Ikenberry, S. O., & Friedman, R. C. (1972). *Beyond academic departments: The story of institutes and centers*. San Francisco: Jossey-Bass.

Kellogg Foundation. (2004). *W. K. Kellogg Foundation logic model development guide*. Battle Creek: Author.

Mort, P. R. (1953). Educational adaptability. *The School Executive, 71*, 1–23.

Pellegrino, J. W. (2007). From early reading to high school mathematics: Matching case studies of four educational innovations against principles for effective scale-up. In B. Schneider & S. K. McDonald (Eds.), *Scale-up in education: Issues in practice* (Vol. II, pp. 131–139). Plymouth: Rowman & Littlefield.

Rogers, E. M. (2003). *Diffusion of innovations* (5th ed.). New York: Free Press.

Scheirer, M. A., & Dearing, J. W. (2011). An agenda for research on the sustainability of public health programs. *American Journal of Public Health, 101*, 2059–2067.

Stake, R. E. (1995). *The art of case study research*. Thousand Oaks: Sage.

Wiggins, G., & McTighe, J. (2005). *Understanding by design* (2nd ed.). New York: Prentice Hall.

Yin, R. K. (2014). *Case study research: Design and methods*. Thousand Oaks: Sage.

Chapter 6
System Scaling in Singapore: The STELLAR Story

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Abstract It is not an uncommon goal amongst policymakers to have a successful programme in one school be scaled up to more or even all schools in the system. However, the poetry of aspiration must be translated into the prose of implementation. Recent studies, such as those described in this book, have indicated that the scaling up of educational innovations across multiple settings requires a confluence of sociocultural factors. In this chapter, we describe a successful educational innovation in Singapore, the Strategies for English Language Learning and Reading (STELLAR) programme, and discuss the implementation approach and the critical success factors, which have contributed to its effective scaling up, at a system level.

System Scaling in Singapore

Stringfield and Datnow (1998) define scaling up as 'the deliberate expansion to many settings … that previously has been used successfully in one or a small number of school settings'. Fishman (2005: 64) explains that the purpose of scaling up is '[w]hen collaboration produces truly usable innovations for particular contexts, it becomes possible to move beyond the innovators and early adopters and foster adoption by the majority. Only when that happens will … innovations have a broad impact on teaching and learning'. When a proven educational innovation, possibly developed in a more well-resourced school, is spread to benefit other schools, more students – regardless of socio-economic background – can be provided with the same quality teaching and learning experience. Thus, scaling-up successful programmes can be one of the levers in achieving equity of educational opportunities for all students.

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Recent research has unequivocally found that an effective educational innovation in a particular institution cannot be successfully scaled up by a mere exact replication of the same innovation in other contexts. This is because, besides the innovation itself, the confluence of sociocultural factors which resulted in the successful implementation of the educational innovation in the original context, which may not be present in the new context, has to be accounted for. For instance, Peurach and Glazer (2011) challenge the assumption that replicating innovations would 'enable rapid large-scale improvement'. This is because 'capabilities' and the 'coordinated, interdependent practices of its members' are often not duplicated. Fishman (2003: 1) similarly discusses the importance of studying the process of innovating, rather than only focusing on the final innovative elements, in the scaling up of an educational innovation. More critically, he emphasises that 'the process of scaling up an innovation is fundamentally about the adoption and diffusion of ideas across contexts' and not merely a replication of the innovation regardless of contexts.

As Hung et al. (2015) observe, scaling up in education is fundamentally different from scaling up in the medical sciences. The human physiology (including the reactions to drugs and medical procedures), which is the context by which medical innovation operates within, varies to a much lesser extent between individuals across ethnic, cultural and social groups than the way students respond to instructions, curriculum and learning experience. As such, Hung et al. (2015) argue for an ecological perspective to scaling, where the confluence of sociocultural factors is taken into account. These factors include, but are not limited to, teachers' capacity, school's culture, leadership support and resource allocation. In addition, Teh et al. (2013) articulates the need to adopt a different scaling approach when the knowledge that undergirds the innovation is tacit by nature (Cowan et al. 2000), instead of knowledge that can be explicated and transmitted easily. This means that rather than a mechanistic replication of an effective educational innovation, the innovation should be appropriately recontextualised in different school settings, taking into consideration both structural and individual adaptivities (Hung et al. 2014).

It is also well understood amongst the community in the field at present that the effectiveness of scaling up an innovation is not simply measured by counting the instances of successful implementation of that innovation. For instance, Coburn (2003: 3) observes that '[d]efinitions of scale have traditionally restricted its scope, focusing on the expanding number of schools reached by a reform' and explains that '[s]uch definitions mask the complex challenges of reaching out broadly while simultaneously cultivating the depth of change necessary to support and sustain consequential change'. She highlights the importance of studying other 'qualitative measures that may be fundamental to the ability of schools to engage with a reform effort in ways that make a difference for teaching and learning' (Coburn 2003: 4). In this light, she proposes four dimensions of scaling to provide a more comprehensive understanding of its complexities and to represent the multifaceted nature in the scaling up of an innovation. An additional dimension is subsequently included, and altogether, these five dimensions are (1) depth, (2) sustainability, (3) spread, (4) shift and (5) evolution (Dede and Honan 2005; Dede 2006, 2007). For an innovation to be successfully scaled, attention must be given to all these dimensions, not just one.

Given the recognition of the interplay of sociocultural factors in the scaling up of effective educational innovations, as well as the complex multifaceted dimensions of scale, it is suggested that policymakers carefully consider the conditions in which to put in place the requisite enablers that support the successful scaling up of an innovation. This set of considerations includes, and go beyond, the nature of the innovation. For instance, in an earlier seminal work describing the diffusion of innovations, Rogers (1962) identifies several intrinsic characteristics of innovations that influence its subsequent spread. He lists the factors as (1) relative advantage, (2) compatibility, (3) complexity or simplicity, (4) trialability and (5) observability. Beyond the nature of the innovation, Dede and Honan (2005) also describe other sociocultural considerations for the successful scaling up of an innovation, including (1) managing change, (2) promoting ownership, (3) building human capacity and (4) effective decision-making. Glennan et al. (2004) also discusses other success factors, such as alignments of the programme with policy, local accountability requirements and infrastructure support, in order to sustain the practice in the long run. In turn, Sabelli (2008: 5) maintains that '[s]uccessful adaptations need long-term collaborations, and benefit from a support infrastructure (literature, specific expertise, the design of the innovation, colleagues' experiences, additional research, etc.)'.

With these considerations in mind, how can successful scaling up of educational innovations be supported and even engendered? Peurach and Glazer (2011) highlight a 'knowledge-based logic' approach which is useful in the successful scaling up of educational innovation. The 'knowledge-based logic' emphasises the 'centrality of routines' as well as the importance of having a 'knowledge base co-emerge and co-evolve over time'. It also provides allowances for 'hubs that don't [always have to] optimise, but, instead satisfice' and for knowledge to 'be recreated' by growing from 'fidelity then adaptation'. Specifically, Peurach and Glazer (2011) emphasise that the '[r]ecreating [of] essential knowledge involves a developmental sequence that progresses from fidelity of implementation to adaptive, locally-responsive use'. In a similar vein, Leusner et al. (2008) also highlighted the 'tight but loose framework', by which the 'synthesis of both bottom-up and top-down approaches' allows the 'flexibility of taking advantage of local opportunities when accommodating existing local constraint, on the other hand, in the fidelity to core principles of innovation or practice'.

Community building can also be used as a strategy to scale up effective educational innovations (see for example, Sutton and Rao 2014). The focus lies with developing teachers' capacity and building of teachers' ownership through forming communities of practice. For instance, Bryk (2007) highlights the importance of developing expert human resources through professional learning and the usefulness of forming social networks to support continued learning. Communities of practice (Wenger and Snyder 2002) are useful in spreading 'tacit knowledge which cannot be transferred merely by artefacts containing the information related to particular innovations. Instead, such a passing on of tacit understandings has to be in the interplay of doing-performance of the practice and the actual dialogues around it (e.g., policy thinking and enactments)' (Hung et al. 2014). While the community building approach suggests an organic and more emergent touch to the scaling up endeavour,

this has to be balanced with well-defined structures that can create and support the enabling conditions for success, that is, structured informality. The principle of structured informality is approximated from the work of Savery and Duffy (1995), Lim et al. (2012) and O'Halloran et al. (2013) which promotes designing of structured informal learning experiences to meet objectives but allowing openness and flexibility for discovery, interaction and a joint construction of knowledge.

Drawing on the above literature, we hope that the discussion on the scaling strategies for STELLAR programme in this chapter will provide a perspective on the implementation approach and critical success factors which have contributed to the successful scaling up of an effective educational innovation at the system level.

Singapore and Its Education System

Singapore is a small and highly urbanised city state with a heterogeneous population. It has a total population of 5.399 million with a population diversity of 7,540 per sq km in 2013 (Department of Statistics 2014). Based on the latest official estimates, Chinese, Malays and Indians make up 74 %, 13 % and 9 %, respectively, of the Singapore resident population today. The rest of the population are classified as 'Eurasians' (i.e. from European and Asian descent) or 'others'.

The resultant challenges of having to manage diversity and the scarcity of resources necessitates the setting up of a robust school system. There are about 190 primary schools (grades 1–6), 170 secondary schools (grades 7–10) and about 20 junior colleges, centralised institute and specialised schools that offer academic preuniversity curriculum (grades 11–12). All these publicly funded schools employ the English language as the medium of instruction and cater to almost all Singaporean students of schoolgoing age. More information about the Singapore education system can be found in MOE (2013).

The Singapore education system today is highly centralised and regulated following three decades of reorganisation, rationalisation, consolidation and reformation. Nevertheless, this highly centralised and highly efficient education system is a relatively recent development. The transformation that the Singapore education system has undergone since the late 1950s, when Singapore achieved self-governing status from the United Kingdom, is significant. Until the early 1980s, the Singapore education system was a system with four different languages of instruction (i.e. English, Chinese, Malay and Tamil) in essentially one single academic stream. In 1959, less than half or 47.4 % of all Singaporean students were in the English stream (with English as medium of instruction). Although this percentage grew to 88.9 % by 1979 (Goh et al. 1979), even until the end 1980s, there were still Singaporean students whose medium of instruction was not English.

However, despite decades of adopting English as the medium of instruction in schools since the 1980s, the home language profile of Singapore students is still complex and diverse. This can be observed from PISA 2012 which reported the variation in the proportion of students who did not speak the language of assessment at home

Table 6.1 Proportion of students speaking the language of assessment at home and mean reading score by economies

	Overall mean reading score	Students speaking the language of assessment at home		Students speaking another language at home		Missing or invalid response category	
		% of student	Mean reading score	% of student	Mean reading score	% of student	Mean reading score
China (Shanghai)	570	97.7	572	1.4	476	0.9	481
Hong Kong-China	545	91.4	549	6.7	506	1.9	488
Singapore	542	42.4	575	50.6	524	7.0	481
Japan	538	97.9	541	0.4	NA	1.8	481
Korea	536	98.7	537	0.1	NA	1.2	478
Finland	524	94.9	529	4.5	459	0.6	417
Canada	523	79.5	529	16.7	525	3.8	443
Ireland	523	93.2	526	4.8	503	2.1	465
Chinese Taipei	523	78.1	536	15.4	485	6.5	458
Poland	518	97.6	519	0.8	515	1.5	462
Estonia	516	93.3	519	5.5	493	1.3	475
Liechtenstein	516	82.6	527	11.0	446	6.4	NA
Australia	512	87.0	516	9.4	514	3.6	447
New Zealand	512	82.3	524	15.8	471	1.9	409
Netherlands	511	89.6	519	6.1	461	4.2	428
Belgium	509	73.3	523	20.2	478	6.6	452
Switzerland	509	79.0	521	15.6	470	5.5	447
Macao-China	509	82.1	517	12.9	477	5.0	471
Germany	508	87.7	521	7.0	471	5.3	447
Vietnam	508	97.8	509	2.2	464	0.0	NA

OECD (2014)

across the participating countries and economies and their respective PISA scores. Referring to Table 6.1, PISA 2012 data shows about 50.6 % of Singaporean students do not speak the language of assessment at home. This percentage is the highest amongst the top 20 countries/economies with the highest mean PISA 2012 reading scores. Furthermore, the difference in the mean reading score of students who speak English at home and that of students who do not is very high, standing at 51 points.

The STELLAR Programme

Given the diversity in the home language profile of students in Singapore, it was necessary for MOE to develop an English language curriculum that was contextualised to meet the learning needs of the Singaporean student, particularly in the

foundational primary school years. Since the 1980s, with the decline of vernacular medium schools and the adoption of English as the medium of instruction, the teaching and learning of English in Singapore's schools has been guided by the English language syllabus. The syllabus is developed by curriculum planners and experienced language educators from MOE. Instructional materials, in the form of textbooks, were developed centrally by the Curriculum Development Institute of Singapore until 1996, when the Institute was restructured and reorganised as two divisions within MOE. Thereafter, while the English language syllabus continued to be developed centrally, the development of English textbooks and workbooks was undertaken by commercial publishers contracted by MOE.

By 2005, after just one cycle of materials development by commercial publishers, it was found that having a variety of textbooks did not appreciably improve the quality of English language teaching. Furthermore, the kind of teacher development support offered by publishers was variable and based on market needs rather than pedagogical and educational principles. As a result, an alternative model of curriculum development and teacher support was needed.

The review of the English language syllabus was the main impetus for change, coupled with the first ever, publicly fronted English Language Curriculum and Pedagogy Review in 2006. Curriculum planners were able to garner support and resources to start a new programme of instruction based on the revised syllabus. The programme, Strategies for English Language Learning and Reading (STELLAR), is based on language and literacy research as well as both first and second language learning principles. It drew considerably from the pedagogical principles developed in the Reading and English Acquisition Programme (REAP) that MOE implemented in all schools at the lower primary levels (grades 1 to 3) from 1985 to 1991.

The evaluation of REAP showed that it was a sound programme of instruction that led to positive student outcomes (Ng 2001; Ng and Sullivan 2001). While some measures were put in place to incorporate the REAP instructional strategies into the 1991 English language syllabus and instructional materials, support for teacher professional development was not sustained beyond 1991. To update a programme that had been carefully researched and tried and tested in Singapore classrooms with evidence of improved student outcomes was a more viable option than coming up with a wholly new programme. At the same time, curriculum planners were mindful of the need to learn from the past and to ensure that support and sustainability measures were put in place.

Hence, from the outset, STELLAR was positioned as a national curriculum. This ensured that teachers would not see it as an optional add-on. To ensure the sustainability of the new curriculum, adequate teacher support was planned, including materials development, teacher development workshops, on-site one-on-one mentoring and ongoing monitoring through feedback gathered from teachers. As the programme had been successfully implemented at the lower primary level in the past, the curriculum was scaled up in stages, from primary (grades) 1 to 3, from 30 to all primary schools, over a period of 5 years. At the same time, as the upper primary (grades 4 to 6) curriculum was new and would involve a redesigning of the

national examinations at grade 6, only 25 schools implemented the new curriculum throughout grades 1 to 6. Feedback from these 25 schools enabled adjustments to be made before the upper primary curriculum was offered to more schools.

To ensure school ownership of STELLAR and internal capacity building, curriculum planners started the STELLAR Teacher Mentor scheme from the second year of implementation onwards. After 2 years of support through centrally planned workshops and on-site mentoring, each school would nominate two teachers to be trained as STELLAR teacher mentors. These teacher mentors would attend specialised professional learning sessions to enable them to carry out school-based training and mentoring for newly deployed teachers. This process was repeated for the upper primary levels, so that each school would eventually have both lower and upper primary STELLAR teacher mentors.

Implementation Approach

End-to-End Support

Any scaling-up effort requires support in various forms to increase the probability of success. The STELLAR story is exemplary of how implementation support was thoughtfully and purposefully provided to help primary schools adopt the new curriculum. STELLAR's implementation support plan is called the STELLAR 4Ms approach, the 4Ms comprising materials, methodology, mentoring and monitoring. Each of these aspects is elaborated below.

Materials

All primary schools were provided with high interest, enlarged children's books (big books) for lower primary and digital and printed copies of age-appropriate teaching texts at upper primary. For each of the big books and teaching texts used in the STELLAR curriculum, there was an accompanying unit of specific guidelines developed in-house by MOE's curriculum planners. Each set of specific guidelines came complete with details of teaching steps and suggestions for implementing language activities in the classroom. Each guideline had a unit overview listing the learning objectives for the various areas of language learning, such as vocabulary, word identification and grammar. Resource sheets for the teacher and learning sheets for students accompanied each guideline. Where appropriate, audio recordings of songs and stories and video-based teaching resources were also provided. Except for the big books, which MOE procured and distributed to schools, all other resources were made available to teachers online through a dedicated website. In this way, curriculum planners ensured that all schools had equal access to high-quality instructional materials in both print and digital media.

Methodology

STELLAR made use of research-based teaching methods to promote students' enjoyment and engagement in learning English. At the lower primary levels, the Shared Book Approach, Modified Language Experience Approach and Learning Centres were the main teaching methods used. At the upper primary levels, as students made the transition from teacher-guided shared reading to independent silent reading, guided reading techniques (called supported reading), K-W-L (know, want to know, learnt), retelling, writing process cycle and differentiated instruction techniques were employed to facilitate students' learning. These teaching methods made up the STELLAR pedagogic frameworks for lower and upper primary. The specific guidelines for each STELLAR unit systematically guided teachers in using these instructional techniques in the classroom. More importantly, professional development workshops were conducted for all teachers by levels and by phases. The use of training videos, developed in-house with the help of teachers, was particularly important for demonstrating the teaching methods in STELLAR. In addition to training videos, hands-on activities, role-play and professional sharing by teachers were important for creating buy-in for STELLAR's teaching methodology.

Mentoring

Mentoring is a capacity building strategy that is central to supporting STELLAR's long-term viability. Mentoring took the form of classroom advisory visits where one-on-one mentoring was provided by a team comprising curriculum planners from MOE, as well as specially trained retired teachers. The aim of such 'just-in-time' visits was to contribute to teachers' professional growth and to gather teachers' feedback on the STELLAR curriculum, including instructional materials and teaching methodology. Lower primary STELLAR teachers were allocated five advisory visits, while upper primary teachers, three. To maintain and enhance mentoring efforts without actually increasing the number of staff at MOE, an innovative strategy was employed: retired teachers who had a wealth of teaching experience underwent an internal process of training to become mentors of the STELLAR programme. These STELLAR mentors served as STELLAR ambassadors and enabled MOE to maintain the same level of professional development support for each phase of implementation and scaling.

In effect, all these measures were powerful attempts to create deep and consequential change in classroom practice (Coburn 2003: 4), specifically, STELLAR teachers' beliefs of what materials could be used in class (the best writing – big books in the primary classroom), what constituted good teaching, how students should be engaged through real-world reading tasks and how they themselves could teach more effectively. One-on-one mentoring thus helped ensure fidelity in STELLAR schools to STELLAR's core teaching principles and methodology.

Monitoring

It is critical for the success of any scale-up efforts that a process of evaluation and continual improvement takes place. Monitoring for formative purposes was an ongoing process. Teachers' written feedback after every workshop was collated and analysed, followed by an after-action review session. Suggestions for improvement were noted for follow-up in the revision of the workshop materials for the following year's workshop sessions. Classroom observation data during advisory visits was collected systematically, coded using standardised descriptors, collated and analysed. Post-lesson conferencing sessions during advisory visits provided informal, qualitative data that was routinely shared during weekly or fortnightly team meetings. In addition, teachers were surveyed twice a year every year during every phase of implementation. The self-reported teacher survey data, classroom observation data and workshop evaluation data were collated, analysed and reported, along with recommendations for improvement, in annual reports to MOE's senior management.

To evaluate the impact of the STELLAR curriculum on students' language learning, a summative evaluation study was carried out over a period of 6 years (2007–2012). The study utilised a pre-post, quasi-experimental, longitudinal design. It tracked a group of children undergoing the new curriculum from grade 1 to 6. The study compared the listening, speaking, reading, writing and grammar skills of 160 children in 10 STELLAR pilot schools and a group of 160 children of similar socio-economic and home language background from 10 control schools. Stratified random sampling techniques were used to draw the two samples for the study. In selecting the control schools, care was taken in sampling schools similar in socio-economic background and overall academic performance to the 10 STELLAR pilot schools. While the children, 16 from each school, were sampled from intact classes, they were randomly selected from across all the classes in a level. Statistical tests were performed to ensure that the two groups of children sampled were similar in terms of socio-economic status and home language background. A pretest was conducted at the beginning of grade 1 for the 160 children in the 10 STELLAR pilot schools and the 160 children in the 10 control schools. Over the next 6 years, the same two groups of children were tested on their language skills using instruments designed and field-tested by MOE. The results showed that the sampled children in the 10 STELLAR pilot schools performed significantly better on some of their language skills as they progressed through the levels, particularly in speaking and reading, compared to the children sampled from the 10 control schools. Effect sizes ranged from 0.32 ($p=0.005$) to 0.45 ($p=0.000$) for speaking from grade 3 to 5 and from 0.34 ($p=0.003$) to 0.45 ($p=0.000$) for reading from grade 3 to 5. This finding has been corroborated by teacher survey data which indicated relatively higher approval ratings for the oral and reading strategies the teachers have tried. Classroom observation data across the years from primary 1 to 6 also showed that STELLAR teachers in the pilot schools implemented the teaching techniques as advocated by the programme.

Ensuring Sustainability over Time

The notion of sustainability relates mainly to time in terms of how an innovation is sustained in the original and subsequent schools (Coburn 2003). Indeed, there was a genuine concern on the part of curriculum planners that STELLAR teachers might revert to previously established ways of teaching when professional development support was withdrawn from the school.

Experience has shown that one main cause of regression is a lack of adequate support for sustainability, which in turn affects the practitioner's attitude towards (and perceptions of) the innovation. As such, the curriculum planners for STELLAR operationalised sustainability in four key ways: capacity building through school-based teacher mentors, establishment of centres of good practice, establishment of the STELLAR Centre for ongoing support and parental engagement.

STELLAR Teacher Mentor Scheme

Ownership over any innovation could be shifted from the originators of the innovation to those who have the capacity to sustain, spread and deepen (Coburn 2003) the process of implementing the innovation. STELLAR planners have attempted to do so through a number of ways.

As a first step to address this problem, since the beginning of 2007, STELLAR planners invested effort in developing the STELLAR Teacher Mentor (STM) scheme in which selected teachers were equipped with skills, including leadership and communication skills, as well as those related to the STELLAR teaching methodology. In the STM scheme, two to three lower and upper primary STELLAR-trained teachers from each participating school were developed as teacher-leaders to work together collaboratively with the teachers in their own schools as they took on implementation challenges. These STMs were given additional professional development opportunities to help them acquire a deeper understanding of the principles underlying STELLAR and educational change. In short, they became ambassadors for the STELLAR curriculum who reached out to other teachers and created buy-in. STMs continued to receive professional learning opportunities in the form of regular meetings, sharing sessions and, for selected teachers with a track record of sustaining change in their schools, overseas professional learning trips. Ownership of the innovation was gradually transferred from the STELLAR team to the teacher champions enacting the programme in the schools, resulting in sustainability of the innovation.

Beyond sustaining the programme in their schools, STELLAR teacher mentors have gone further to develop instructional resources and activities to enhance the core learning experiences in STELLAR. For instance, some STELLAR teacher mentors have taken the lead in the use of digital tools and resources such as podcasting and immersive digital stories to further develop their students' oral reading fluency. Other ground-up innovative practices include the creation of differentiated

learning activities to meet diverse students' needs and the development of school-based curriculum that incorporates content area learning such as the learning of science and social studies concepts contextualised within the big book stories at lower primary.

Recognising Schools with Good Practices

The purpose of this strategy was to recognise schools that had strong support from their school management and good student outcomes. These centres of good practice could then serve as role models and motivate other schools into doing away with ineffective teaching practices to make way for improved pedagogies. The teachers were encouraged to present at large-scale meetings, seminars and events organised by MOE – yet another way of acknowledging and sharing the good practices of the schools that have embraced the new curriculum. These strong STELLAR schools were also earmarked as schools for visiting delegations.

Establishment of the STELLAR Centre

The STELLAR Centre was set up to bring people and resources together in a single place to allow for focused learning as well as the efficient distribution of teaching resources, such as the big books used at the lower primary levels. Having a dedicated centre meant that MOE could aggregate the demand for specific book titles to achieve greater economies of scale and even negotiate with vendors to republish titles that had gone out of print. It acts as a hub for the creation and distribution of teaching and learning resources for the primary schools, including advance planning for new schools. The STELLAR Centre also provides training facilities and resources for ongoing professional learning for teachers, teacher mentors as well as the retired teachers who have played and continue to play a critical role in guiding teachers who are new to the programme.

Parental Engagement

Parental support is pivotal to ensuring the success of any new educational innovation. Right from the start, curriculum planners implemented strategies to help parents understand and work more closely with schools on the STELLAR programme. This went a long way in creating understanding and legitimacy for the STELLAR programme. Examples of the parent support programme for schools include communication packages and resources for parents, consisting of briefing slides, information videos on STELLAR, tips for parents as well as book recommendations for parents and children. A dedicated website on the STELLAR programme was also set up to reach out to parents. Interestingly, the usefulness of the website was even spread through word of mouth by parents to other parents, which further helped to

create understanding of STELLAR amongst parents and encourage their buy-in. In some schools, teachers have built on the resources provided by MOE to design and conduct customised workshops targeted at parents, enabling these parents to better understand the STELLAR programme and teaching techniques used through live lesson observations and demonstrations by teachers.

Critical Success Factors

There is never one singular cause or a fixed formula responsible for the successful scaling up of an educational innovation. STELLAR's success is the result of an interplay of human designed factors and good timing enacted in a conducive environment. Following from our discussion of the implementation approach in the STELLAR programme, we discuss some critical success factors which have contributed to the success of the scaling up of the programme.

Quality of Innovation

As Rogers (1962) famously observes, a decisive factor in the spread of innovations is the quality of the innovation, i.e. its intrinsic characteristics. In other words, the innovation must have been proven to work, and can work, just as effectively, across different settings. This demands that the innovation has a stable and sound internal logic, or theory of action (Argyris and Schon 1974; Rogers and Weiss 2007), that will support its adaptation in different contexts while not compromising its core principles. This theory of action is an articulation and explication of the logical linkages between the utilised resources, planned and enacted activities, the programme output and the desired outcomes. In the case of STELLAR, the consistent positive feedback received from teachers and students and the learning gains evident in the later comparative and longitudinal studies are testimony to the quality of the educational innovation. The programme has also benefited from the insights derived from MOE's experience with an earlier English literacy programme, REAP (Reading and English Acquisition Programme), that was implemented in the 1980s. The consultant for the STELLAR programme was one of the developers of REAP, and a number of teachers who had implemented REAP went on to serve as mentors to teachers in the STELLAR programme. The strong sense of continuity, both in the programme's core principles, and in the people involved, ensures a certain quality of the innovation. The STELLAR programme draws on various evidence-based understandings derived from international research in literacy. It is noteworthy that the STELLAR programme builds on the learning from the various research projects that have been done, both locally and internationally, instead of developing new research on its core principles *tabula rasa*. This eclectic approach has

facilitated the development of a hybridised model in the STELLAR programme that is contextualised to the Singapore classroom and localised to the students' needs, against the backdrop of the Singapore education system.

In the recontextualisation of the STELLAR programme across different classrooms, there is flexibility exercised to allow for adaptations to meet specific local needs while retaining a strong focus on the fidelity of implementation. This is possible because the internal logic, i.e. the theory of action of the innovation allows it to be pliant such that consistency to the core principles is ensured even as it undergoes adaptation. The pedagogic framework is designed to invite principled adaptation of the curriculum. Drawing from the range of teaching methods in STELLAR, teachers learn to differentiate their lessons to meet the learning needs of their students. This allows for an incremental evolution of the innovation to more appropriately meet local needs and bring about a gradual shift in ownership from the STELLAR team to the teachers implementing the programme. When asked to share their thoughts on being a STELLAR teacher in open-ended surveys, many teachers acknowledged the benefits of the programme in promoting student learning:

Primary 1 and 2

- *I enjoy teaching the P1 and P2 students using the STELLAR materials. The STELLAR Guide is easy to follow but at the same time allows us the option to be creative to use our resources and materials.*
- *I love MLEA (Modified Language Experience Approach) the most. My pupils are better able to provide a richer content for their writing. Learning has been made fun for them.*

Primary 3

- *It gives opportunity for the teacher to empower the children with language ability. It is also a platform to build the children's esteem and confidence.*

Primary 4

- *It allows me to be more creative in my teaching with varied activities that the students enjoy. It's not that easy to carry out all the activities in the guidelines, so I need to adapt and adjust accordingly. I learnt to be flexible and creative as well, so overall it's still a good experience.*

Primary 5

- *STELLAR to me brings back the fun and dynamism to EL learning. I am in full support of it. However, teachers are often at the mercy of 'teaching to the test/ exam'. We need and certainly want more time to do the 'right' thing (STELLAR) in the EL classroom.*

Primary 6

- *Learning English through the reading of varied texts is a great way to expose pupils to the world around them.*
- *My students definitely improved in their writing and reading comprehension.*

Strong Support

No educational innovation can be scaled up without resources, both symbolic, in the form or authority and trust given, and material, in the form of manpower and finances provided. Another key factor for the success of the STELLAR programme is the conspicuous executive sponsorship and strong management endorsement the programme received from the start. There was interest and involvement from MOE's senior management. The unanimous support for the STELLAR programme from the professionals and policymakers in MOE paved the way for firm commitment from the other stakeholders, such as school leaders. This was instrumental to the effective implementation of the programme and opened doors to the essential resources for the programme from its very inception. With the recognition and support, the STELLAR programme was designed from the outset to be an integral part of the revised English language syllabus. The innovation's incorporation in the syllabus ensured that all schools in Singapore had access to the curriculum resources as well as support from the STELLAR team.

Curriculum Coherence

Scaling up an educational innovation across the entire nation requires sensible and practicable implementation strategies complemented with bold and strategic leadership. The STELLAR programme is fortunate to have both. As the discussion of the programme implementation approach has been made in the previous section, the focus here is on the leadership of STELLAR.

The critical role of MOE's policymakers and STELLAR planners in providing the STELLAR programme with a long runway for development could not be overemphasised in the success of the STELLAR story. From the outset, MOE was supportive of STELLAR planners' bold, long-term vision of how the comprehensive teaching programme could impact primary school children in Singapore. To this end, policymakers gave the STELLAR programme a longer development and implementation time frame (5 years of phased-in implementation instead of the norm of 3 years for most projects), recognising that to be successful and to gain sustainability, effectiveness rather than expedience had to be the priority.

In turn, over the years, STELLAR planners were adroit, adept and careful to (re)position the STELLAR programme within the larger MOE landscape for continual relevance. For instance, STELLAR planners were able to complement the STELLAR programme with other key or signature MOE initiatives such as the twenty-first-century competencies and holistic assessment, a key recommendation of the Primary Education Review and Implementation (PERI) committee. The deliberate strategic alignment of the STELLAR programme with the various initiatives and foci of MOE situates the programme firmly within the educational ecosystem and ensures its continued relevance and support.

The STELLAR programme is also a realisation of a fresh approach to curriculum implementation, that is, one of end-to-end design, implementation and support. In this model, the planning, implementation, support and evaluation of the curriculum is conducted by the same team of people so as to prevent misalignment and reduce the disjoint between classroom materials and the syllabus. Likewise, the STELLAR programme also represents a new and different model in the procurement of teaching resources for schools, that is, MOE procures or licenses the teaching texts to be used in schools. Previously, the schools had identified the textbooks to be purchased by their students from approved vendors. The new model has proven to be effective as it ensured equity of access to a common set of quality curriculum resources and contributed to the fidelity in the implementation of the STELLAR programme. The leadership has also been unconventional in its procurement of manpower resources. Retired teachers were contracted to work closely with STELLAR officers to lend support to schools as mentors, to codevelop instructional materials or to work on special projects, for example, the development of assessment resources.

Challenges

Data and observations from the last 8 years of implementation have shown the STELLAR curriculum to be effective and beneficial, but there remain significant challenges. Ongoing professional learning support needs to be provided although the degree and intensity of it is likely to be less than during the initial start-up years. This is one aspect of support that curriculum planners found to be important from feedback and interactions with teachers, heads of department and school leaders. A second challenge lies in the fact that the STELLAR curriculum needs to be adapted by teachers in a thoughtful and principled way to cater to the specific needs of their students. The curriculum is centrally planned and caters to the learning needs of the majority of students. While there is flexibility given in the teaching guidelines, teachers have reported their difficulty in meeting the learning needs of their low and high progress students. A third challenge, which is not specific to English teaching, is the examination culture in our schools which places a premium on exam-centric pedagogies. Teachers have reported that ‘it is difficult to balance the STELLAR approach and the traditional approach in preparing for exams’. STELLAR planners will need to continue working on balancing assessment for and of learning in the support plans for the coming years.

Future Plans

To enable more students to benefit from the teaching methods used in the STELLAR curriculum and facilitate a smooth transition from primary to the secondary level, MOE has started piloting a lower secondary curriculum that uses some of the

teaching techniques in the STELLAR pedagogic framework. This project seeks to improve students' language learning by building the pedagogical capacity of secondary school teachers through lesson study. At the same time, MOE is also trialling a new early childhood English curriculum based on the STELLAR pedagogical approach. As early intervention is critical to closing learning gaps before they widen over time, the important lessons learnt in designing and implementing the STELLAR curriculum will be applied to raise the quality of language teaching at the kindergarten level.

Conclusion

One chief lesson to be drawn from the STELLAR story is that the success of any scaling-up endeavour comes about from a confluence of many elements: the implementation approach of the STELLAR 4Ms, strategies to ensure the sustainability of the programme over time, maintenance of the quality of the innovation, provision of strong support from MOE's senior management and coherence of the curriculum. Yet, without concomitant vision, long-term planning, sustained commitment from various stakeholders and the capacity to anticipate and cope with challenges in the implementation of the innovation, the STELLAR story would not have been possible as well. Most significantly, however, as has been reiterated time and again by many researchers (see, e.g. Fullan 2011; Hargreaves and Shirley 2012; Thomas and Brown 2011), scaling-up of educational innovations takes time and patience. Indeed, in reflecting on the implementation of research ideas in innovative projects, Ng and Sullivan (2001: 177–178), who had been involved in the planning and implementation of the Reading and English Acquisition Programme (REAP) in Singapore in the 1980s, aptly sum it up, 'Education innovations are definitely not for the impatient nor for the faint-hearted. Working on what needs to be changed and how that change is to be achieved are only the initial stages of educational improvement. What needs to follow is attention to how the change can be sustained in a particular context'. And it is the sustained change brought about by the STELLAR programme that qualifies it as a successful educational innovation – scaled up at a system level in Singapore.

References

Argyris, C., & Schon, D. A. (1974). *Theory in practice: Increasing professional effectiveness* (A joint publication in The Jossey-Bass higher and adult education series and the Jossey-Bass management series). San Francisco: Jossey-Bass.

Bryk, T. (2007). *Ruminations on re-inventing an R and D capacity for educational improvement*. Paper prepared for the American Enterprise Institute Conference on the "Supply Side of School Reform.", Washington, DC.

Coburn, E. C. (2003). *Rethinking scale: Moving beyond numbers to deep and lasting change*. Retrieved from http://vocserve.berkeley.edu/faculty/CECoburn/coburnscale.pdf

Cowan, R., David, P. A., & Foray, D. (2000, June). The explicit economics of knowledge codification and tacitness. *Industrial and Corporate Change*, Oxford University Press, *9*(2), 211–253.

Dede, C. (2006). Scaling up: Evolving innovations beyond ideal settings to challenging contexts of practice. In R. K. Sawyer (Ed.), *The Cambridge handbook of learning sciences*. Cambridge: Cambridge University Press.

Dede, C. (2007, Spring). Exploring the process of scaling up. *Threshold: Exploring the Future of Education, 5*, 16–17.

Dede, C., & Honan, J. P. (2005). Scaling up success: A synthesis of themes and insights. In C. Dede, J. P. Honan, & C. P. Laurence (Eds.), *Scaling up success: Lessons learned from technology-based educational improvement* (pp. 227–239). San Francisco: Jossey-Bass.

Department of Statistics, Singapore (DOS). (2014). *Yearbook of statistics, Singapore, 2014*. Retrieved from http://www.singstat.gov.sg/publications/publications_and_papers/reference/yearbook_2014/yos2014.pdf

Fishman, B. J. (2003). *Collaborating towards scale: A framework for examining innovations and their contexts of use*. Retrieved from http://isites.harvard.edu/fs/docs/icb.topic443490.files/Fishman7-16-03.pdf

Fishman, B. J. (2005). Adapting innovations to particular contexts of use. In C. Dede, J. P. Honan, & C. P. Laurence (Eds.), *Scaling up success: Lessons learned from technology-based educational improvement* (pp. 48–65). San Francisco: Jossey-Bass.

Fullan, M. (2011). *The six secrets of change: What the best leaders do to help their organizations survive and thrive*. San Francisco: Jossey-Bass.

Glennan, T. K., Bodilly, S. J., Galegher, J., & Kerr, K. A. (Eds.). (2004). *Expanding the reach of education reforms: Perspectives from leaders in the scale-up of educational interventions*. Santa Monica: RAND.

Goh, K. S., & The Education Study Team. (1979). *Report on the ministry of education 1978*. Singapore: Ministry of Culture.

Hargreaves, A. P., & Shirley, D. L. (2012). *The global fourth way: The quest for educational excellence*. Boston: Corwin.

Hung, D., Lee, S. S., Teh, L. W., Vishnumahanti, S., Widiastuti, A., & Kwan, Y. M. (2014). An ecological perspective on scaling: Balancing structural and individual adaptivities. In D. Hung, K. Y. T. Lim, & S. S. Lee (Eds.), *Adaptivity as a transformative disposition for learning in the 21st century*. Dordrecht: Springer.

Hung, D., Lee, S. S., & Wu, L. K. (2015). Towards an educational view of scaling: Sufficing standard and not a gold standard. *Educational Research for Policy and Practice, 14*(1), 77–91.

Leusner, D. M., Ellsworth, J., & Goe, L. (2008). Scaling up across diverse contexts: Lessons learned from five implementations of the keeping learning on track program. In E. C. Wylie (Ed.), *Tight but loose: Scaling up teacher professional development in diverse contexts* (pp. 105–124). Princeton: ETS.

Lim, F. V., O'Halloran, K. L., & Podlasov, A. (2012). Spatial pedagogy: Mapping meanings in the use of classroom space. *Cambridge Journal of Education, 42*(2), 235–251.

Ministry of Educations, Singapore (MOE). (2013). *Education statistics digest 2013*. Retrieved from http://www.moe.gov.sg/education/education-statistics-digest/files/esd-2013.pdf

Ng, S. M. (2001). Chapter 4: The Brunei Reading and Language Acquisition Project. *International Journal of Educational Research, 35*(1), 169–179.

Ng, S. M., & Sullivan, C. (2001). Chapter 3: The Singapore Reading and English Acquisition program. *International Journal of Educational Research, 35*(1), 157–167.

O'Halloran, K. L., Podlasov, A., Chua, A., Tisse, C.-L., Lim, F. V., & Smith, B. A. (2013). Challenges and solutions to multimodal analysis: Technology, theory and practice. In Y. Fang & J. Webster (Eds.), *Developing systemic functional linguistics: Theory and application*. London: Equinox.

OECD. (2014). *PISA 2012 Results: What students know and can do- Student performance in mathematics, reading and science* (Volume 1, Revised edition, February 2014). PISA, OECD Publishing. http://dx.doi.org/10.1787/9789264208780-en

Peurach, D. J., & Glazer, J. L. (2011). Reconsidering replication: New perspectives on large-scale school improvement. *Educational Change, 13*(2), 155–190.

Rogers, E. M. (1962). *Diffusion of innovations*. New York: Free Press of Glencoe.

Rogers, P. J., & Weiss, C. H. (2007, Summer). Theory-based evaluation: Reflections ten years on: Theory-based evaluation: Past, present, and future. *New Directions for Evaluation, 2007*(114), 63–81.

Sabelli, N. H. (2008). *Applying what we know to improve teaching and learning*. Retrieved from http://dev.opeq.blenderbox.com/uploads/files/c6c854c9-7190-416e-9b2c-4ffb1c480814.pdf

Savery, J. R., & Duffy, T. M. (1995). Problem based learning: An instructional model and its constructivist framework. In B. Wilson (Ed.), *Constructivist learning environments: Case studies in instructional design* (pp. 135–150). Englewood Cliffs: Educational Technology.

Stringfield, S., & Datnow, A. (1998). Scaling up school restructuring designs in urban schools. *Education and Urban Society, 30*(3), 269–276.

Sutton, R. I., & Rao, H. (2014). *Scaling up excellence: Getting to more without settling for less*. New York: Crown Business.

Teh, L. W., Hogan, D., & Dimmock, C. (2013). Knowledge mobilisation and utilisation in the Singapore Education System: The nexus between researchers, policy makers and practitioners. In B. Levin, J. Qi, H. Edelstein, & J. Sohn (Eds.), *The impact of research in education: An international perspective* (pp. 41–63). Bristol: The Policy Press.

Thomas, D., & Brown, J. S. (2011). *A new culture of learning: Cultivating the imagination for a world of constant change*. Lexington: CreateSpace Independent Publishing Platform.

Wenger, E., & Snyder, W. (2002). *Cultivating communities of practice*. Boston: Harvard Business School Press.

Chapter 7
Design and Implementation of an Educational Innovation in Different Contexts: A Case Study of Group Scribbles

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Abstract This chapter articulates a research approach that incorporates critical elements of design-based research (DBR) and design-based implementation research (DBIR) to implement and scale up technology-supported educational innovations. Following this research approach, Group Scribbles (GS)-supported collaborative learning has been implemented and sustained to improve classroom-based teaching and learning of various subjects (including Science, Mathematics, First Language/English, and Second Language/Chinese) in more than ten local schools in Singapore. The GS project has been recognized as making good contributions to mainstreaming computer-supported collaborative learning (CSCL) in formal learning contexts. In this chapter, a chronological account of the iterative cycles of design and implementation of GS in a primary school with average technology provision, and in a technology-rich endowed secondary school, is provided to help illustrate and elaborate the proposed scale-up research approach. The strategies and structures placed in schools of different profiles that prove effective in addressing common implementation and scale-up challenges are distilled and discussed to help inform future work on sustaining and spreading educational technology research-based practices.

Introduction

Being cognizant of the significant role technologies can play in mediating learning and preparing students for the challenges and opportunities of the knowledge-based economy in the twenty-first century, government and funding agencies worldwide have long funded and supported educational technology research. Decades of funded research have produced interesting ideas and small-scale proofs of concept, yet most innovations made still remain fragmentary and scattered and have not

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resulted in pervasive, sustainable, and large-scale improvements in the "core" of the educational system (Elmore 1996; Sabelli and Dede 2001; Haertel and Means 2003).

In contrast to experiences in other sectors of society, scaling up successful programs proves very difficult in education (Dede et al. 2005). This difficulty, as discussed below, can be largely ascribed to the lack of adaptability of the innovation itself and the inadequacy of capacities of the local users to apply the innovation. Adaptability and capacity building are two critical components of proliferating educational innovations, and educational researchers should strive to achieve them in designing and deploying such innovations. In this chapter, we present the developmental trajectory of a design-based research project – the Group Scribbles (GS) project which has shown much potential to support routine practices of computer-supported collaborative learning (CSCL) in primary and secondary schools in Singapore. It is hoped that through the elucidation of the iterative cycles of design and implementation of the GS innovation undertaken by the researchers in different school contexts, the readers can understand the critical role researchers can play in mediating between policy directives and school needs and in coordinating efforts from multiple communities to bridge the disconnect between educational technology research and practice (Lagemann 2000). The effective strategies that the research team has developed and deployed in schools to ameliorate the challenges encountered can inform future practices of designing and disseminating technology-supported educational innovations to a broader range of contexts.

In the sections below, the common challenges to sustain and spread educational innovations are firstly distilled. We then introduce our research approach that incorporates critical elements of the design-based research (Barab and Squire 2004) and design-based implementation research (Penuel et al. 2011). The main part narrates the chronological, ethnographic account of the research trajectory of GS in Singapore schools. The implementation of GS in some schools has obtained traction in terms of spread and sustainability resulting from the strategies developed and deployed as embodiments of the design approach. In the discussion and conclusion section, some reflections on the GS research and implementation trajectories are shared.

Implementation and Scale-Up Challenges

The scaling of educational innovations often steps into the "replica trap," i.e., repeating everywhere what worked locally without taking into account of individual variations in needs and assets of the other sites (Wiske and Perkins 2005). As a result, the efficacy of scaling is often eroded by the variations in implementation contexts (Clarke et al. 2006). As educational practices are localized to the interactions of a particular student or a group of students, with a particular teacher, and within a particular context, any general conclusions and recommendations from prior research need to be adapted to specific local conditions and capacity before the expected results can be shown (Sabelli and Dede 2001). Conceived in the fertile

greenhouses, a promising innovation, even if it has been successful in a small-scale pilot, often withers and dies when scaled up to schools with limited capacities and commitments (Dede et al. 2005).

Contextual variables have substantial influence in shaping the desirability, practicality, and effectiveness of educational interventions (Clarke and Dede 2009). Failures in diffusing educational innovations call for the abandonment of the "One-Size-Fits-All" approach and the empowerment of the users to adapt the innovation to foster effective usage across contexts, especially in barren settings where some conditions for success cannot be obtained. The lack of adaptability in innovations that were being scaled has been well noticed in the community. Coburn (2003) has defined scale as encompassing four interrelated dimensions of depth, sustainability, spread, and shift in reform ownership. The dimension of sustainability centers on the issue of contextual variation and the need for adaptation. Focusing on "design for scalability," the River City MUVE project has adopted a "robust" design approach (Clarke and Dede 2009). The solutions (e.g., train the trainers) generated in this project have helped attain the conditions for success (e.g., teacher preparation) and ensured the efficacy of the design in improving science learning by secondary school students (Nelson et al. 2007). Adaptation to local contexts is also one of the essential components in the "Tight but Loose framework" developed in Marnie and Dylan (2009) which proves effective for scaling up school reforms.

Besides lacking adaptability, another prominent issue identified is the negligence of appropriating and acculturating the users into the innovative practices enabled by technologies. One naïve belief behind the "fingertip effect" (Perkins 1985) is that novices will automatically understand and take advantage of a new tool's affordances to the same extent as an expert, just by receiving access to the tool (Nelson et al. 2007). In reality, the scale-up endeavors made may only result in improved scope of adoption, which yet is a very poor proxy for assessing the extent of scaling (Cohen and Ball 2006). The essence of scaling lies more in qualitative changes in school practices rather than mere advancements in quantitative measures (Cohen and Ball 2006). The outcomes of educational research include tools, knowledge, and people, and the transfer between research and practice is implemented through both scholarly products and human capacity building (Sabelli and Dede 2001). Prior research on technology-based educational improvement clearly indicates the importance of empowering teachers to effect deeper changes in teachers' beliefs, knowledge, and practices (Fishman 2005). Yet under the illusion of "spontaneous adoption," the processes of building capacities in school practitioners are often insufficiently attended to.

The need for capacity building in schools is increasingly reflected in the models and approaches developed for DBR and DBIR. Establishing capacities for sustaining change in systems is one of the very pursuits of DBIR researchers through iterative cycles of design and implementation (Penuel et al. 2011). In the aforementioned Coburn's (2003) scaling framework, the dimension of shift in ownership, which underlines deepening, sustaining, and spreading of the impact of the innovation by teachers, schools, and districts, is only feasible when school practitioners have aligned their beliefs and knowledge to the technological and pedagogical practices embedded in the innovation.

Scale-Up Research Based on DBR and DBIR

Getting to scale is an important mandate for educational researchers (Elmore 1996). To mitigate the scaling-up dilemma of innovations that were proven effective in specific settings, orchestrated efforts from policymakers and ground-level actors in the educational system are required in seeking alignment with policy imperatives. Our argument is that such orchestration of efforts can be achieved through the DBR approach that highlights the involvement of practitioners in the creation of evocative, theory-based designs to solve complex problems in authentic classroom learning (Barab and Squire 2004). Positioning practitioners as codesigners of solutions to problems encourages appreciation, adoption, and ownership of the usable tools and strategies developed (Penuel et al. 2011) and thus improves the capabilities and practices of the practitioners to adopt and adapt the design. It also enables the generation of practical theory and tools that can solve contextualized problems. Also, as the process of DBR is iterative in nature, it can inform needed adjustments to programs (Cobb et al. 2003) to accommodate the needs and characteristics of the local contexts.

In the literature, DBR has been identified as a promising approach to scaling as it attempts to design theory-based innovations that are of sizable effect, reasonable plausibility, and generalizability (Penuel et al. 2011). Yet as contextual variables often impact the effectiveness of the design, surfacing the "conditions for success" of the design in local contexts becomes vital to appropriation and adaptation while retaining its efficacy (Penuel and Fishman 2012). This calls for devotion to iterative implementation of the innovation in diversified contexts to distill the common and specific conditions that contribute to buy-in and sustainability. During implementation, researchers not only intervene to enhance the attitudes, knowledge, and skills of school practitioners but also iteratively interpret the structures that facilitate or inhibit sustainable use of the design.

Thus, our research approach also shares common ground with DBIR in foregrounding the early incorporation of considerations for implementation and sustainability in the development of innovative programs. Through narrating the story of GS design and implementation, we hope to provide an existential example of an innovation and intervention program that can address issues of implementation in different school contexts and yet still respects traditional learning science concerns of deriving design principles and theory. In studying the implementation issues, we hope to uncover the kinds of capacities required for the schools to implement the program and to unpack the supports that are needed for school practitioners to adapt the program in ways that are in concert with its core design principles (Penuel and Fishman 2012). We will provide a discussion of the school-based research and development of GS through discussing the efforts to improve a set of interrelated dimensions that impact classroom practices including curriculum, pedagogical practices, assessment, teacher knowledge, technical infrastructure, and other logistical and social supports (Chang et al. 1998; Fisher et al. 1996; Means 1994; Sandholtz et al. 1997).

An Example of Scale-Up Research in CSCL: The Group Scribbles Project

The GS project is provided as a worked example because it has made good achievements in mainstreaming CSCL in formal schooling in Singapore. The GS innovation has been used in the classroom lessons for different subjects to varying depth and breadth in more than ten schools since its premiere in one school in 2007 (Table 7.1). Through long-term and deep involvement in the initial four schools, the researchers have created new knowledge about the nature and design of CSCL and improved the classroom practices. Altogether, 109 GS lesson plans have been developed for various subjects (including Mathematics, Science, English language/First language (L1), and Chinese language/Second Language (L2)) and 146 GS lessons have been enacted, observed, and studied. Numerous teacher professional development and GS lesson discussion sessions have been conducted. With long-term commitments and efforts from multiple parties, the GS project has gained broad recognition, even in the international arena. GS has been cited in the USA's National Educational Technology Plan 2010 as a successful innovation tried out in Singapore schools (US Department of Education 2010). GS-supported collaborative learning has also been used by educators in Taiwan to improve classroom learning and teaching (e.g., Lin et al. 2013).

Developing and Scaling Up Educational Innovations in Singapore

This section presents the broad social-cultural background of the generation and generalization of educational innovations in Singapore to help readers position the GS project. Educational policymakers, researchers, and practitioners worldwide are grappling with the "wicked problem" (Rittel and Webber 1994, p. 161) of understanding the affordances of emerging technologies to formulate meaningful directions for pedagogy-driven reforms to improve school-based teaching and learning. For educators in Singapore, the challenge is to develop students' twenty-first-century competencies and dispositions with learner-centered teaching and learning approaches and to integrate information and communication technology (ICT) into classroom practices to support these approaches (Liew 2013). In Singapore, there exists a combination of strong, explicit top-down directives (as reflected in the three consecutive Masterplans of ICT in Education proposed by the Ministry of Education, MOE) and bottom-up desire for transforming school practices. The development and scaling of educational innovations features centralization and is often practiced via top-down approaches. With the policymakers (MOE) having a strong presence in enacting directions, taking initiatives, and playing driving forces, there exists a central theme in the educational reform that is reflected in the intended outcomes, processes, and strategies prescribed by MOE (e.g., "Building

Table 7.1 Stages of DBR on GS

Time	Design principles	Curricular products	Technology development	Professional development	Spread of innovation
July–Oct 2007	Derived 10 Rapid Collaborative Knowledge Improvement (RCKI) principles	GS lessons for P4 Science	Limitations of GS 1.0 were encountered; these informed the design of GS 2.0	Two P4 science teachers were trained	Two classes from school M used GS for one subject
Jan–May 2008	Use of 10 principles to design lessons	GS lessons for P5 Science, Mathematics, and Chinese language (CL)	GS 2.0 (beta) deployed, but several performance issues were encountered; these informed the next design of GS	The same teachers were supported to design and enact GS activities in Mathematics. Additionally, 2 CL teachers were trained	Same classes and teachers from school M continued their use of GS for the three subjects
	Better understanding of affordances of F2F vs online collaboration (Chen et al. 2010)	A wider repertoire of pedagogical patterns used			
July–Oct 2008	10 principles were too challenging for teachers to apply, so they were rationalized into six principles	GS lessons for P5 Science and CL	A more robust GS 2.0 version was deployed; the large amounts of classroom interaction data motivated the building and design of the analytical tool in GS	Continuous PD for the participating teachers	Same classes and teachers from school M continued their use of GS for two subjects
	Logic models were developed to explain how each principle works (Looi et al. 2010b)				

Jan–Mar 2009	Designed principles for sustaining classroom community	More pedagogical patterns experimented such as the cooperative jigsaw pattern	GS 2.0 with activity management is deployed	School M identified key GS teachers to be the pioneers to conduct PD for other teachers	Same classes from school M continued the use of GS; new cohort of Primary grade 4 and 5 teachers implemented GS lessons by using the lesson plans developed previously
				Researchers conducted PD for teachers in two secondary schools (W and F)	School M helped other schools adopt the GS innovation; their teachers did action research on GS
					GS research scale-up to two secondary schools (W and F) in three subjects
					School M, W, and F shared their GS experiences in different events/occasions
April–Oct 2009	Use of classroom data to study the RCKI principles helped sharpen understanding of the principles and conditions for their use	More diverse pedagogical patterns for secondary Science, Mathematics, and CL were designed	Analytical tool used to view interaction data; technical challenges for schools to install GS 2.0	Continued PD sessions for teachers	Same classes and teachers from three schools continued the use of GS
					Primary school M scaled to more classes and continued their sharing and helped other schools
					Secondary school F used GS for Chinese language learning and Math (two classes);
					Secondary school W used GS for Chinese language learning and Science (two classes)

(continued)

Table 7.1 (continued)

Time	Design principles	Curricular products	Technology development	Professional development	Spread of innovation
Jan–Nov 2010	Explored GS collaborative patterns further for language learning, sharpening RCKI principles, and conditions for language learning	More pedagogical patterns for language learning designed and deployed	GS in 1:1 MacBook with wireless network environment, refine GS2.0, analytic tool, and activity management	Researchers and the teachers from three schools conducted two workshops for teachers from 20 schools in Singapore	Same classes from three schools continued
					Schools F and W continued their own scalability journey on GS
				Researchers conducted PD for English and Chinese language teachers in school S	A team from MOE's Educational Technology Division worked with six other schools in Singapore on using GS for collaborative learning
Jan–Nov 2010	Explored GS collaborative and pedagogical patterns (e.g., Funnel Model) for language learning (both L1 and L2), sharpening understanding of RCKI principles, and its application to language learning	GS lessons for S1 English and Chinese (including composition, comprehension, and oral expression) were designed and enacted	Develop GS 3.0, refine GS analytical tool, and activity management	Two seed teachers (one for English and one for Chinese) altogether with the whole departments were trained on a weekly basis; their lessons were observed; post-lesson PD sessions were held	One S1 class used GS routinely for learning English and one S1 class for Chinese learning from school S

Jan–Nov 2011	GS collaborative and pedagogical patterns were further specified, implemented, and evaluated for learning composition and comprehension in the language classroom	GS lessons for S2 English and Chinese (including composition, comprehension, and oral practice) were designed and enacted	GS 3.0 and analytical tool were deployed and refined	Four seed teachers (one for English and three for Chinese) altogether with the whole departments were received PD on a weekly basis	The same English class and their new teacher used GS on a routine basis when they progressed to S2. Another two classes from the same level with the same teacher also used GS routinely in their English lessons
					The same Chinese class with the same teacher and later a new teacher continued using GS routinely when they progressed to S2
Jan–Nov 2012	GS collaborative and pedagogical patterns for language learning were refined	GS lessons for P1 English were redesigned and enacted	Refine GS 3.0, analytical tool	With assistance from the researchers, the MOE officer and the school teacher conducted PD for the whole English department	With assistance from researchers and one MOE officer, the school continued the use of GS in S1 English on their own

Updated from Looi et al. (2011)

the Foundation" for the first Masterplan/MP1 1997–2002, "Seeding Innovation" for the second Masterplan/MP2 2003–2008, "Strengthening and Scaling" for the third Masterplan/MP3 2009–2014) (MOE 2009a, b). The top-down approaches accelerate the adoption rate of technology in classrooms. Meanwhile, researchers, school practitioners, and industrial partners initiate ground-level efforts with and without support from the centralized planning agencies. As the top-down and bottom-up approaches coevolve, the use of ICT in Singapore schools becomes increasingly pervasive. With all agents accepting accountability for implementing constant checks and balances, policies become dynamic in nature so as to timely reflect the changing needs of the global landscape.

The scaling of educational innovation is not likely to succeed if perfect solutions to the nested, multifaceted, and interwoven sets of problems are expected and educators are required to choose the most appropriate innovations for specific settings (McDonald et al. 2006). In Singapore, the research communities do play a mediating role in selecting and elaborating innovative practices that reflect the goals set by the policymakers and to adapt these innovations to accommodate different school contexts. MOE intends that new concepts and methods of ICT-infused pedagogy be prototyped, piloted, and transferred to classrooms and schools. Researchers play a key role as the conduit that "provide(s) a means to re-interpret macro-level changes and to access the range of new choices that they present to subject factions and associations" (Jephcote and Davies 2004, p. 549). They undertake active research programs funded by MOE on the use of ICT in education to expose and acculturate school leaders, teachers, and students (in)to point-at-able models (i.e., demonstrable models that policymakers and practitioners can look toward as desired models) to transform their mind-sets and practices. In various school-based research projects, researchers facilitate schools to adopt and adapt the innovation, initially with researcher guidance and gradually on their own. These processes of researchers co-constructing meaning with both the policymakers and practitioners support the scalability of educational innovations in the Singapore context.

Research Trajectory of Group Scribbles

The GS innovation was conceptualized, developed, and implemented in more than ten Singapore schools following the design research approach outlined above. It helps illustrate how researchers can interface with policymakers and school practitioners to identify problems in local schools, to render plausible solutions, and to scale up to make an extensive and profound impact.

The depiction of the GS developmental trajectory is organized into four parts: the first is the identification of the problems and the underlying context, the second is GS prototype development, and the third and fourth are the implementation in a primary school M and a secondary school S. Actually, in the course of research, GS has been practiced on a routine basis in four schools. Yet due to space limitation, we only provide the stories that occurred in two schools. These two schools are selected

for closer examination because it offers the opportunity for readers to observe how the GS innovation has been implemented and assimilated in schools with different profiles (M is a typical school with average ICT resources and support, while S is a technology-rich endowed school), upon which the common and specific conditions favoring/hindering the progression of the innovative program can be distilled.

Problem and Its Context

The first endeavor the research team made was to negotiate with multiple stakeholders to identify the needs in typical Singapore schools, basing on which the prototype solution can be created. The macro-environment of the schools is shaped by MP3, the key guideline for the national educational reform. With the awareness about the goals, achievements, and gaps of MP1 and MP2, the focus of MP3 is to develop twenty-first-century competencies in students through a greater level of technological integration into school practices (MOE 2008). MP3 explicitly foregrounds a specific outcome for technology-enabled learning which is to nurture or develop students to be collaborative learners and self-directed learners. It recognizes the need to systematically address the curriculum, pedagogy, and assessment conundrum to improve school-based teaching and learning. The research team sought to work with schools to design a computer-supported collaborative learning environment that could be scaled to a wide range of school contexts to equip students with good competencies, mind-sets, and dispositions for *collaborative learning*.

Due to the explicit emphases by policymakers, there were common occurrences of the concept of "collaborative learning" in the discourse of teachers, school leaders, and other stakeholders. Formal and informal structures were gradually put in place to support teachers to practice collaboration-based pedagogies in classrooms. Yet as literature indicates, the idea of combining computer and collaboration to enhance learning however is often a challenge in school contexts (Stahl et al. 2006). Our conversations with Singapore teachers showed that they had deep concerns about pedagogical approaches that could promote student agency and social interaction because the school assessments and national examinations were still individual based and that collaborative pedagogies might not work for academically lower-achieving students. In classrooms, IRE (teacher initiation-student response-teacher evaluation) (Lossman and So 2010) was still the typical and dominant discourse pattern, and the epistemic agency still mainly rested upon the teacher.

GS Prototype Development

With an understanding of the problem, the researchers came up with the initial classroom-based collaborative learning design. As previous studies suggest, in scaling up classroom innovations, attention must be paid to the trade-off between

the degree of ambition in an innovation and its degree of elaboration (Cohen and Ball 1999; Cohen et al. 2003). All innovations are to some extent elaborated, yet vary in degree. Less elaborated innovations may only constitute goals, principles, and visions that reflect broad directions, while more elaborated ones may also include curriculum, pedagogical practices, and assessments (Cohen and Ball 2006). Innovations that are close to current classroom practices require little elaboration, yet ambitious innovations that deal with deep changes need substantial elaboration (Roschelle et al. 2008). As the GS project aimed to transform the deep-seated teacher-centric discourse pattern in classrooms (which is indeed ambitious), considerable elaboration was needed. The researchers also recognized the necessity for constant (re)elaboration as the users might reorganize the practices around them in unpredictable ways (Cohen and Ball 2006).

Conceptualizing the CSCL theory and the supportive tool is an integral part in elaborating the innovation. The researchers intended to equip students with a critical twenty-first-century competency, namely, collaborative knowledge construction. The notion of Rapid Collaborative Knowledge Improvement (RCKI) (Looi et al. 2011) for designing and implementing collaborative knowledge construction activities in classroom settings (where time constraint is a perennial issue) was derived. RCKI sought to harness the collective intelligence of groups to learn faster, to conceive new possibilities, and to reveal latent knowledge. Its techniques included problem identification, brainstorming, prioritizing, concept mapping, and action planning (diGiano et al. 2006; Looi et al. 2010b). The interactive technology incorporated to support RCKI was Group Scribbles (GS) codeveloped by LSL and SRI International (SRI International 2006; http://gs.lsl.nie.edu.sg). Based on the metaphor of "sticky notes" and "whiteboard" that both students and teachers are familiar with, GS attempted to maximize the power of digital scribbling and interactive engagement. It enabled the collaborative generation, collection, and aggregation of ideas through a shared space based upon individual effort and social sharing of notes in both graphical and textual forms.

The GS interface typically presented a two-paned window (users could slide more panes if they like): the lower pane was the personal working area or the "private board" which provided virtual pads of "scribbles" for user to draw or type; the upper pane was the public working area or the "public board" for publishing scribbles that was synchronized and shared on all learning devices (Fig. 7.1). The scribbles on the "public board" could be organized, removed, and taken back to private board for further improvement. Besides sharing ideas within the group, users could also view and act upon the scribbles published on other groups' boards by selecting the group board via the drop-down menu on the upper right corner of the window. The GS technology was highly customized as users could insert pictures, templates, and movie clips onto the public board. The essential feature of GS was the synergy of autonomous and collaborative cognition and the support for different levels of interaction (private, group, class, group/private) and the seamless switch between them.

To address engagement in online collaborative environments, mechanisms that support multimodal expression (i.e., the combination of typing, writing, and

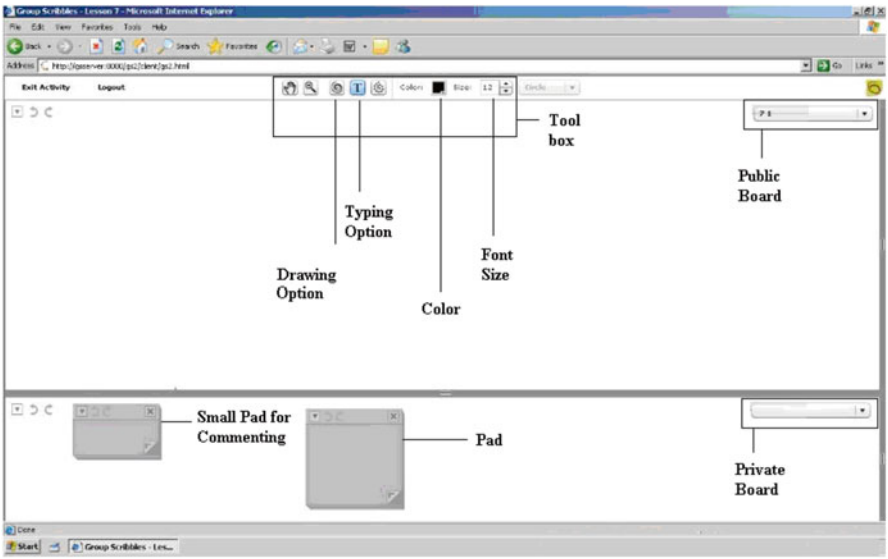


Fig. 7.1 The user interface of GS with a two-paned window

drawing) and multifaceted interactions (i.e., private interaction on GS private board, group interaction on GS group public board and/or face-to-face discussion, and intergroup/class interaction via GS) that prove effective in improving students' participation and engagement in collaborative activities (McCullough 1996; Vahey et al. 2007) were incorporated. GS was also designed to enable lightweight, paralleled, and anonymous contributions from students. The lightweightedness and parallelism in student contributions could particularly afford RCKI activities as their presence could help avoid "production blocking" (Suthers 2006) and fasten the collaborative knowledge construction processes. GS was designed to be flexible, customizable, and content independent so that teachers could improvise different collaborative patterns for students without the need for additional programming (Chaudhury et al. 2006; Roschelle et al. 2007).

First Cycles of School-Based Research in School M

With the CSCL design conceived, the research team started to work with Singapore schools to implement and iteratively improve it. The first school which GS was introduced to was a primary school M. Three cycles of design and implementation were carried out in this school. The first participants included students and science teachers from two Primary 4 classes (40 students for each class) with different profiles, one being a high-ability class led by a senior female teacher (Jeanette, who had good pedagogical knowledge but limited ICT expertise) and the other being a

mixed-ability class led by a young female teacher (Janet, who had less teaching experience but more competency in using ICTs). This implementation design enabled the researchers to examine the efficacy of the innovation for diverse user groups, basing on which they could further improve the innovation and enhance its robustness for adaptation to a broad spectrum of learning contexts. The research team followed the same cohort of students for 2 years as they progressed from Primary grade 4 to grade 6. They worked closely with the teachers to design, enact, and evaluate GS science lessons on a routine basis. The school leaders also followed and supported the project with keen interest. The Head of the Department of ICT was the key coordinator for the project. He participated in almost all the meetings and professional development sessions and sat in the GS lessons as much as he could. The school principal also participated in sessions where the researchers shared their findings with the school.

At this outset of research, the focus was to understand and cultivate the classroom culture, to codesign GS activities and integrate them into holistic lesson plans, to conduct teacher professional development, to address technical issues, and to inform the technological design. Before implementation, the researchers observed a few normal science lessons to understand the classroom culture. School leaders and teachers were also interviewed to find out more information of the students, the established curriculum, and lesson objectives. The analyses of the baseline data revealed the presence of multifaceted problems that hindered the design and implementation of collaborative pedagogies in the partner school despite the existence of some favorable conditions (e.g., support from school leaders):

- Dominance of didactic teaching: teachers still regarded standard test scores as the most valid indicator of student learning. Most curriculum time was spent on teaching content knowledge and having students do worksheets.
- Limited understanding of collaborative learning by teachers and students: teachers regarded all group work as collaborative learning despite the absence of interdependence and individual accountability. On scarce instances of group work, students would distribute the work and proceeded individually instead of negotiating to reach a common problem space and solution.
- Constrained technology integration: ICT use was still teacher directed. PowerPoint presentation was often used to display content for teaching.

Tapping on these observations and a further literature review, the research team came up with an intervention framework (please refer to Looi et al. 2011) and the corresponding implementation strategies. To address the lack of pedagogical and technological competencies in teachers, GS professional development was provided on a weekly basis to help the teachers manage the RCKI tool and pedagogy. The researchers observed all the GS lessons the teachers had enacted. These observations served as a critical reference for the post-lesson discussion during which the researchers provided timely feedback and engaged teachers in reflection and retrospection right after the lesson This critical window of sharing was not always available in other schools due to the teaching schedules of the participating teachers as they might have other lessons right after the GS lessons. The researchers

also shared with the teachers the analyses of group process data (captured by video cameras and voice recorders set up in individual groups and the screen capturing software installed on students' tablet PCs), which was a critical indicator of teacher enactment quality. All these strategies helped the teachers improved their mind-sets, competencies, and knowledge for collaborative learning (especially RCKI).

Meanwhile, prior lessons were conducted to acquaint students with practices of collaboration as the students were noted as having inadequate understanding and skills of collaboration. We called these enculturation lessons as they initiate and familiarize students to the practices of collaborative learning. During the six enculturation weeks, Post-it notes (i.e., paper scribbles) were used to mediate the collaborative learning sessions (1.5 h each week) codesigned by the teachers and researchers. Students used 3 × 5 in. Post-it® notes to interact. They contributed their ideas on their group boards and commented on other groups' ideas facilitated by the teacher. Through iterative rounds of paper scribble activities, the students were gradually acculturated into rapid collaborative brainstorming and critiquing and developed their own protocols and social etiquettes (e.g., respect each other's ideas, critique each other's work in a polite way).

Once the GS technical training (two 1-h sessions) was completed, GS was used routinely in the science lessons of the two classes for 10 weeks. There was a 1-h GS lesson in the computer lab and a 1-h traditional (non-GS) lesson each week. In GS lessons, each student was equipped with a tablet PC with GS 1.0 installed. The topics covered were in line with the standardized syllabus for Primary grade 4 curriculum (including the circulatory system, energy, light, and heat). As early as the first cycle of implementation, evidence was mined to examine the efficacy of the innovation. Student scores in the school's science summative assessments in both GS classes and non-GS classes were collected and put into comparison. The GS classes learnt the subject better than the non-GS classes as measured by the tests on mastery of content as set by the school (Looi et al. 2010a). Analysis of the process and perception data also indicated that GS facilitated students' collaborative learning and improved their epistemology and attitudes toward science learning (Looi et al. 2010a). In GS lessons, students were more engaged in peer discussion through both online-based and face-to-face discussion (Chen et al. 2010; Chen and Looi 2011).

Encouraged by the achievements made, more intensive use of GS in the science lessons was pursued in the same two classes in the second implementation cycle. Moreover, the innovation was expanded to other subjects (i.e., Mathematics and Chinese language). As more teachers were involved, a small community for sharing and supporting the innovative teaching emerged and evolved. The four participating teachers constantly discussed their lesson design and enactment. They also disseminated the innovation to other peers. With more time allocated, the students better appropriated the innovative learning practices. As the teachers reflected, the students were able to think actively, articulate ideas clearly, and critique others' work constructively. They also become more appreciative of the role technologies could play in their learning. Gradually, the individual learning-based classroom was transformed into a community of collaborators well seeped in rapid knowledge improvement practices across different curricula.

Table 7.2 RCKI design principles

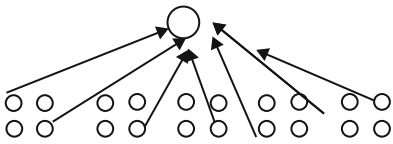
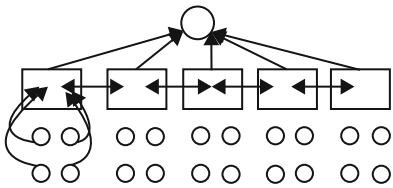
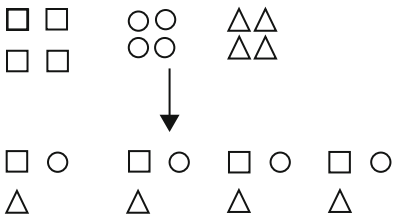
Distributed cognition – designing for thinking to be distributed across people, tools, and artifacts
Volunteerism – letting learners choose what piece of the activity they want to participate in
Spontaneous participation – designing for quick, lightweight interaction driven by student themselves
Multimodal expression – accommodating different modes of expression for different students
Higher-order thinking – encouraging skills such as analysis, synthesis, evaluation, sorting, and categorizing
Improvable ideas – providing a conducive environment where ideas can be critiqued and made better
Idea diversity – exploring ideas and related/contrasting ideas, encouraging different ideas
Epistemic agency – encouraging students to take responsibility for their own and one another's learning
Democratized knowledge – everybody participates and is a legitimate contributor to knowledge
Symmetric knowledge advancement – expertise is distributed and advanced via mutual exchanges

Table 7.3 Simplified RCKI design principles for teachers

Make everybody think, as individuals and in teams
The class accepts new ideas and constantly improves ideas
Explore many ideas, from different angles
Students take initiative for their own learning
Everybody participates actively and contributes to knowledge
Students organize their ideas and are self-reflective

During these two cycles, the researchers developed a set of RCKI design principles (Table 7.2) (Looi et al. 2010b). These generic principles were articulated to the teachers and applied to guide the design and enactment of RCKI activities for the three different subjects. After our observations of how much the teachers were able to apply and appropriate these principles, we simplified the principles and expressed them in a more comprehensible language (Table 7.3). Meanwhile, curricular products including RCKI activity designs and lesson plans were developed, evaluated, and documented in the GS website managed by the research team. Different collaborative patterns were reified as objects for further discussion (Table 7.4). These lucid patterns enabled the teachers, especially teachers coming onboard to use GS to see the set of possible collaborative patterns and consider how they might apply them to their own lessons. They constituted important resources that promoted the use and spread of collaborative activities in the classroom using GS. After more than 60 GS lessons, a mature community for collaborative knowledge construction was formed, and students could learn better within the collective.

Table 7.4 Collaborative patterns used in GS lessons

Collaborative pattern	Activity sequence	Diagrammatic representation
1. Idea aggregation	All students post on one public board	
	Teacher selects interesting posts to teach certain concepts to class	
2. Progressive collaboration	Students post individually onto respective private boards (individual)	
	Students post on their respective group boards (intragroup). They can discuss and comment on each other's postings face to face and/or through GS	
	Students do a gallery walk on other group boards to comment and discuss (intergroup). Sometimes, students can be asked to present their ideas to the class	
3. Jigsaw	Each home group is given a particular task. The task is split equally among the members of the home group. Each member is an expert in the subtask	
	The experts come together as a group, i.e., expert groups to discuss their subtasks, and post their findings onto their group boards	
	With the task is completed, the experts return to their home group to share their findings with their home group members	

On the technology aspect, there were indeed some frequent clashes of the GS system during the initial months of installation. GS 1.0 was built based on the thick Java client model, running on a Tuple Space server (normally on the teacher machine). However, as the Tuple Space server could not handle the large amount of data fetching between the students' machines and the server, it often caused the teacher machine to undergo a memory crash when the system data loading became heavy. This motivated the building of GS 2.0. GS 2.0 was coded with improved user interface, a centralized system running on a three-tier architecture, accessed by thin clients through browsers with Adobe Flash Player. As no client installation was needed, usability was enhanced.

The positive experience gained encouraged the school leaders and teachers to extend and expand the use of GS. Through continuous efforts by the researchers to develop the pedagogical and technological capacity of the school teachers and

the curricular products for RCKI, the school was able to and started to implement and scale up GS on its own. They identified the key GS teachers as the pioneers to conduct professional development for other teachers in the school. Another computer lab had installed GS to enable concurrent sessions of GS lessons. The school also adopted GS as the ICT platform for a 2-year school initiative that aimed to improve students' English literacy through their English lessons in five Primary 3 classes. For Primary 4 and 5 classes, GS was used in their science learning. At the end of the research collaboration, the school assumed ownership of the innovation and encouraged and facilitated other schools to adopt the innovation. The teachers shared their GS experiences with leaders and teachers from other schools in their school cluster in a variety of educational events organized by MOE. They also worked with the researchers to conduct a GS workshop for 30 teachers from more than ten Singapore schools in 2010. Some teachers also conducted action research and shared their findings in multiple educational conferences. All these facilitated the dissemination of the innovation. The school also helped other schools set up their own infrastructure and conduct pedagogical training for the teachers. Based on these efforts, another six schools used GS for their classroom practices with the help from the Educational Technology Division of MOE.

Cycles of School-Based Research in School S

As the partner school M continued and expanded the innovation on their own, the researchers went on to diffuse the GS innovation into two secondary schools (school F and school W) employing the same approach. Elaborations were made to accommodate the specific requirements and environments of the two schools, and the iterative cycles of implementation again brought about quite satisfying outcomes (see Table 7.1). In 2010, the GS team started to work with school S which is different from previous schools where ICT-supported teaching and learning mainly occurs within the computer labs. Instead, it provides 1:1 computing environments. On the networked campus, each and every student and teacher is equipped with a MacBook, and the teaching and learning practices in all the classrooms are delivered using various ICT platforms. As school S is one with excellent ICT infrastructure and good ICT literacy, the researchers planned a more ambitious implementation of GS.

At this stage, the focus was on elaborating and implementing GS-supported RCKI to improve language learning. In the first year, one English class and one Higher Chinese class (about 20 students for each class) and their teachers (Reid for English and Jane for Chinese, both with considerable teaching experience and good ICT competencies) were involved. As for the first few schools, the researchers started off by observing the normal (non-GS) classes to understand the participants and the environment. More information was gained through interviews with the school teachers and leaders. During these researcher-school practitioner interactions, the expectations from both sides were shared and appreciated. This built a good

foundation for collaboration. The data collected revealed that the teachers and students had good understanding and competency of collaborative learning and technology-enhanced learning and there was a strong desire to sustain and spread CSCL in the school. Students approached collaborative work as completing the tasks instead of constructing and advancing knowledge collectively. This indicated that there is a role in inculcating students with RCKI practices.

In the following, a series of preparation activities were delivered by the researchers, including GS 2.0 technical testing in wireless environment, technical training, teacher professional developments (in which the RCKI design principles and pedagogical patterns were elaborated), and student enculturation (four paper scribble lessons). When the students and teachers were ready, GS was used on a weekly basis in the two classes. The topics of instruction followed the curriculum and scheme of work used in the school. The researchers and teachers codesigned and reflected upon the GS lessons before and after the implementation.

As the teachers and students were more acculturated into the GS-based RCKI activities, the research team went for another round of implementation. In this cycle, two more classes (one for Chinese language and one for English language) and two more teachers (Jenny for Chinese and Elizabeth for English) came on board. At this moment, the research team encountered a big challenge in that the English teacher (Reid) left the school for personal reasons. The teacher (Elizabeth) replacing him was an experienced one who just joined in the school. Though Elizabeth had good pedagogical knowledge and skills, she initially held reservations toward using technology in the classroom as reflected in the interview. Understanding this, intensive professional developments were delivered to familiarize Elizabeth with GS. And to further encourage her, the whole English department was invited to join the sessions. Though the same problem was not met in the Chinese department, the researchers also expanded the professional development to the whole department to prepare for any potential departure of the seed teachers. This strategy adopted played a critical role in maintaining and radiating the innovation as there was frequent teacher turnover in the school S.

During the second cycle, 12 Chinese and 7 English GS lessons focused on collaborative writing were implemented and found effective. The researchers modified the RCKI principles to suit the specific demands and features of language learning and derived some pedagogical models (e.g., Funnel Model, Wen et al. 2011). The researchers also compared the enactments of the GS activities by different teachers (Wen et al. 2012b) and student groups (Xie et al. 2012) and examined their impact on students' learning outcomes and perceptions. The factors that could facilitate or impede the implementation of the innovation were subsequently identified. GS technological development was also attained. Based on teacher feedback, evaluating students' participation, engagement, and work quality was a big challenge in the class given the short class time. The research team thus decided to embed an analytical tool in GS 3.0 to help the teachers monitor and manage students' collaboration. The analytical tool could support real-time display of the frequency of different types of student actions (i.e., publishing scribbles) and the number and content of scribbles generated using multiple forms of visualizations (i.e., line charts).

At the very start of the third cycle, one of the seed Chinese teachers (Jane) also left the school. Yet the use of GS was continued in the two Chinese classes, thanks to the strategy of expanding school-based professional development in the previous cycle. Jenny, who did not start off well in enacting GS activities (e.g., she did not provide sufficient encouragement and guidance to students), was more confident and competent in enacting GS lessons with the intensive pedagogical training and lesson discussion. In this cycle, she played a key role in maintaining the innovation and inspiring and facilitating other Chinese teachers (especially Anna, the new teacher who replaced Jane). At this moment, a new issue emerged. The students become bored with using technology in the classroom. Unlike the students in normal schools who found technology a new ingredient in their learning and were usually fascinated about it, the students in the schools with richly endowed IT provisions sometimes dislike the use of technology due to the long-term and intensified interactions with the computers both in and out of school. The negative attitude was observed as the students progressed into Secondary Two (when they had already used GS for 1.5 years on a routine basis). This became the obstacle of the GS lessons as reflected in the sometimes reduced student participation and engagement. Some students even mentioned that they missed the paper scribble lessons. Though somewhat discouraged, the research team regarded this phenomenon as natural as there always exists a "U-shaped" developmental trajectory in being acculturated into any new type of culture (e.g., cross-cultural adaptation, Kim 2001). To solve this "boredom" issue, more diversified activity designs were used, and more topics were engaged (including writing, comprehension, and oral expression). Other ICT platforms (e.g., Google Docs) were incorporated into GS lessons. As observed, the GS had good compatibility with other platforms for its generality and flexibility. This further improved its scalability.

Subsequently, the sustaining and scaling of GS were gradually shifted to the school side as the mind-set and capacity for RCKI had already been established. Though the second seed English teacher (Elizabeth) also left the school, GS was continuously used. Another teacher (Charles) who had gone through the GS professional developments in the second cycle introduced the use of GS to Secondary 1 classes. Though the research team decreased their presence in the school, they also made their contribution in terms of developing the system and pedagogical supports. GS 3.0 was finalized and installed in the school. The analytical tool was further enhanced by integrating peer rating, a mechanism that found beneficial to students' learning. To reduce the burden on the server, the GS online version (GS Lite) was developed and released. To help the teachers and students better reflect on their performance and track their progress, My Collection, a student learning portfolio where student-generated artifacts were chronologically documented and could be annotated upon, was developed. With regard to pedagogical development, a GS teacher handbook that articulated the RCKI principles, collaborative patterns, and activity design was composed and shared with the school.

Scaling Up GS to Different Schools: Commonality and Specificity

A tailored model approach to scale-up has different requirements in each implementation site for integrating GS into their lessons. The trajectory of research in different schools has led us to build up a set of design principles, a set of teacher's orchestration skills (Dillenbourg 2009), and curricular products and resources. These reifications provide the basis for new teachers coming on board to use GS to have access to information on the essential features of the innovation, enabling them to focus on how they might adapt or adjust for their own school, class, and subject environment.

Reflecting upon the whole process of moving the discourse of RCKI from the research lab to different school sites, the research team has identified the favorable conditions and challenges for scaling up educational innovations in school settings, some of which are common across schools and some of which are specific to individual schools. We first look at the common agencies and resources engaged. Firstly, in all the partner schools, there existed a strong desire and commitment for innovation from not only the research team but also the school practitioners. Responding to the policy directives, the school leaders played a driving force for transforming the traditional teacher-centric, individual-based classrooms into student-centric, collaborative classrooms. Under such supportive leadership, teacher involvement in the design and implementation of the innovation with the researchers was recognized and rewarded. This promoted the generation of solutions that catered to the school's practical needs. Secondly, there is the comprehensive intervention approach adopted by the researchers. To sustain and scale the implementation of the innovation, the researchers strived to improve a set of interrelated factors that impact classroom practices including curriculum integration, pedagogical practices, teacher knowledge, technical infrastructure, and other logistical and social support. Professional developments were intensively and extensively conducted to improve teachers' understanding of RCKI, its related design principles, and its supporting tool. Various pedagogical patterns and activity designs were established to help teachers design and enact GS lessons.

Another contributing factor for the GS success was the down-to-earth and step-by-step working philosophy adopted by both the researchers and school practitioners. As both sides realized that cultural change would require long-term immersion in the communities and practices of the target culture, iterative implementation on a routine basis to acculturate users was prioritized. This gradual change helped ameliorate the inertia when the change was introduced. In this prolonged process, more problems were exposed and addressed. The innovation was constantly adapted and tested in more contexts as the classroom social structure was dynamic. These all improved the robustness and adaptability of the innovation and thus facilitated its scaling.

When a school responded well with the implementation of GS, the seeds of an innovative mind-set were sown. The importance of establishing an innovative mind-set is being recognized in the CSCL community (e.g., Roschelle et al. 2011). In this perspective, classes and schools are viewed as an ecological and evolving system with potentials to change, and school leaders and teachers can and should be the source of the driving forces for the modifications and renovations of the structure and culture of schools and classes. Instead of being passive recipients of innovative programs delivered by the external providers (e.g., researchers), school practitioners who have the best understanding of the ecological system, among all the stakeholders, can become the champions (Carlson and Wilmot 2006) who guide teams to create new educational value based on the innovation in their respective schools and classrooms (Roschelle et al. 2011). The affordances of the innovative programs are not designed by the external providers but are enacted by the school practitioners in their own dynamic contexts of teaching and learning. Once such innovative mind-sets are established as observed in the partner schools, the ecological system in the school will become self-organized to harness the innovations to accommodate the changing priorities and requirements from both the outside and within.

From the innovation perspective, the roles that educational researchers play are also enriched through design-based implementation research. They are not necessarily "transferring" or delivering innovative programs to the class but in essence guiding the school practitioners to appropriate the innovations to afford their educational objectives. To achieve this, researchers need to provide "compound resources" that involve substantial configuration, elaboration, and organization in classrooms and schools rather than solely providing the technological or pedagogical developments (i.e., the "simple resources") (Grubb 2009; Roschelle et al. 2011). These processes are reciprocal in nature and are also beneficial to researchers as they can further improve the robustness of the innovation through observing its adoption and functioning in the field outside of controlled or laboratory settings. A productive view of scaling from a bottom-up perspective is thus one of researchers providing the compound resources for schools to take ownership, to adopt innovative mind-sets, and to innovate with these resources.

Besides the favorable conditions, there also existed some barriers that were universal to all the schools. One of the common challenges was the need for teachers' competencies to solve the operational problems when implementing the innovation in the classroom. Following the DBR approach, the innovative teaching and learning practices were codesigned, co-implemented, and co-evaluated by both the teachers and researchers. The effectiveness of the innovation ultimately depended on how well the practitioners enacted it. The teaching and learning practices in the classroom settings were dynamic processes encompassing multiple interrelated factors. No matter how well the lesson plans were elaborated, the enactment quality might be eroded due to unexpected deviations (Looi and Song 2013). It was the teachers' capacity to orchestrate (i.e., to coordinate activities in an environment plagued by multiple constraints such as the classroom management problems, curriculum and assessment requirements, tight schedules, students' learning spaces and needs, etc.)

(Dillenbourg 2009) that predicted the impact of the elaborated design. As reflected in literature, the improvement in teacher enactment is usually a long-term process. Only when iterative design, enactments, and reflections were conducted would the teachers appropriate the practices intended. Therefore, at the initial phases of change, frustration and suspicion from the teachers and students usually plagued, and how to deal with these negative sentiments was indeed challenging. Another common challenge faced when teachers implemented GS lessons was the lack of time. Many teachers mentioned that "GS lessons take more time to prepare," and "insufficient time factored into the timetable to complete a GS lesson." This is not peculiar to GS lessons but for all ICT-based lessons. Teachers reflected that GS lessons could have had better impact on student learning if the lesson duration could be longer than 1 h so that more time could be given for consolidation and reflection. However, the timetable was beyond the teacher's control.

Except for the commonalities, the ingredients for success and challenge also differed in different school sites. In school S, the good ICT provision and application greatly benefited the smooth implementation of the innovation. Alongside the "hardware," the school also provided good "software" for the project. In the school, there was a technical support unit, and resources from this unit were assigned to the GS project. The technical support team held responsibility for setting up the environment, maintaining the system, collecting and transferring the data, and on-site problem shooting during the GS lessons. When the research team left the school, the school technical team took over the role of conducting GS technical training for new users and supporting the implementation of GS lessons. In school M, participants of diversified profiles were involved in the innovation. This enabled the researchers to examine the effectiveness of the innovation for a wide range of audiences.

With regard to challenges, in the primary school M whose structure and setting were more traditional, the limited ICT resource was a big constraint. As GS could only be accessed in the computer labs, the number of classes who could use the innovation was restricted, which to a great extent hampered the scaling of the innovation. In contrast, though the ICT provision was extensive in the secondary school S, the intensive exposure to ICTs resulted in new issues that might disrupt the implementation (e.g., teachers and students having a sense of "ICT fatigue"). Localized contextual conditions from a school site may therefore affect the implementation of an innovation in ways that might not be easily foreseen at the outset.

Conclusion

The GS developmental trajectory started off with a DBR approach in 2007. In retrospect, it also reflected some intentions of DBIR (though the term DBIR did not quite appear at the outset of the research). At the very beginning, the researchers planned for usability, sustainability, and scalability. Through iterative elaboration and implementation, the GS innovation has been successfully adapted to a cluster of schools which provided different contexts and local adaptability for RCKI. It might

be said that the systemic context of the schools was the same under the same centralized education system, but with these systemic constraints, the schools had different material contexts (such as the school ICT facilities and infrastructure), social contexts, and different degrees of agency and capacity among the teachers, students, administrators, and school leaders. Despite these contextual-based differences, a same positive impact has been created in each school. It demonstrates that the GS innovation is supple enough to maintain robustness in the context of different situational variables.

The journey of successive and effective implementations in different schools enabled us to demonstrate adaptability of the GS innovation with each new school as its new context. In DBR, DBIR, and scaling literature, the significance of generating an innovation that is of good adaptability so as to accommodate the opportunities and challenges of a local context has been long acknowledged. The researchers in the GS project have attached great importance to enabling the "variable" part of the design to enhance adaptation. The collaborative tool envisioned is generic. It is based on a daily metaphor of "sticky notes" and "whiteboard" that both students and teachers are familiar with and is used in many different settings. Its simplicity and flexibility has facilitated the adoption of and mastery over the tool by a large audience with different profiles. The collaborative patterns and pedagogical designs developed mainly prescribe the patterns of social interactions by the students and are therefore domain independent and can be used across classrooms of different subjects.

While focusing on "variability," the research team also highlighted the core, the "invariant," or the "nonnegotiable" aspects of the innovation when being implemented in different schools, and this strategy has been demonstrated to be necessary to ensure that the adaption is productive and there is no lethal mutation. As most ICT-based educational innovations, the teaching and learning experience enacted in the GS lessons is quite deviant from the traditional lesson that the teachers and students are comfortable with. Such evocative, theory-based practices need to maintain its core philosophy and central principles (McLaughlin 1990) to accomplish the intended outcomes. In the GS project, the core part (i.e., RCKI theory and design principles) has been established and continuously strengthened, and the adherence to the core has helped avoid the GS impact being dampened by the local constraints. This implementation and scale-up approach reflects "assimmodation" proposed by Diebold et al. (2000) that advocates the balance of assimilating innovations into existing structures and accommodations of the structures to integrate the key elements of the innovation. Given the revolutionary nature of the innovation, the researchers need to lead the fashion, especially at the beginning stage.

As noted by Barab and Squire (2004), demonstrating local consequence and utility is necessary but not sufficient as design scientists need to draw connections to theoretical assertions and claims that transcend the local context. Through the processes of school-based research, the theory of RCKI has been refined to achieve better understanding of the design principles (Looi et al. 2010b). From the practice perspective, the range of collaborative patterns and repertoires used in the classroom for different subjects has been broadened (Wen et al. 2012a). In addition to the

school implementation work, in the National Institute of Education, GS pedagogy was introduced to many cohorts of preservice teachers taking the LST AG core Instructional Technology and ICT for Meaningful Learning modules over the years, thus creating awareness of teachers about the potential of using GS. With the advent of new web-based applications and tools, teachers have also tapped on off-the-shelf products like www.padlets.com and www.linoit.com to implement RCKI lessons.

Another mechanism critical to the GS success is the gradual development of mind-sets and capacities in teachers to design and enact RCKI activities via teacher professional developments and the establishment of a teacher community of practicing GS. Educational innovations are predominantly depending on human operators rather than technologies (Elias et al. 2003). Understanding the important role of teachers, GS researchers have struggled to improve the pedagogical and technological knowledge and skills of CSCL (RCKI). It should be noticed that the efforts did not only direct at the participating teachers but at a large pool of teachers as far as the research team can reach. This is deemed fundamental to scaling as each teacher has to independently appropriate the innovation given the complexity of the systems in which classrooms exist, the separateness of these classrooms, and the private nature of the activity of teaching (Marnie and Dylan 2009). Apart from researcher coaching and consultation, the school teachers' knowledge and expertise are also key in diffusing the innovation. In the GS project, the researchers have set up a teacher forum on the GS website to facilitate the sharing and discussion among the teachers. This strategy has provided both technical and emotional support for the teachers.

In summary, a case study of Group Scribbles, a DBR to scale up CSCL in Singapore primary and secondary schools, has been delineated and discussed in this chapter. GS has shown great impacts on improving classroom teaching and learning and huge potentials to be further scaled up. It is believed that reviewing and reflecting upon the developmental trajectory of the GS project can shed light on how to translate and transfer innovative classroom practices from its original sites to more schools, a challenge that proves difficult yet essential in enabling large-scale, systemic, and profound change.

References

Barab, S., & Squire, K. (2004). Design-based research: Putting a stake in the ground. *Journal of the Learning Sciences, 13*(1), 1–14.

Carlson, C. R., & Wilmot, W. W. (2006). *Innovation: The five disciplines for creating what customers want*. New York: Crown Publishing Group.

Chang, H., Henriquez, A., Honey, M., Light, D., Moeller, B., & Ross, N. (1998). *The Union City story: Education reform and technology-Students' performance on standardized tests* (Technical Report). New York: EDC/Center for Children and Technology.

Chaudhury, S. R., Roschelle, J., Patton, C., Brecht, J., DiGiano, C., Schank, P., & Tatar, D. (2006, November 9–12). *Coordinating student learning in the collaborative classroom with interactive technologies*. Poster presented at the 3rd International Society for the Scholarship of Teaching and Learning (IS-SOTL) conference, Washington, DC.

Chen, W., & Looi, C. K. (2011). Active classroom participation in a Group Scribbles primary science classroom. *British Journal of Educational Technology, 42*(4), 676–686.
Chen, W., Looi, C. K., & Tan, S. (2010). What do students do in a F2F CSCL classroom? The optimization of multiple communications modes. *Computers & Education, 55*(3), 1159–1170.
Clarke, J., & Dede, C. (2009). Design for scalability: A case study of the river city curriculum. *Journal of Science Education and Technology, 18*(4), 353–365.
Clarke, J., Dede, C., Ketelhut, D. J., & Nelson, B. (2006). A design-based research strategy to promote scalability for educational innovations. *Educational Technology, 46*(3), 27–36.
Cobb, P. A., Confrey, J., diSessa, A. A., Lehrer, R., & Schauble, L. (2003). Design experiments in educational research. *Educational Researcher, 32*(1), 9–13.
Coburn, C. (2003). Rethinking scale: Moving beyond numbers to deep and lasting change. *Educational Researcher, 32*(6), 3–12.
Cohen, D. K., & Ball, D. L. (1999). *Instruction, capacity, and improvement* (No. CPRE Research Report No. RR-043). Philadelphia: University of Pennsylvania, Consortium for Policy Research in Education.
Cohen, D. K., & Ball, D. L. (2006). *Educational innovation and the problem of scale*. Retrieved on October 15, 2013, from http://www.sii.soe.umich.edu/documents/CohenBallScalePaper.pdf
Cohen, D. K., Raudenbush, S., & Ball, D. L. (2003). Resources, instruction, and research. *Educational Evaluation and Policy Analysis, 25*(2), 1–24.
Dede, C., Honan, J., & Peters, L. (Eds.). (2005). *Scaling up success: Lessons learned from technology-based educational innovation*. New York: Jossey-Bass.
Diebold, C., Miller, G., Gensheimer, L., Mondshein, E., & Ohmart, H. (2000). Building an intervention: A theoretical and practical infrastructure for planning, implementing, and evaluating a metropolitan-wide school-to-career initiative. *Journal of Educational and Psychological Consultation, 11*, 147–172.
diGiano, C., Tatar, D., & Kireyev, K. (2006). Learning from the post-it: Building collective intelligence through lightweight, flexible technology. In *Conference on computer supported cooperative work companion, Banff*. Retrieved on December 16, 2010, from http://groupscribbles.sri.com/publications.html
Dillenbourg, P. (2009). *Exploring neglected planes: Social signals and class orchestration*. Retrieved on June 30, 2010, from http://www.isls.org/CSCL2009/Dillenbourg.htm
Elias, M. J., Zins, J. E., Graczyk, P. A., & Weissberg, R. P. (2003). Implementation, sustainability, and scaling up of social emotional and academic innovations in public schools. *School Psychology Review, 32*(3), 303–319.
Elmore, R. F. (1996). Getting to scale with good educational practice. *Harvard Educational Review, 66*(1), 1–26.
Fisher, C., Dwyer, D., & Yocam, K. (Eds.). (1996). *Education and technology: Reflections on computing in classrooms* (Jossey-Bass education series). New York: Jossey-Bass.
Fishman, B. (2005). Adapting innovations to particular contexts of use: A collaborative framework. In C. Dede, J. Honan, & L. Peters (Eds.), *Scaling up success: Lessons learned from technology-based educational innovation* (pp. 48–66). New York: Jossey-Bass.
Grubb, W. N. (2009). *The money myth: School resources, outcomes and equity*. New York: Russel Sage Foundation.
Haertel, G. D., & Means, B. (2003). *Evaluating educational technology: Effective research designs for improving learning*. New York: Teachers College Press.
Jephcote, M., & Davies, B. (2004). Recontextualizing discourse: Exploring the meso-level. *Journal of Education Policy, 19*(5), 547–564.
Kim, Y. Y. (2001). *Becoming intercultural: An integrative theory of communication and cross-cultural adaptation*. Thousand Oaks: Sage.
Lagemann, E. (2000). *An elusive science: The troubling history of education research*. Chicago: The University of Chicago Press.

Liew, W. L. (2013). *Development of 21st century competencies in Singapore*. Presentation at OECD-CCE-MOE "Educating for Innovation" Workshop, 15 January 2013. Retrieved on March 17, 2014, from http://www.oecd.org/edu/ceri/02%20Wei%20Li%20Liew_Singapore.pdf

Lin, C., Chen, W., Yang, S., Xie, W., & Lin, C. (2013). Exploring students' learning effectiveness and attitude in Group Scribbles-supported collaborative reading activities: A study in the primary classroom. *Journal of Computer Assisted Learning*. doi:10.1111/jcal.12022.

Looi, C. K., & Song, Y. (2013). Orchestration in a networked classroom: Where the teacher's real time enactment matters. *Computers & Education, 65*(2), 510–513.

Looi, C. K., Chen, W., & Ng, F. K. (2010a). Collaborative activities enabled by Group Scribbles (GS): An exploratory study of learning effectiveness. *Computers & Education, 54*(1), 14–26.

Looi, C. K., Chen, W., & Patton, C. (2010b, September–October). Principles and enactment of rapid collaborative knowledge building. *Educational Technology Magazine*, 26–32.

Looi, C. K., So, H. J., Toh, Y., & Chen, W. (2011). The Singapore experience: Synergy of national policy, classroom practice and design research. *International Journal of Computer-Supported Collaborative Learning, 6*(1), 9–37.

Lossman, H., & So, H. J. (2010). Toward pervasive knowledge building discourse: Analyzing online and offline discourses of primary science learning in Singapore. *Asia Pacific Education Review, 11*(2), 121–129.

Marnie, D., & Dylan, W. (2009). Tight but loose: A conceptual framework for scaling up school reforms. In E. C. Wylie (Ed.), *Listening, learning, leading research report* (RR-08-29). Princeton: ETS.

McCullough, M. (1996). *Abstracting craft: The practiced digital hand*. Cambridge: MIT Press.

McDonald, S.-K., Keesler, V. A., Kauffman, N. J., & Schneider, B. (2006). Scaling-up exemplary interventions. *Educational Researcher, 35*(3), 15–24.

McLaughlin, M. W. (1990). The rand change agent study revisited: Macro perspectives and micro realities. *Educational Researcher, 19*(9), 11–16.

Means, B. (1994). *Technology and education reform: The reality behind the promise* (1st ed.). San Francisco: Jossey-Bass.

Ministry of Education Singapore. (2008). *Opening address by Dr Ng Eng Hen, Minister for Education and Second Minister for Defence at the International Conference on Teaching and Learning with Technology (iCTLT)*. Retrieved on December 6, 2010, from http://www.moe.gov.sg/media/speeches/2008/08/05/opening-address-by-dr-ng-eng-h-1.php

Ministry of Education Singapore. (2009a). *Third Masterplan of ICT use in education.* Retrieved on October 10, 2012, from http://www.moe.gov.sg/media/press/2008/08/moe-launches-third-masterplan.php

Ministry of Education Singapore. (2009b). *ICT connection – Harnessing ICT, transforming learner.* Retrieved on November 17, 2012, from http://ictconnection.edumall.sg/cos/o.x?c=/ictconnection/pagetree&func=view&rid=665

Nelson, B. C., Ketelhut, D. J., Clarke, J., Dieterle, E., Dede, C., & Erlandson, B. (2007). Robust design strategies for scaling educational innovations: The River City MUVE case study. In B. E. Shelton & D. Wiley (Eds.), *The design and use of simulation computer games in education* (pp. 209–231). Rotterdam: Sense Publishers.

Penuel, W. R., & Fishman, B. J. (2012). Large-scale science education intervention research we can use. *Journal of Research in Science Teaching, 49*(3), 281–304.

Penuel, W. R., Fishman, B. J., Cheng, B. H., & Sabelli, N. (2011). Organizing research and development at the intersection of learning, implementation, and design. *Educational Researcher, 40*(1), 331–337.

Perkins, D. N. (1985). The fingertip effect: How information-processing technology shapes thinking. *Educational Researcher, 14*(7), 11–17.

Rittel, H., & Webber, M. (1994). Dilemmas in a general theory of planning. *Policy Sciences, 4*, 155–169. In N. Cross (Ed.), *Developments in design methodology* (pp. 135–144). Chichester: Wiley.

Roschelle, J., Tatar, D., Chaudhury, S. R., Dimitriadis, Y., Patton, C., & DiGiano, C. (2007). Ink, improvisation, and interactive engagement: Learning with tablets. *Computer, 40*(9), 38–44.

Roschelle, J., Tatar, D., & Kaput, J. (2008). Getting to scale with innovations that deeply restructure how students come to know mathematics. In A. E. Kelly, R. Lesh, & J. Y. Baek (Eds.), *Handbook of design research methods in education* (pp. 369–395). New York: Routledge.

Roschelle, J., Patton, C., Schank, P., Penuel, W., Looi, C. K., & Dimitriadis, Y. (2011). CSCL and innovation: In classrooms, with teachers, among school leaders, in schools of education. In *Proceedings of connecting computer-supported collaborative learning to policy and practice: CSCL2011 conference proceedings* (pp. 1073–1080). Hong Kong: ISLS.

Sabelli, N., & Dede, C. (2001). *Integrating educational research and practice: Re-conceptualizing goals and policies: "How to make what works, work for us?"*. Retrieved on October 15, 2013, from http://www.forschungsnetzwerk.at/downloadpub/2001_sabelli_policy.pdf

Sandholtz, J., Ringstaff, C., & Dwyer, D. C. (1997). *Teaching with technology: Creating student-centered classrooms*. New York: Teachers College Press.

SRI International. (2006). *Tuple Spaces project: GroupScribbles innovation*. Retrieved on January 10, 2010, from http://groupscribbles.sri.com/download/papers/GroupScribblesBrochureLong.pdf

Stahl, G., Koschmann, T., & Suthers, D. (2006). Computer supported collaborative learning: An historical perspective. In K. Sawyer (Ed.), *Cambridge handbook of the learning sciences* (pp. 409–426). New York: Cambridge University Press.

Suthers, D. D. (2006). A qualitative analysis of collaborative knowledge construction through shared representations. *Research and Practice in Technology Enhanced Learning, 1*(2), 1–25.

U.S. Department of Education. (2010). *Transforming American education: Learning powered by technology*. USA's National Educational Technology Plan (2010). Retrieved on October 15, 2013, from https://www.ed.gov/technology/netp-2010

Vahey, P., Tatar, D., & Roschelle, J. (2007). Using handled technology to move between private and public interactions in the classroom. In M. van't Hooft & K. Swan (Eds.), *Ubiquitous computing in education: Invisible technology, visible impact* (pp. 187–210). Mahway: Lawrence Erlbaum Associates.

Wen, Y., Looi, C. K., & Chen, W. (2011). Towards a model for rapid collaborative knowledge improvement in classroom language learning. In S. Hans, S. Gerry, M. Naomi, & L. Nancy (Eds.), *Connecting research to policy and practice: Proceedings of CSCL 2011* (pp. 836–851). Hong Kong: ISLS.

Wen, Y., Looi, C. K., & Chen, W. (2012a). Supporting teachers in designing CSCL activities: A case study of principle-based pedagogical patterns in networked second language classrooms. *Educational Technology and Society, 15*(2), 138–153.

Wen, Y., Chen, W., & Looi, C. K. (2012b). Comparing enactments of a collaborative writing activity in a networked language learning classroom. In G. Biswas et al. (Eds.), *Proceedings of the 20th international conference on computers in education*. Singapore: Asia-Pacific Society for Computers in Education.

Wiske, M. S., & Perkins, D. (2005). Dewey goes digital: Scaling up constructivist pedagogies and the promise of new technologies. In C. Dede, J. Honan, & L. Peters (Eds.), *Scaling up success: Lessons learned from technology-based educational innovation*. New York: Jossey-Bass.

Xie, W., Chen, W., Wen, Y., & Looi, C. K. (2012). Reasoning and reformulating for linguistic knowledge improvement: A comparative case study in CSCL classrooms. In G. Biswas et al. (Eds.), *Proceedings of the 20th international conference on computers in education*. Singapore: Asia-Pacific Society for Computers in Education.

Chapter 8
Seeding a Curricular Innovation from One School to Five Schools: A Case Study from Singapore

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Abstract Scaling up curricular innovations is inherently complex. The scaling complexity comes from not only the influences arising from policy imperatives, government, or other top-level support but also the uptake of the practitioners. In the literature, factors that affect the degree of uptake and scale-up of innovations have been frequently discussed. However, evidence is lacking from scaling practices in specific contexts. Few studies have discussed the relationship between the application of scaling strategies and patterns, and the transformation of teaching and learning. This chapter presents a 6-year innovation scaling in one school and the continuous scaling to another five schools in order to paint a picture on how scaling practitioners design and implement the scaling strategies to promote teacher adoption and adaption of the innovation (the Mobilized 5E Science Curriculum, M5ESC). We first review literature that addresses mobile learning in science education, scale-up challenges and perspectives, and evidence-based scaling for framing the scale-up strategies of the innovation. Then we describe the scaling progression of the M5ESC innovation that encompasses intraschool and interschool scaling phases. Finally we draw some implications from the outcomes of the scaling progression at the interschool level.

Introduction

In the context of Singapore, the initiative of the government's third Masterplan (mp3) for information and communications technology (ICT) in education (MOE 2008) provides a policy imperative for teachers and schools to conduct sustainable curricular innovations for efficacious use of ICT in teaching and learning. The

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emphasis is on integrating ICT into curricula through developing new pedagogies and cultivating twenty-first-century competencies. Practice-based professional development models are integral to improving the adaptation of the ICT-supported curricula by teachers and for improving the sharing of best practices and successful innovations. Following this initiative, ICT-supported curricular innovations have been developed and implemented in various subjects and grade levels in Singapore schools (Looi et al. 2009; Sun and Looi 2013; Wong et al. 2011), especially in future schools. In Singapore, these future schools are developed to serve as peaks of excellence in an ability-driven education paradigm and to encourage innovation and enterprise in schools (MOE 2008). These schools will not only enhance the diversity of educational offerings to cater to learners' needs but also provide possible models for the seamless and pervasive integration of curricular innovation that can be shared and implemented in more contexts – a process which is typically referred to as "scaling."

Scaling is identified as "the practice of introducing proven interventions to new settings with the goal of producing similarly positive effects in larger, more diverse populations" by McDonald et al. (2006). In a wider context, scaling has become an important agenda for international education researchers and practitioners to enable innovations to become widespread (Kezar 2013; Scherrer et al. 2013; Smith and Petersen 2011). Yet, the complication and complexity of scaling innovations have been discussed for long. The study of scale-up in education is still under-theorized and under-explored (Lynch et al. 2012). Current literature discusses issues about scaling educational innovation and possible ways to address them (Clarke and Dede 2009; Elmore 1996; Klingner et al. 2013). There is not only one model for successful scaling – there are probably as many scaling models as there are the unique contexts (Leusner et al. 2008). Thus, the scale-up of innovation does not mean one-to-one mapping of the successful scaling model. Factors in the innovation context need to be considered in more specific ways. The scaling process can be complicated due to not only the daunting number of classrooms but also the complexity of the systems in which classrooms are situated, the distinctiveness of these classrooms, and the private nature of the activity of teaching which means that each and every teacher has to interpret and implement the innovation in his/her classroom alone (Thompson and William 2007).

To describe the innovation scale-up in the educational context of Singapore, as well as to inform both theoretical and practical studies on scale-up of educational innovations, we investigated the scaling process of the innovation which first took place in a future school and then in five government schools. We focus on the developmental process of a curricular innovation scaling with the purpose of illustrating how an innovation can be scaled across grades and schools in the context of Singapore schools. We also present the scaling process of the innovation both within a school and cross schools with a focus on the discussion of the strategies adopted for scaling, especially for the establishment of a teacher learning community. The chapter is organized as follows: we first discuss the literature for mobile learning in science education and for the scaling-up of evidence-based practices. We then provide the contextual information of the development of the seamless learning

curricular innovation, namely, Mobilized 5E Science Curriculum (M5ESC). We next provide a narration of the scaling progression of the innovation within and cross schools. The interpretation of the scaling progression focuses on elaborating upon the stage-based scaling pattern, the strategies used in building the teacher learning community, the outcomes of implementing the innovation, and the customization of the innovation based on the readiness and needs of different schools. The initial scaling results are also discussed.

Literature Review

Mobile Learning in Science Education

With mobile technology, the science learning environment can be mobilized and moved with the students to the field site, to the laboratory and beyond (Martin and Ertzberger 2013). The extension of the learning environment enables students to investigate more science phenomena in real life and to demonstrate principles and scientific knowledge in different contexts other than the laboratory (Shih et al. 2010). Furthermore, social networking opens up opportunities for students to do socially mediated knowledge-building associated with learning science by doing science at anytime and anywhere. Science projects using mobile technology have demonstrated the merits of mobile learning and its learning effectiveness for students (Pea and Maldonado 2006).

Ahmed and Parsons' (2013) study focused on using a mobile learning system ThinknLearn for supporting students' abductive science inquiry throughout the process of exploration, examination, selection, and explanation. The findings suggested that with mobile learning, students improved in their skills on generating hypotheses and critical thinking skills. In another study, a mobile plant learning system (MPLS) was used for supporting students' outdoor investigation of plants through searching, creating, and sharing the knowledge of plants. The study revealed that MPLS helped students to acquire knowledge, stimulated their motivation and enthusiasm for engaging in outdoor mobile learning, as well as promoted social interaction and discussion about the course materials (Huang et al. 2010). In Ruchter, Bernhard, and Geigers' study on the investigation of mobile computers in environmental education, the mobile tour system boosted student's learning about environmental literacy as well as their learning attitudes and motivation (Ruchter et al. 2010). Song et al. (2012) proposed a goal-based approach to design a mobilized curriculum to guide students' personalized inquiry learning of primary science. The approach has been verified with evidence that showed students' acquiring scientific knowledge and developing self-directed learning skills. These studies collectively point toward the particular role that mobile learning can play in science education and that the combination of mobile learning system/apps and the appropriate pedagogical approaches (e.g., inquiry-based principles) could have special educational value for students' science learning related to knowledge, skills, competences, and attitudes.

However, mobile learning studies typically focused on either formal or informal settings and failed to examine the integrated and synergetic effects of linking these two contexts or environments of learning (Beale 2006; Sharples 2006). Given the increasingly pervasive and ubiquitous nature of mobile technology, it has now arrived at a point where it is becoming more affordable for students to possess and use these tools in both formal and informal settings. However, a large research gap exists. There is the need to bridge the formal and informal settings in order to construct a seamless learning environment and to conduct longitudinal studies to explore the affordances of such learning environments in promoting twenty-first century knowledge, skills, and attitudes toward learning (Looi et al. 2010a, b). The M5ESC was thus developed and scaled for addressing the above issues.

Challenges and Perspectives in Scaling Practice

In this literature review, we briefly scan the key challenges and perspectives to scaling. One of the issues faced lies in the tension between the desire to scale effective practice, on the one hand, and the issues of adaptation and customization, on the other (Honey and McMillan-Culp 2000). According to Ball and Cohen (1999), this challenge can be analyzed in terms of specifications versus development. Specification is the degree of details an innovation is described in for school take-up, while development refers to the provision of resources required to enact innovations. Specification without development requires teachers to figure out how to enact the innovation in their local settings, which can be a barrier to the teachers who are the practitioners of the innovation. Development without specification provides resources for improvement, but a clear picture of what goals are to be attained is missing. Therefore to bring about change requires strong leadership and astute management (Fullan 2002). Such daunting task may not seem palatable at the onset to many schools and policy leaders. Hence, scaling practice requires not only the holistic view of the innovation but also the detailed strategies for supporting the practitioners to adopt and then adapt the innovation in their own contexts.

One strategy proposed by Hargreaves and Fink (2004) is to use model successes to reculture as well as to restructure schools, i.e., to adopt the philosophy and intentions into the existing culture of the adventurous volunteer schools before enacting the structures for change. The goal of systemic innovations must first be established in the larger cultural context so that it becomes an "entire continent of change" (Hargreaves et al. 1996). It is argued that educators should go beyond the policy makers by making their practices and improvements visible to the public so that a broad social movement for large-scale, deep, and sustainable transformation can be created (Hargreaves 2001). Concomitant to this notion, Cuban, in an interview with John O'Neil (2000), highlighted that the innovations that have the best chance of sticking are those that have constituencies grown around them. An example he cited is that of special education. When reform efforts reflect some deep-rooted social concerns such as preparing autistic children to lead fulfilling lives, they will be widely accepted over a sustained period of time.

Considering the complexity and interplay of multiple dimensions of education reforms, we view the spread of the innovation from a systemic change perspective that includes the micro, meso, and macro levels of educational systems. The policy imperatives governing Singapore's educational landscape constitute the macro-level factors, the contextualized classroom-based work and interactions the micro-level factors. By meso levels, we refer to the view of Jones et al. (2006) where they define: "Meso is an element of a relational perspective in which the levels are not abstract universal properties but descriptive of the relationships between separable elements of a social setting" (p. 37). Meso-level forces are situated within the encompassing sociocultural environment where learning takes place. Meso-level agencies can be perceived as the "recontextualizers" or "constructors of pedagogic discourse who de-locate and re-locate discourse, moving it from its original site to a pedagogic site" (Jephcote and Davies 2004, p. 549). The sociocultural factors of a school's learning ecology constitute the meso-level environment, and researchers can play the role of meso-level actors who work in that environment to recontextualize pedagogic discourses. They help the school practitioners understand and interpret policy imperatives and actualize them into classroom teaching and learning practices in ways that are informed by research and theories. The orchestration of efforts from all actors will contribute to the explanatory power of the sustainability of an intervention. Overall, the challenges and the strategies discussed above guide the planning and execution of the scaling both in small- and large-scale implementation and within a school and across schools.

Scaling Up Evidence-Based Practices

Fullan et al. (2005) pointed out that understanding the change process is a big driver in educational reform because such understanding can help establish the conditions for continuous improvement to persist and overcome inevitable barriers to reform. With absence of evidence from the change process, reform efforts can be compromised (Geier et al. 2008). Evidence-based practices serve the purpose of gathering evidence from a staged-based curriculum innovation to establish the connection between consecutive stages. The evidence captured is especially beneficial to practitioners for understanding the change process of the curriculum reform and for assisting them to implement the innovation. Scaling up evidence-based practices is the process in which researchers and practitioners initially codesign and implement innovations or interventions on a small scale, validate them, and then implement them more widely in broader contexts (Klingner et al. 2013). Dunlap et al. (2009) delineate four phases of implementation involved in scaling up an evidence-based practice: (a) emergence, (b) demonstration of capacity, (c) elaboration, and (d) system adoption and sustainability. Emergence happens when the school leaders in consultation with the developers of the curriculum decide that it may actually be scalable. In the demonstration phase, researchers determine whether the practice is feasible and whether it has a significant effect on target outcomes. In the elaboration

phase, teachers implement the practice more broadly, drawing on the lessons learned during the demonstration phase and building on the capacity of the school leaders to implement the practice. In the final phase of system adoption and sustainability, the practices are integrated into the normal routines of the school so that they continue over time. These conceptual lenses pave the ways for the scaling of the curricular innovation based on the evidence from the learning and teaching practices that resulted.

The Curricular Innovation: M5ESC

The M5ESC was developed by a design-based research and implementation approach with iterative research cycles over a period of 6 years (Penuel and Fishman 2012). The basic rationale of the M5ESC is that it is not feasible to equip students with all the skills and knowledge they need for lifelong learning solely through formal learning (or any other single learning space); hence, student learning should go beyond the acquisition of content knowledge to develop the capacity of learning seamlessly (Chen et al. 2010). The key epistemological design commitments of the curricular innovation are learning as drawing connections between ideas and learning as connecting science to everyday lives across multiple learning spaces (i.e., between formal and informal learning settings, individual and social settings, and learning in physical and digital realms). The curricular commitments are seamless learning and inquiry-based facilitation and learning.

Concerning the abovementioned curricular commitments, the Ministry of Education of Singapore has advocated teaching and learning science through inquiry and proposed the use of BSCS 5E Instructional Model in science learning (Bybee 2002). This 5Es model consists of the following phases: engagement (access to know students prior knowledge and make them engaged in the science phenomena), exploration (opportunities are provided for students to investigate the science phenomena or principles), explanation (students are encouraged to interpret their understanding of science phenomena and relevant principles or concepts), elaboration (students' understanding of the phenomenon is challenged and deepened through new experiences), and evaluation (students' understanding is assessed by appropriate assessment methods). Thus, each phase has a specific function and contributes to the teacher's coherent instruction and to the learners' formulation of a better understanding of scientific and technological knowledge, attitudes, and skills. Integrated with mobile learning activities, 5E inquiry is conducted in a seamless learning environment. In M5ESC, the technological commitments include technology for construction, technology for communication, and technology for sharing anywhere anytime.

In M5ESC, the MyDesk software that runs on a Microsoft Windows Mobile operating system is flexibly integrated with the 5E inquiry phases. MyDesk is developed by our collaborators Elliot Soloway, Cathy Norris and students from the University of Michigan. With MyDesk Teacher Portal, teachers create learning activities for the 5E inquiry-based lessons by employing multiple media and appli-

cations (e.g., text, graphical, spreadsheet, animations, etc.) and then review and comment on students' work generated in the activities (Looi et al. 2009). Students can assess to the learning activities and complete their tasks using learning tools in the students' module of MyDesk.

Table 8.1 depicts the learning tools and their functions and the exemplar mobile learning activities in the lesson unit on Fungi in P3 science.

The combination of these tools with 5E inquiry activities is intended to facilitate students to develop sophisticated and systematic understanding of scientific concepts and to enhance skills in modeling, reasoning and reflective thinking, and self-directed learning skills in and out of the classroom, in particular (Brooks and

Table 8.1 The learning tools of MyDesk learning system

Tools	Functions	Mobile activities in a lesson unit on Fungi
 (KWL)	A self-reflection tool supporting students reflecting upon learning process and conceptual changes through responding questions (i.e., what do I already *k*now? What do I *w*ant to know? What have I *l*earned?) to allow students to learn in a self-regulated way	*Engagement*: students respond to "what do I already know" about fungi in KWL
		Exploration: students respond to "what do I want to know" about fungi in KWL
		Evaluation: students respond to "what I have learnt" about fungi in KWL
 (Sketchbook)	An animation/drawing and picture annotating tool to assist students' establishing connections between knowledge learned in the classroom and knowledge applied outside the classroom	*Engagement*: students record the changes of moist bread and toasted bread using Sketchbook
 (MapIt)	A concept map tool that allows students to develop conceptual understanding through creating, sharing, and exploring concept maps	*Elaboration*: students draw concepts maps of the characteristics of fungi using MapIt
 (Blurb)	A question setup tool which facilitates the teacher to set up specific questions to ask students to give short opinions or feedback on their inquiry activities or their understanding of knowledge	*Exploration*: students respond to the question: how do the fungi grow? in Blurb
 (Recorder)	A voice recorder tool for students to record the process of the experiment, fieldtrip, and the observation of teacher demonstration, and students' reflection and conclusion are also recorded as a data for teachers' to review their progress and improvement in inquiry	*Exploration*: students record their questions when observing the moist and toasted bread using Recorder
 (Notepad)	A data recording tool for students to record the results or process of experiments, fieldtrip, and observation of teacher demonstration	*Engagement*: students write their observations of the moist and toasted bread using Notepad

Brooks 1993; Greca and Moreira 2000). Other supporting tools are also incorporated (e.g., mobile blogs, online discussion forum, video/photo-taking, and search engine). With these tools, students' prior knowledge and ideas can be accessed and addressed for building new and deep scientific understanding through inquiry. Meanwhile, other constructivist practices are supported to foster meaningful science learning.

Scale-Up of the M5ESC Innovation

Scaling up an evidence-based practice is the process in which researchers and practitioners initially codesign and implement innovations or interventions on a small scale, validate them, and then implement them more widely in broader contexts (Klingner et al. 2013). However, research emphasized that bringing an innovation to scale in schools, districts, and states (while minding the need to conduct valid and reliable research) is a complex endeavor that defies tidy organizational plans (Lynch et al. 2012). Moreover, Penuel and Fishman (2012) pointed out that the pathway to identifying effective innovations or interventions requires a long time frame and the employment of range of methodologies, including design-based research studies in classrooms and small-scale field tests to establish the feasibility of implementing interventions in multiple settings (Sloane 2008). Thus, M5ESC scaling design and implementation runs in a stage-by-stage developmental pattern along with a plan for long-term intervention (from the school year of 2009 to the present, 2014 at this time of writing). Four stages of scaling are proposed and implemented in sequence (Lincoln 1987) (Fig. 8.1).

- Stage 1: Class-level scaling. The codesign of the innovation and pilot studies of the innovation implementation in a limited context, say a class and a teacher, to customize the innovation and evaluate its efficacy in the pilot school.
- Stage 2: Grade-level scaling. Spreading the innovation to more classes and more teachers within a grade level and eventually to the whole grade level with the aim of supporting teacher appropriation and to identify students' readiness and learning outcomes. From 2012 to 2014, the M5ESC innovation has be scaled from grade P3 to both grades P3 and P4.
- Stage 3: School-level scaling. Spreading the innovation from one school to a cluster of schools (i.e., five schools) for more schools to benefit the innovation and disseminating the experience and knowledge by the pilot school. Starting from 2013, the M5ESC has been spread to another five schools, along with continuing implementation at the pilot school.
- Stage 4: District or national level scaling. The diffusion of the innovation can produce wider policy implications. In the future, the M5ESC can be spread at a larger scale with more schools adopting and adapting the curricular innovation.

In summary, scaling-up of an innovation is a complex process. If the execution of each scaling activity proceeds in a stage-by-stage manner with design-based

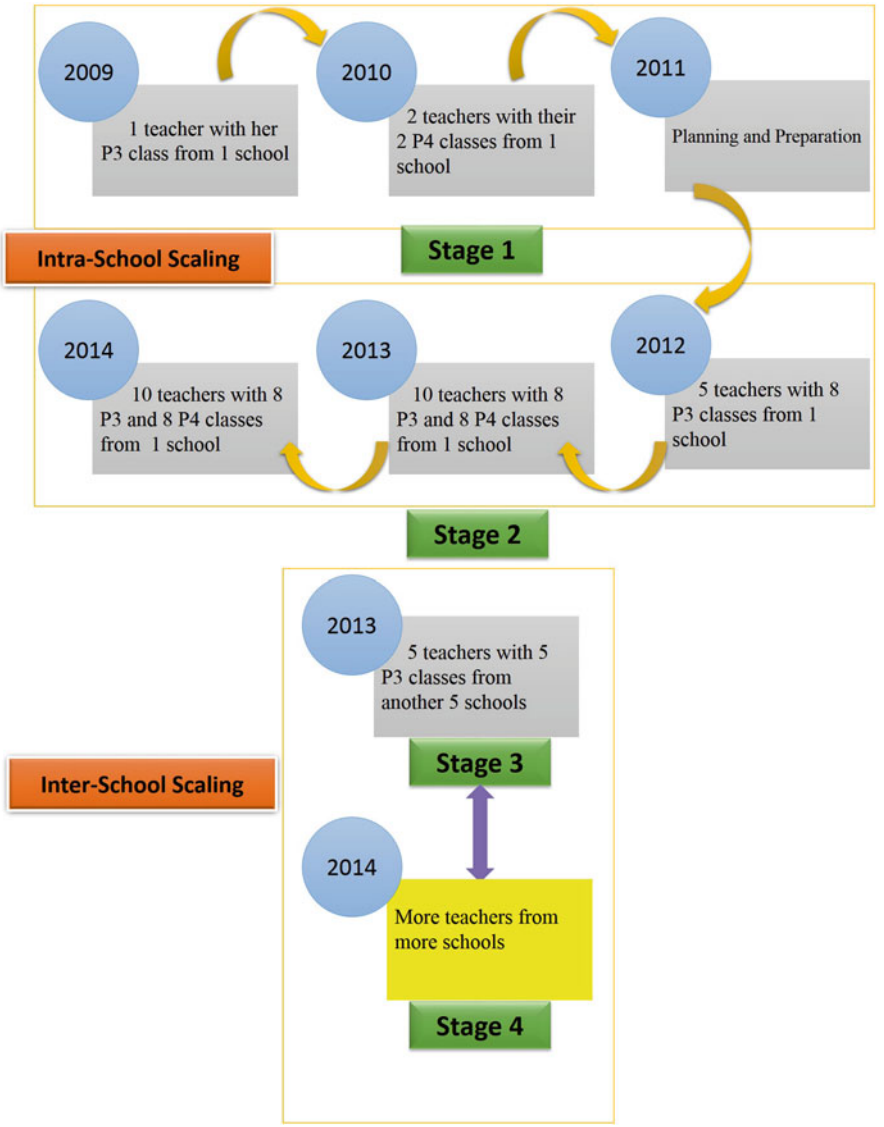

Fig. 8.1 The scaling developmental process of M5ESC

research providing persuasive evidence, the innovation is more likely to be sustained and scaled. In the following sections, we will discuss and interpret the scaling processes that have happened and are still happening in the pilot school and in the five schools. From the interpretation of the scaling progression both intra- and inter-

schools, the strategies used and the teaching and learning outcomes generated will be discussed to inform future studies.

Intraschool Scale-Up of M5ESC Innovation

Lessons learned from prior technology-based educational improvement research indicate the importance of empowering teachers and building capacity to effect deeper changes in teachers' beliefs, knowledge, and practices (Fishman 2005). In our review of current ICT-facilitated research, especially research on mobile learning, there is much less focus on long-term classroom observation of teacher enactment. Most studies conducted short-term or topic-based classroom observation (Clough et al. 2008; Ruchter et al. 2010) which were not adequate for examining teachers' overall instructional performance and changes (e.g., pedagogical beliefs) and student performance and achievement in the long run. As a result, how teachers use the planned curriculum in the actual classroom in the long term has been the crucial element in the implementation of an innovation. The failure to detect the problems in teacher enactment will probably make the desired effects beyond reach (Rodríguez et al. 2012). Hence, in M5ESC innovation scaling, we devoted great efforts to building a teacher-researcher learning community for facilitating the interaction between researchers and teachers, the sharing between novice teachers and expert teachers with the intention for improving teachers' appreciation of the curriculum, as well as for curriculum elaboration in the pre-scaling and scaling phase within the same school. As Fig. 8.3 shows, the progression of the establishment of a teacher-researcher learning community advocates the evolution of teachers' instructional practices, researcher-teacher collaboration on curriculum development, and teachers' involvement in decision-making (Day 1999; Orlando 2013).

The development and scaling of M5ESC went through two stages: class-level scaling phase (years 2009[1] and 2010 and 2011) and grade-level scaling phase (years 2012 and 2013). In 2009, we worked with one experimental class in P3 (with 44 students) and the science teacher Jodie who had a 6-year teaching experience in science to implement the mobile curriculum. Upon completion of the lesson plans for six P3 topics, the lessons were enacted by Jodie in her class.[2] Two researchers observed the lessons with a focus on teacher's and students' verbal behavior, teacher-student interaction patterns, student activity organization, and technology integration (An and Reigeluth 2012; Inan et al. 2010). Post-lesson feedback

[1] The school academic year starts from January and end in November of the year; thus it is straightforward to refer to the school year by the calendar year.

[2] To support the long-term learning activities, 34 students from the experimental class were each assigned a smartphone with 24×7 access in order to mediate a variety of learning activities such as in-class small-group activities, field trips, data collection and geo-tagging in the neighborhood, home-based experiments involving parents, online information search and peer discussions, and digital student artifact creation, among others.

regarding instruction and adaptation to student's needs was provided by researchers. This was followed by data analysis of classroom observations with the purpose of detecting the inconsistencies between the actual and the expected teacher performance. Students' artifacts in MyDesk were assessed as another indicator for teacher performance. The findings informed the curriculum elaboration at stage 3, where teachers and researchers sat together to revise the lesson design, to reflect upon teaching practices, to share analytical findings, and to discuss the gaps between the intended and enacted lessons.

In 2010, we continued our research by working with this same class who had by then moved up to P4. Particularly, our design was not just integrated as a project or activity in the class, but as a curriculum containing all topics in P3 and P4 science, harmonizing with the science syllabus and classroom realities (student needs, student-teacher relationships, school culture, and textbooks) (Ertmer et al. 2012), and following the same class schedule and assessment schemes as the nonexperimental classes did. Changes occurred in the experimental class and the teacher involved with evidence from research analysis (Looi et al. 2011a, b; Zhang et al. 2010) during the 2 years of intervention[3] and from interviews with the stakeholders (school leaders and teachers). In the mobilized lessons, we observed students engaging in science learning in personal and engaged ways, and they performed better than other classes in traditional assessments for the science subject (Looi et al. 2011a, b; Sha et al. 2012). We also saw a shift in the teacher's attitudes and behaviors toward science teaching, from a style preoccupied with curriculum covering to the one that focus on facilitating students' work for the inquiry activities on their handhelds.

When the curricular innovation using mobile devices had been codeveloped and studied in the context of one class and the empirical evaluation of the mobilized curriculum had shown its potential for learning effectiveness, the school leaders identified M5ESC as a worthwhile innovation and, in consultation with the researchers and collaborators, decided to scale up the innovation. The evidence of efficacy from the evaluation demonstrated that the scaling-up of the curricular innovation was feasible and worthwhile. Thus, in the year of 2011, researchers and teachers discussed, reflected upon, and elaborated the designed lessons for supporting the scaling of the curriculum at the P3 level. They also discussed the possible issues when the curriculum was scaled at the whole P3 level. Once prepared, the curriculum was scaled at all P3 classes in the year of 2012, which we identified as the demonstration phase of the innovation scaling. In that year, besides Jodie, other five teachers joined M5ESC[4] (we regarded them as novice teachers in the sense that they were new to M5ESC).

[3] During the curriculum implementation, PD sessions in the form of regular meetings were conducted for improving teacher's understanding of and skills in implementing M5ESC, as well as for transforming pedagogical beliefs on the use of mobile technology. Meanwhile, the researchers sat in the classes and observed the teaching practices and learning activities so as to explore the gap between the desired curriculum and the enacted curriculum.

[4] There were six teachers for these eight classes, and they included the teacher in our initial study. Four teachers started the implementation at the beginning of the academic year, while the other two teachers were assigned later to join the implementation a few months later.

To facilitate teacher adaption of M5ESC, a teacher learning community comprising the newly joined teachers, the subject head, ICT head, curriculum planner, programmers, and researchers was formed. It was conducted on a weekly basis during stage 5. We found this community to be very influential in establishing ownership that positively impacted teachers' approach to curriculum development and their engagement. As a leading teacher, Jodie provided valuable experiences and knowledge on the instruction of M5ESC, the principles of organizing activities, the supports and scaffolds given to the students, and the patterns of constructivist practices of technology integration in and out of the classroom. In the teacher-led working sessions, they reviewed and revised the enacted lesson plans, discussed and sought consensus on the proposed teaching strategies for future lessons, and adapted them to classes of different abilities and cultures. Additionally, workshops to develop teachers' PCK of 5E, inquiry-based instruction, and mobile technology use both in and out of the classroom were conducted. Moreover, some novice teachers' classes were selectively observed by experienced teachers and researchers (Cuckle and Clarke 2002). At stage 6, fine-grained data analysis was conducted to identify differences between teachers and classes and the difficulties encountered by the novice teachers.

In M5ESC scaling, collective participation of teachers from the same school, department, or grade was a critical feature of effective professional development as teachers developed common goals, shared instructional materials, and exchanged ideas and experiences arising from a common context (Desimone 2009). Therefore, teacher sharing sessions were regularly held for discussing the ideas, problems, and the solutions. The research team particularly emphasized critical pedagogical reflections on teaching (Penso et al. 2001). Moreover, teachers negotiated solutions to mediate the tensions between the traditional assessment and the formative assessment of M5ESC.

Year 2013 was the elaboration phase of M5ESC scaling. More efforts were placed on the teacher professional development, the elaboration of school-based worksheets, and the linkage of informal learning with formal learning. This was the stage to deepen the use of intended pedagogical principles of M5ESC in science classes and to elaborate lesson plans based on the problems and challenges identified during the curriculum implementation in 2012. The evidence and outcomes generated in 2013 will support the sustainability of the innovation in more grade levels and schools (Fig. 8.2).

In our viewpoint, the scaling of curricular innovation is not only about spreading the curriculum and pedagogy, it is also about creating sustainable and scalable programs of professional development to help teachers develop skills and competency at curriculum design and implementation (Fishman et al. 2001; Fishman and Gomez 2000). The same applies to the innovation scaling across schools, with the establishment of a PD community to connect teachers from different schools with the researchers and the pilot school.

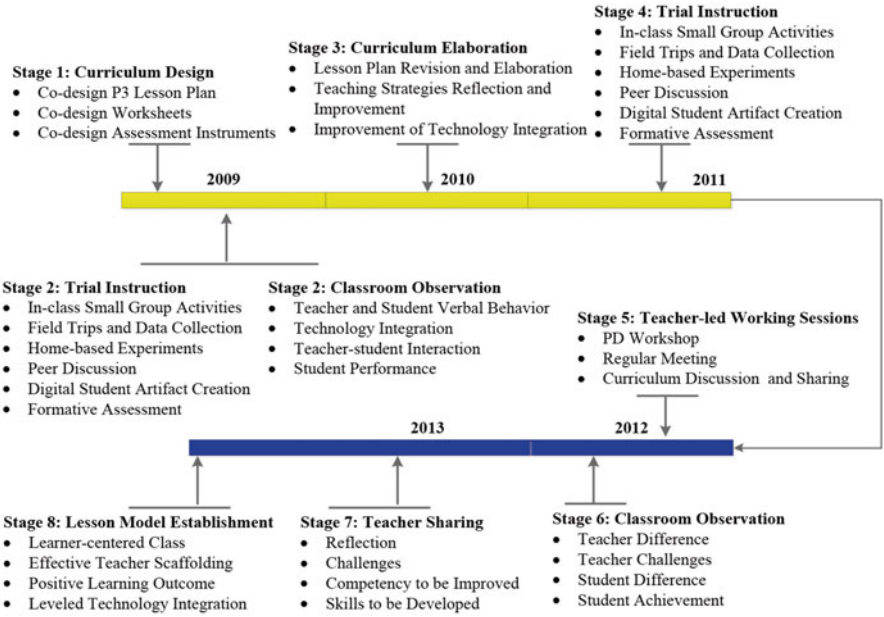

Fig. 8.2 The building of teacher-researcher learning community in the intraschool phase

Interschool Scale-Up of M5ESC

In contrast in the other sectors, scaling up successful programs has proved very difficult in education (Dede et al. 2005). In an attempt to scale an innovation in a wider range of contexts (i.e., from grade level to school level), the scaling process will inevitably become more complex and difficult. Teachers from different schools, beyond the pilot schools, who participate in the interschool level scaling will add to the levels of complexity of implementation. How will these "later" teachers perceive the innovation? How will they develop their readiness for implementation? How will they adapt the M5ESC according to their school context and enact it? How will the learning outcomes be impacted by M5ESC at these "seeded" schools? There is much complexity in understanding the issues in scaling at the interschool level. There is also no universal model for the operationalization of scaling in the educational research community.

With these questions in mind, we argue that teacher perception and capacity building would be the key issues for the innovative practice to be widespread in different contexts. We seek to address the pressing need of enacting scaling in innovative schools to spread the impact and to move potential curricular innovations toward a scaling framework that will inform decision-making and policy formulations. It is but one step in addressing the broad challenges of scaling efforts to

spread curricular innovations, inquiry learning, and innovative pedagogies in local schools. As the scale-up of M5ESC across schools is still at the initial stage, here we present the initial progress and discuss our proposals on how we will conduct the scaling at such a large scale. Particularly, we will share our experience on the initial scaling stage with focuses on teacher's reflective learning and across-school teacher learning community building.

The Proposed Scaling Pattern

In scaling of innovations, one of the key factors is the adopters' characteristics. Adopters include individual professionals, individual schools, districts, states, and federal agencies (Cohen and Ball 2006). When M5ESC is scaled at the interschool level, it may not reach all adopters at the same time. The implementation and adaption of an innovation has been proposed to follow an adaptive-evolutionary approach which accepts that the innovation as it has been devised will be modified in the course of its implementation. When the innovation is adapted to its institutional context, organizational patterns are adapted to meet the demands of the project (Altrichter 2005; Berman and McLaughlin 1977). Thus, with different intentions and efforts, our scaling pattern across schools is akin to a tree structure, as demonstrated in Fig. 8.3. The innovation was developed and scaled-up in the pilot school-school A, as described in the previous section. It spread from the pilot school to another five schools within the same cluster, thus benefiting more teachers and students. In this process, different school contexts must be considered and implications must be drawn with regard to the scaling-up pattern and adaptation of the innovation. In the following phase, the five individual schools may go through the scaling-up progress as occurred in the pilot school and grow as potential schools to influence more schools in the district, region, or nation, and consequently the innovation scaling-up comes to the national level and has wider policy implications.

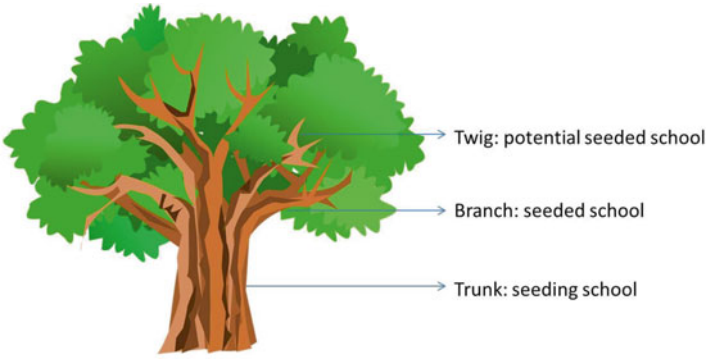

Fig. 8.3 The metaphor of scaling at the interschool level

In the tree structure, the pilot school is regarded as the "seeding school" in that it is seeding the innovation to different schools, and the five schools are considered as the "seeded schools" to sprout up and evolve the innovation.

In general, the interschool scaling is and will be following four stages: infusion, adoption/adaption, dissemination, and evolution. By infusion, we refer to the intentional design for sharing the innovation practices with seeded practitioners, including teachers and school administrators who will take an active part in adopting, appropriating, adapting, and elaborating the innovation practices in their own respective institutions or sites (this is the current stage of interschool scaling). Subsequently, their own recontextualized and elaborated innovation will proceed to dissemination, i.e., participants disseminate their reifications of the original innovative practices in their own site. Through the process of dissemination, better understanding of the innovation develops in implementers in different sites leading to further evolution of the innovation through their own lens of implementation. Participants new to the process will be gradually enculturated through interaction with different members of the community of practice, such as researchers and practitioners. As a whole, outcomes of the scaling process, consisting of infusion, adoption/adaption, dissemination, and evolution, must be important and feasible to practitioners of multiple contexts, addressing issues of local circumstances (Barab and Luehmann 2003).

The Scaling Efforts on Seeding-Seeded Relationship

To promote the successful scaling of the curricular innovation at the interschool level, we attempted to establish networks for supporting different levels of participants and building strong seeding-seeded relationships for later schools to adapt the curricular innovation to cater to the needs of their school contexts. Specifically, we identified our efforts on the scaling at the interschool level as the metaphor of "seeding effect." It mainly refers to the efforts on tightening the seeding and seeded partnership among practitioners that serves the purpose of scaling an innovative practice from early adopters to a wider context. Peurach and Glazer (2011) consider organizational replication as a strategy for large-scale school improvement and propose a strategy that features a "hub" organization collaborating with "outlet" schools to enact school-wide designs for improvement. In our context, the "seeding" practitioners are those who have established expertise as early adopters and are qualified to play the "hub" role to disseminate innovative practices to peer practitioners (e.g., Jodie and other science teachers in the pilot school as we mentioned in the section of intraschool scaling). The "seeded" practitioners refer to those who have developed some awareness of innovative practices and are willing to be involved in the dissemination circle. In our case, they are the representatives from the five schools in the interschool scaling stages. Drawing upon the seeding school's experiences, all the five schools decide to start with one experimental class in the year 2014. The five schools have varied profiles on demographics and school development visions, and they also have different visions toward innovation adoption, which influence their selection of piloting teachers and students. Table 8.2

Table 8.2 The general information of a seeded school and the seeding schools

Seeding school	From school year of 2009 to 2014
School A (the pilot school)	*Adopters changes*:
	From one P3 and P4 class to all class at P3 and P4 Grades
	From one teacher for each class to four teachers for each Grade
	Teacher capacity building
	P3 teacher-research learning community
	P4 teacher-research learning community
	P3 and P4 sharing session
	Mentorship program
Seeded schools	From 2013 – present
School B	One teacher with 5 years' teaching experiences for the experimental class
	One participating teacher, but the school intends to send another science teacher in the across-schools COP
School C	One teacher with a 1-year teaching experience for the experimental class
	Two participating teachers in the across-schools COP
School D	One teacher with a 13-year teaching experience for the experimental class
	Three participating teachers in the across-schools COP, with one senior science teacher
School E	One teacher with a 2-year teaching experience for the experimental class
	Two participating teachers in the across-schools COP
School F	One teacher with a 6-year and another with a 10-year teaching experience co-teach for the experimental class. And the former teacher is also the science head of department (HoD) in the school
	Four participating teachers in the across-schools COP. The four teachers are all teaching Primary three
	The four participating teachers have regular professional learning community meetings (weekly formal meeting and occasionally after-lesson discussion)

depicts the general information of the seeding school (School A), the seeded schools (School B, School C, School D, School E, School F), as well as the participated teachers in this project.

In the year 2013, teacher representatives from the five schools went to the seeding school to join the fortnightly lesson observation and lesson codesign sessions. In the codesign session, teachers from these five schools and Jodie formed an across-school community of practitioners (COP) for the analysis, criticism, and communication of ideas, practices, and reflections.

In the following subsections, on the basis of relevant literature, we further unpack what the key elements to formulate the seeding-seeded partnership among practitioner are, which include teacher-level capacity building, school-level networking, and system-level systemic support.

Teacher-Level Capacity Building

In Fullan's model of change (2007), he has emphasized "continuous capacity building" as the key element of coherence to achieve organizational change. For Fullan et al. (2005), capacity building involves developing new knowledge, skills, and competencies; new resources (time, ideas, materials); and new shared identity and motivation to work together for greater change. They further reveal that a more notable social phenomenon is that capacity building is often "missing" even when people agree on the need for change. In our context, we continued to emphasize the establishment of the teacher-researcher leaning community for fostering teacher's capacity building. Teachers assume the major responsibilities to enact the innovative practices in classrooms, schools, and clusters. There needs to be a high degree of coherence in the beliefs and actions of all the involved teachers and the commitment to work collaboratively to achieve the shared goals (Looi et al. 2014a). To our perspective, to maximize the "scaling effect" as mentioned earlier, the implementation of teacher capacity building should be consistent with the vision, values, and priorities of the schools, and all teachers shall align their actions to a common outcome.

In different stages of the interschool scale-up, different strategies are applied for teacher capacity building. In the infusion stage, teachers' acquisition of knowledge of the innovation and gathering of and codeveloping of curriculum resources were the focuses. In the adoption/adaption stage, teachers are to develop more pragmatic knowledge of the innovation and skills in orchestrating mobilized lessons through teaching practices, and in the dissemination and evolution stage, teachers gain the competencies and may gain more ownership of the innovation and will become the opinion leader in their own schools. Throughout the process, the across-school COP plays a critical role in teachers' professional development, as it supports curricular resource sharing, access to expertise from piloting teachers, and discussion of curriculum and teaching in depth and in congruence with the spirit of the innovation (Coburn and Russell 2008). It is worthwhile to mention that learning not only occurs to seeded teachers but also to seeding teachers. The seeding-seeded collaboration allows learning to happen in a reciprocal way and leads to greater potential for growth on both sides.

The model for teacher capacity building for implementation and dissemination of M5ESC is depicted in Fig. 8.4. The infusion stage consists of four types of activities and involves different levels of learning agents for improving teacher appropriation of M5ESC.

1. In the first type of activity which we call the kickoff meeting, different parties in the scaling-up project, including all the teachers and school administrators from the seeded schools, as well as the MOE officers, gather to reach an initial understanding of the innovation about "what it is" and "why it works" from perspectives of both researchers and pioneer practitioners. In the meeting, the effectiveness of M5ESC on students' learning was presented to teachers, especially about students' improvement in answering multiple choice questions (MCQ) and open-ended questions (OEQ) and the total scores in semester assessments. The

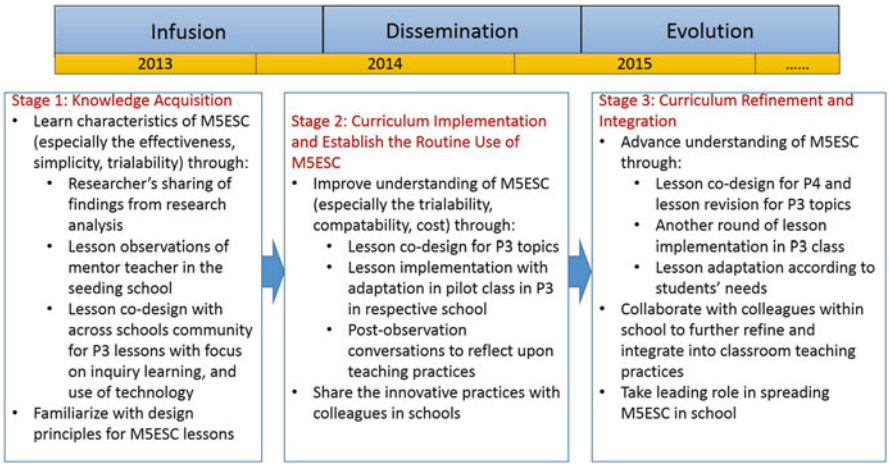

Fig. 8.4 Model for Teacher Capacity Building for M5ESC

objective of the project was made clear to all the parties, as well as the responsibility and key performance indicators.

2. In the "lesson observation" activity, the Seeded Teachers (SedTs) have opportunities to be exposed to the real classroom, which was taught by the Seeding Teacher (SingT) Jodie from school A. Starting from February and lasted for half a year, 12 lesson observations were held fortnightly with a focus on demonstrating to the SedTs how students learnt collaboratively, especially with the use of their smartphones, and how the SingT Jodie taught/facilitated students' inquiry learning. The administrators from each school also observed a few lessons to have a sense of what their own students might be experiencing.
3. The lesson codesign forms a teacher learning community where the SingT and SedTs exchange ideas on lesson designs for the innovative curriculum, as well as other issues regarding innovation diffusion. After each lesson observation, the SedTs had an 1-h session with Jodie to codesign lessons for the topic themes of P3 (i.e., living and nonliving things, plants, animals, fungi and bacteria, materials). There were nine sessions of codesigning in total from March to October. Teachers shared their experiences conducting those specific lesson topics in their own schools and brainstormed some possible activities with affordance of the technology. Finally the SedTs from each school selected one lesson, revised or adapted the lesson plan, and uploaded it to the Google sites for community sharing. The lesson design followed the structure of 5E, with considerations of congruence with the values and beliefs of the M5ESC, as depicted in above section.
4. In the "Elaboration of Implementation" session, school A further detailed the project execution plans, and the seeded schools expressed their concerns regarding adopting the innovation. Each school had two Q&A sessions with school A, one in the early phase and the other in the later phase when the five schools gained

more understanding about the innovation. Not only the SedTs but also the administrators joined the session so as to consider and discuss issues of adoption and adaption from a more holistic viewpoint. It is an opportunity not only for interactions between the seeded schools and school A but also for mutual understanding within the seeded schools, such as between administrators as decision-makers/support providers and teachers as practitioners.

In the dissemination stage, the SedTs adapt the codesigned lessons to their own context, and the lesson observation group (consisting of Jodie, researchers, and Minister of Education officers) goes to each school once every 2 weeks. There is a 1-h session of post-observation discussion between the implementation teacher(s) and the observation group, focusing on discussing lesson conduction, reflecting upon lesson design and improvement, identifying students' learning performance, and sharing of good practices and strategies by other schools. The lesson codesign sessions among the five schools continues at this stage and are still conducted fortnightly, with a reflection and feedback activity on teaching practices added. We are currently at this stage.

In the evolution stage, we are planning to give more ownership to the SedTs and to provide only necessary supports for capacity building. At this stage, the SedTs will have gained more competencies in designing and conducting M5ESC lessons, and we plan for more working sessions for in-depth discussion on the rationales of specific activity design, such as collaborative activity design principles and strategies, inquiry activity facilitation skills, follow-up to students' responses, and design of emergent activities. At the same time, the SedTs will have opportunities to organize professional learning sessions within their own school to share and disseminate the innovation and influence more teachers to adopt the curriculum.

This multistep procedure is important to ensure that the key practitioners-teachers engage in a series of active learning activities and are given various opportunities to share and reflect upon their teaching practice. In the continuous efforts of teacher capacity building, we hope to see the transformation of the SedTs from early adopter to opinion leaders in their own schools and Jodie from early adopter to a more influential changing agent.

School-Level Networking

McLaughlin and Talbert (2006) outline the resources and supports necessary to build and sustain a long-term, school-based teacher professional community. In the authors' view, teachers need a professional culture that requires their active involvement in a school-based learning community. Researchers also have pointed out the value of networks of teachers that span school boundaries to promoting reflection on practices (Lieberman 2000; Lieberman and Wood 2002). These all refer to the importance of building a school-level relationship network for interschool scaling. With a similar structural view of "hub-outlet" organization, we propose the establishment of a school-level seeding network to facilitate the scaling of innovation

across different schools. The seeding school, with its "hub" role, provides learning space for the teachers, heads of departments, and principals from other schools to gain immersive experiences of how the innovation is enacted in authentic environment. In our case, besides the codesign and lesson enactment activities with the leading teacher Jodie, the seeded teachers are also allowed to visit the M5ESC classrooms in school A. This pattern of exchange opens up the minds of the seeded teachers' for lesson enactment of M5ESC. They could obtain more knowledge on how to deal with or respond to students' in-time questions, how to scaffold students' group activities, and how to interact with them. Hence, the infusion of seeded teachers into a practicing community of teachers leads to dissemination of the innovation, how it is practiced, the pitfalls and challenges, as well as the benefits if it is implemented efficaciously. Seeding teachers also gain a weaker sense of living the innovation (by observing classes, by doing mock teaching, and by being part of the conversations of practicing teachers). When the seeded teachers go back to their own schools, they will evolve and customize/adapt their innovation processes or the innovation to their own unique school and contextual conditions. So we envision this seeding framework as an outcome of a social network that grows from practitioner community to a social community and then to a wider social community.

We also received teachers' positive comments on their experience in this kind of relationship network. For example, in the codesign sessions, teachers not only discussed teaching but also shared their understanding of the concepts. Some SedTs commented that through discussion during the lesson codesign, they gained clarification of certain science concepts and hence improved their science content knowledge. The diversity of the school context also provided teachers with more ideas to integrate the innovation and to improve their lesson design. One teacher from school C mentioned that the community of the five school teachers was different from the teacher learning community of their own school, and the knowledge gained regarding designing learning journeys was valuable. The network was also valuable to Jodie as she took different approaches to preparing the teachers, such as leaving the decision about the detailed activities to the SedTs so as to shift the ownership of curriculum design to them in a step-by-step manner. Jodie reflected that the dynamics between her and the SedTs were different from that between her and her school teachers. When communicating with the SedTs, she avoided telling them what to do but suggesting to them to try out something as the context was very different. She therefore gained experiences through working with the SedTs about scaling up M5ESC to different contexts.

System-Level Systemic Support

Cognizant of the multiple level constraints that act on teachers adopting new curricular innovations in the classroom, we consider the complex interplay of multiple dimensions of education reforms. Thus, we approach our program of research from a systemic change perspective that recognizes the micro, meso, and macro levels of educational systems (Looi 2011; Looi et al. 2011a, b). Table 8.3 lists the

Table 8.3 System-level systemic support for teachers

Levels of support	Agency	Purposes	Strategies
Macro-level support	Policy makers and principals	Understand the innovation	To partner the teachers with HOD/IP on the classroom issues
		Set expectations and objectives	Time/trust/opportunity for reflective dialogue among teachers
			Recognition of their work
			Implementation dip
			PD opportunities
			Support to AED/TA
Meso-level support	ETD learning designers, HODs, ICT supporters, and researchers	Predict interrelated tensions and understand teachers' concerns	Offload teachers
		Understand the innovation	Observe lessons and provide feedback
		Curriculum planning	Mediate interrelated tensions
		Teacher employment	Build up inter- and intra-community for sharing, reflection, and improvement
		Curriculum adjustment	
		Assessment adjustment	
Micro-level support	Teachers	Experience the lesson enactment	Provide reflection on teaching
		Reflect and elaborate the teaching strategies	Provide reflection on students' learning
		Evaluate students performance	Elaborate the lesson enactment for students' needs
			Provide suggestions on lesson design elaboration

systemic support in the interschool scaling, from the micro, meso, and macro levels, for teachers to enact the innovative practice in their own contexts.

The orchestration of efforts from all actors will contribute explanatory power to the sustainability of an intervention. By approaching this pedagogy-driven reform at the macro, meso, and micro levels, we seek the alignment of systemic forces at work to provide a buttress for sustainability. Thus researchers, as meso-level actors, help the school practitioners understand and interpret policy imperatives and actualize them into classroom teaching and learning practices in ways that are informed by research and theories.

Scaling Progress at the Interschool Level

In the initial stage of the interschool scaling, we conducted an interview to collect teachers' feedback on their knowledge and experiences of M5ESC after attending the meetings of teacher-researcher learning community and observing the

classroom instruction of M5ESC lessons. Most of the SedTs particularly acknowledged the "seamless" element in the package and viewed it as a linkage between formal learning and informal learning. One of the SedTs, Wilson, stated in the interview that the unique part of M5ESC was that the mobile devices served as a means to make learning real and meaningful via 24/7 access:

> I think (the unique part of M5ESC) is that the students who are embarking on this programme have a means to an end. They have the means to do (inquiry), (and) they have been given a means to explore, research and to be able to do their research easily, how to say, validated, by their teachers, (and) by their peers. Using the mobile device, and like what the programme's name suggest, it is really seamless because they don't just do it in school. They do it at home, (and) they do it on the way home. You know, they can do it anywhere they wish to.… I mean I give them homework, but whether or not they revise and do, that's at home, (and) I am unable to access. But with M5ESC, because they have their mobile device, (so) whatever that they uploaded from home I also know. I mean I can tell that they are doing something at home.

Winston also appreciated one unique feature of M5ESC which is that teachers could evaluate and monitor students' learning progress even when students do the activities at home. Other teachers mentioned that the value of M5ESC lies in students' easy access to vast online information. With the mobile devices, students could search for information whenever they were. But that was not the case in other schools. As Joanna mentioned, she once provided assignments asking students to search for information when they were at home, but some of her students were forbidden to use computers by their parents during weekdays.

SedTs see the potential of M5ESC as a means for students to become self-directed learners. They can spot problems, ask questions, and initiate their research, which changes learning from the passive receiving of knowledge to the actively construction of knowledge. Teachers recognize their role as facilitators, which might be quite a shift for them since most of them have been teaching in a teacher-centered way for a long time. Anna, another SedT, gave an example of what she envisioned for her students and elaborated her understanding of self-directed learning:

> I mean you see it's like, we can give them a topic, and off we go, whether at home, along the road, even when they are in canteen with their friends, they may discover certain things, and then there they post. We can have the discussion forum. They may even notice something during holidays, even post and we have discussion. So that's what we mean by self-directed learning. It's no longer always teachers asking you must do this you must learn this, maybe the child can even post pictures of a creature that looks like an insect but doesn't have the full characteristics of the insect, but we can all discuss this. And teachers (perform) as facilitators. Of course trying to guide them to the right direction if they are too off-track, and maybe at the same time to facilitate the quality of discussion.

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

> It is how you use it to teach, I think that's the key factor. It's not just using technology for its own sake, it's that how we use it in a way that students are engaged and learn further, and learning is enhanced. So the way how teachers use it to enhance the learning is most important. Of course we have other things, but this is the most important one.

Discussion and Conclusion

This chapter retrospectively describes the scaling progression of a curricular innovation in a pilot (seeding) school and the continuous scaling progress and strategies in other five (seeded) schools. The description of the scaling progression paints an overall picture of how an innovation has been designed, implemented, and scaled from one school to five more schools. It illuminates how teachers, researchers, and schools participated in an ambitious program to collaboratively promote the large-scale scaling of an innovation.

Overall, our scaling pattern is developed according to the needs of the local innovation context. Whether at the beginning or the final stage of scaling, the teacher professional learning community is tailored to help teachers understand the underlying principles and pedagogy of the curricular innovation. It helps teachers design, enact, and elaborate the curriculum and finally customize the innovation for better adoption and adaption (Fishman et al. 2004). Teachers need to deal with multiple issues during implementation, and our PD has endeavored to provide the systemic supports (from school leaders to the IT technicians, teaching assistants, etc.) needed for teachers to alleviate them from administrative pressure and to enable them to focus on improving curriculum and instruction. Being different from other teacher PDs in the form of innovators/researchers-to-practitioners interaction, our PD model highlights the interactions between practitioners and practitioners-to-be. Teachers share similar considerations and concerns when adopting an innovation, so the advice and tips from peers would be more practical, relevant, and targeted. The learning within the community of practices benefited teachers in the preparation as shown in the lesson codesign sessions and will facilitate the future implementation and dissemination within each individual school.

The model we proposed here not only applies to the diffusion of educational innovation as in our case but should also apply to the diffusion of innovation in other domains. At the time of writing, the seeded schools are about to implement the mobilized curriculum in its experimental classes. Our observations of the codesign sessions in the community reveal a functioning COP in which teachers discussed pedagogical ideas, co-built knowledge, and collaboratively and iteratively improved the curricular lesson plans and resources. The model of scaling reported here represents an attempt of school-led scaling through working on the Coburn's dimensions of achieving depth and shift of ownership. The five schools will appropriate the innovation differently, and their adaptation and implementation will differ depending on their contextual differences. Other publications have reported the new findings of teacher enactment of M5ESC in the pilot school, and the results indicated the transformation of teachers' pedagogical beliefs and the improvement in students' academic outcomes and performance in science inquiry (Looi et al. 2014a, b). In the follow-up work, we will conduct a series of in-depth investigations of the teaching practice to present the results of innovation implementation in these schools.

The role of the seeding teachers or even researchers is not necessarily one of effecting "technology transfer" – making things to deliver to the classroom – but is

rather one of sharing examples and possible approach for adopting an innovation, i.e., innovation guides. They help schools refine the value proposition of their own transformative work, for example, by helping innovation teams better understand how needs, approaches, benefits, and alternatives fit together compellingly and cohesively. Coburn (2003) has pointed out that the ownership over the reform must shift at scaling so that the innovation is no longer an "external" reform controlled by the curriculum developers and researchers, but rather becomes an "internal" reform with authority held by schools and teachers who have the capacity to station, spread, and deepen the principles themselves. Indeed, recent educational research suggests that the new resources that make a difference and last in schools are not "simple resources" that are used in school unchanged but rather are "compound resources" that involve substantial configuration, assembling, and elaboration in schools sites (Fishman et al. 2009; Grubb 2009; Looi et al. 2010a, b). In our model, the mechanism of the community of seeding and seeded schools serves as the platform for each school to reconfigure, reassemble, and elaborate the innovation curriculum and implement it in their own school contexts.

In summary, it is always a challenging journey to conduct a curricular innovation both at a small scale and a large scale. Multiple factors need to be considered and various challenges will be encountered. Besides building a PD community, we simultaneously focus on a range of systemic issues that needed for innovation success: curriculum development, development of mobile technologies, issuance or purchase of devices, assessment, teacher and school networks, policy and management structures, and parental feedback and concerns. Given the target of ensuring deep changes in teachers, students, and schools, the efforts should go beyond surface structures or procedures (such as changes in materials and classroom organization or the addition of specific activities) to altering teachers' beliefs, norms of social interaction, and pedagogical principles as enacted in the curriculum (Coburn 2003). The provision of stage-by-stage curriculum development and scaling, long-term PD and sharing, in-time feedback to researchers, mutual interaction between researchers, and school leaders and teachers all contribute to deepening changes. The changes may not be expected at the initial stages but more likely at the later stages, and with sustained efforts, they will appear ultimately.

References

Ahmed, S., & Parsons, D. (2013). Abductive science inquiry using mobile devices in the classroom. *Computers & Education, 63*, 62–72.

Altrichter, H. (2005). Curriculum implementation - Limiting and facilitating factors. In P. Nentwig & D. Waddington (Eds.), *Context based learning of science* (pp. 35–62). Münster: Waxmann.

An, Y.-J., & Reigeluth, C. (2012). Creating technology-enhanced, learner-centered classrooms: K-12 teachers' beliefs, perceptions, barriers, and support needs. *Journal of Digital Learning in Teacher Education, 28*(2), 54–62.

Ball, D. L., & Cohen, D. K. (1999). Developing practice, developing practitioners: Toward a practice-based theory of professional education. In G. Sykes & L. Darling-Hammond (Eds.),

Teaching as the learning profession: Handbook of policy and practice (pp. 3–32). San Francisco: Jossey Bass.

Barab, S., & Luehmann, A. (2003). Building sustainable science curriculum: Acknowledging and accommodating local adaptation. *Science Education, 87*(4), 454–467.

Beale, R. (2006). How to enhance the experience without interfering with it. In M. Sharples (Ed.), *Big issues in mobile learning* (pp. 10–14). Nottingham: LSRI, University of Nottingham.

Berman, P., & McLaughlin, M. (1977). *Federal programs supporting educational change* (Factors Affecting Implementation and Continuation, Vol. VII). Washington, DC: US Office of Education, Department of Health, Education and Welfare.

Brooks, J. G., & Brooks, M. G. (1993). *In search of understanding: The case for constructivist classrooms*. Alexandria: Association for Supervision and Curriculum Development.

Bybee, R. W. (2002). *BSCS 5E instructional model*. Colorado Springs: Biological Sciences Curriculum Study.

Chen, W., Seow, P., So, H. -J., Toh, Y., & Looi, C. -K. (2010). *Extending students' learning spaces: Technology-supported seamless learning*. Paper presented at the International Conference of the Learning Sciences 2010, Chicago, USA.

Clarke, J., & Dede, C. (2009). Design for scalability: A case study of the river city curriculum. *Journal of Science Education and Technology, 18*(4), 353–365.

Clough, G., Jones, A. C., McAndrew, P., & Scanlon, E. (2008). Informal learning with PDAs and smartphones. *Journal of Computer Assisted Learning, 24*(5), 359–371.

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

Coburn, C. E., & Russell, J. L. (2008). District policy and teachers' social networks. *Educational Evaluation and Policy Analysis, 30*(3), 203–235.

Cohen, D., & Ball, D. (2006). *Educational innovation and the problem of scale*. Retrieved from http://www.sii.soe.umich.edu/documents/CohenBallScalePaper.pdf

Cuckle, P., & Clarke, S. (2002). Mentoring student-teachers in schools: Views, practices and access to ICT. *Journal of Computer Assisted Learning, 18*(3), 330–340.

Day, C. (1999). *Developing teachers: The challenges of lifelong learning* (p. 11). London: Routledge.

Dede, C., Honan, J., & Peters, L. (2005). *Scaling up success: Lessons learned from technology-based educational innovation*. New York: Jossey-Bass.

Desimone, L. M. (2009). Improving impact studies of teachers' professional development: Toward better conceptualizations and measures. *Educational Researcher, 38*(3), 181–199.

Dunlap, G., Sugai, G., Lewis, T., Goodman, S., & Horner, R. (2009). *Scaling up and sustaining evidenced-based practices.* www.pbis.org. OSEP Center on PBIS.

Elmore, R. F. (1996). Getting to scale with good educational practice. *Harvard Educational Review, 66*(1), 1–26.

Ertmer, P. A., Ottenbreit-Leftwich, A. T., Sadik, O., Sendurur, E., & Sendurur, P. (2012). Teacher beliefs and technology integration practices: A critical relationship. *Computers & Education, 59*(2), 423–435.

Fishman, B. (2005). Adapting innovations to particular contexts of use: A collaborative framework. In C. Dede, L. Honan, & L. Peters (Eds.), *Scaling up success: Lessons learned from technology-based educational innovation* (pp. 48–66). New York: Jossey-Bass.

Fishman, B., & Gomez, L. (2000). New technologies and the challenge for school leadership. In M. Honey & C. Shookhoff (Eds.), *The wingspread conference on technology's role in urban school reform: Achieving equity and quality* (pp. 13–21). Racine: The Joyce Foundation, The Johnson Foundation, and the EDC Center for Children and Technology.

Fishman, B., Best, S., & Marx, R. (2001). *Fostering teacher learning in systemic reform: Linking professional development to teacher and student learning*. Paper presented at NARST 2001, St. Louis.

Fishman, B., Marx, R., Blumenfeld, P., Krajcik, J. S., & Soloway, E. (2004). Creating a framework for research on systemic technology innovations. *Journal of the Learning Sciences, 13*(1), 43–76.

Fishman, B., Penuel, W., Hegedus, S., Moniz, R., Dalton, S., Brookstein, A., Beaton, D., Tatar, D., Dickey, M., & Roschelle, J. (2009). *What happens when the research ends? Factors related to the sustainability of a research-based innovation*. Menlo Park: SRI International.

Fullan, M. (2002). The change leader. *Educational Leadership, 59*(8), 16–21.

Fullan, M. (2007). *The new meaning of educational change* (4th ed.). New York: Teachers College Press.

Fullan, M., Cuttress, C., & Kilcher, A. (2005). Eight forces for leaders of change. *Journal of Staff Development, 26*(4), 54–64.

Geier, R., Blumenfeld, P. C., Marx, R. W., Krajcik, J. S., Fishman, B., Soloway, E., & Clay-Chambers, J. (2008). Standardized test outcomes for students engaged in inquiry-based science curricula in the context of urban reform. *Journal of Research in Science Teaching, 45*(8), 922–939.

Greca, I. M., & Moreira, M. A. (2000). Mental models, conceptual models, and modelling. *International Journal of Science Education, 22*(1), 1–11.

Grubb, W. N. (2009). *The money myth: School resources, outcomes and equity*. New York: Russel Sage Foundation.

Hargreaves, A. (2001). Beyond anxiety and nostalgia: Building a social movement for educational change. *The Phi Delta Kappan, 82*(5), 373–377.

Hargreaves, A., & Fink, D. (2004). The seven principles of sustainable leadership. *Educational Leadership, 61*(7), 8–13.

Hargreaves, A., Earl, L., & Ryan, J. (1996). *Schooling for change: Reinventing education for early adolescents*. London: Falmer Press.

Honey, M., & McMillan-Culp, K. (2000). Scale and localization: The challenge of implementing what works. In M. Honey & C. Shookhoff (Eds.), *The wingspread conference on technology's role in urban school reform: Achieving equity and quality*. Racine: The Joyce Foundation, The Jonson Foundation, and the EDC Center for Children and Technology.

Huang, Y.-M., Lin, Y.-T., & Chen, S.-C. (2010). Effectiveness of a mobile plant learning system in a science curriculum in Taiwanese elementary education. *Computers & Education, 54*(1), 47–58.

Inan, F. A., Lowther, D. L., Ross, S. M., & Strahl, D. (2010). Pattern of classroom activities during students' use of computers: Relations between instructional strategies and computer applications. *Teaching and Teacher Education, 26*(3), 540–546.

Jephcote, M., & Davies, B. (2004). Recontextualizing discourse: Exploring the meso-level. *Journal of Education Policy, 19*(5), 547–564.

Jones, C., Dirckinck-Holmfeld, L., & Lindström, B. (2006). A relational, indirect, meso-level approach to CSCL design in the next decade. *International Journal of Computer-Supported Collaborative Learning, 1*(1), 35–56.

Kezar, A. (2013). *How colleges change: Understanding, leading, and enacting change*. New York: Routledge.

Klingner, J., Boardman, A., & Mcmaster, K. (2013). What does it take to scale up and sustain evidence-based practices? *Council for Exceptional Children, 79*(2), 195–211.

Leusner, D. M., Ellsworth, J., & Goe, L. (2008). Scaling up across diverse contexts: Lessons learned from five implementations of the keeping learning on track program. In E. C. Wylie (Ed.), *Tight but loose: Scaling up teacher professional development in diverse contexts* (pp. 105–124). Princeton: ETS.

Lieberman, A. (2000). Networks as learning communities: Shaping the future of teacher development. *Journal of Teacher Education, 51*(3), 221–227.

Lieberman, A., & Wood, D. (2002). *Inside the national writing project: Connecting network learning and classroom teaching*. New York: Teachers College Press.

Lincoln, P. (1987). *A view from the inside: In the learning school* (pp. 6–28). Boston Spa: The British Library.

Looi, C. -K. (2011). *Sustained innovation in classroom practices: The role of educational researchers as meso-level actors*. Paper presented at the Beijing Forum 2011, Beijing, China.

Looi, C.-K., Wong, L.-H., So, H.-J., Seow, P., Toh, Y., Chen, W., Zhang, B. H., Norris, C., & Soloway, E. (2009). Anatomy of a mobilized lesson: Learning my way. *Computers & Education, 53*(4), 1120–1132.

Looi, C.-K., Seow, P., Zhang, B. H., So, H.-J., Chen, W., & Wong, L.-H. (2010a). Leveraging mobile technology for sustainable seamless learning: A research agenda. *British Journal of Educational Technology, 41*(2), 154–169.

Looi, C. K., So, H.-J., Toh, Y., & Chen, W. (2010b). CSCL in classrooms - The Singapore experience of synergizing policy, practice and research. *International Journal of Computer-Supported Collaborative Learning, 6*(1), 9–37.

Looi, C.-K., So, H.-J., Toh, Y., & Chen, W. (2011a). The Singapore experience: Synergy of national policy, classroom practice and design research. *International Journal of Computer-Supported Collaborative Learning, 6*(1), 9–37.

Looi, C.-K., Zhang, B., Chen, W., Seow, P., Chia, G., Norris, C., & Soloway, E. (2011b). 1:1 mobile inquiry learning experience for primary science students: A study of learning effectiveness. *Journal of Computer Assisted Learning, 27*(3), 269–287.

Looi, C.-K., Sun, D., Seow, P., & Chia, G. (2014a). Enacting a technology-based science curriculum across a grade level: The Journey of teachers' appropriation. *Computers & Education, 71*, 222–236.

Looi, C.-K., Sun, D., Wu, L., Seow, P., & Chia, G. (2014b). Implementing mobile learning curricula in a grade level: Empirical study of learning effectiveness at scale. *Computers & Education, 77*, 101–115.

Lynch, S., Pyke, C., & Grafton, B. (2012). A retrospective view of a study of middle school science curriculum materials: Implementation, scale-up, and sustainability in a changing policy environment. *Journal of Research in Science Teaching, 49*(3), 305–332.

Martin, F., & Ertzberger, J. (2013). Here and now mobile learning: An experimental study on the use of mobile technology. *Computers & Education, 68*, 76–85.

McDonald, S. K., Keesler, V. A., Kaufman, N. J., & Schneider, B. (2006). Scaling-up exemplary interventions. *Educational Researcher, 35*(3), 15–24.

McLaughlin, M. W., & Talbert, J. E. (2006). *Building school-based teacher learning communities: Professional strategies to improve student achievement*. Chicago: University of Chicago Press.

MOE. (2008). *MOE launches third masterplan for ICT in education*. Retrieved from http://www.moe.gov.sg/media/press/2008/08/moe-launches-third-masterplan.php

O'Neil, J. (2000). Fads and fireflies: The difficulties of sustaining change. *Educational Leadership, 57*(7), 6–9, ERIC Journal No. EJ609634.

Orlando, J. (2013). ICT-mediated practice and constructivist practices: Is this still the best plan for teachers' uses of ICT? *Technology, Pedagogy and Education, 22*(2), 231–246.

Pea, R., & Maldonado, H. (2006). WILD for learning: Interacting through new computing devices anytime, anywhere. In K. Sawyer (Ed.), *Cambridge handbook of the learning sciences* (pp. 427–442). New York: Cambridge University Press.

Penso, S., Shoman, E., & Shiloah, N. (2001). First steps in novice teachers' activity. *Teacher Development, 5*(3), 323–338.

Penuel, W., & Fishman, B. (2012). Large-scale science education intervention research we can use. *Journal of Research in Science Teaching, 49*(3), 281–304.

Peurach, D. J., & Glazer, J. L. (2011). Reconsidering replication: New perspectives on large-scale school improvement. *Journal of Educational Change, 13*(2), 155–190.

Rodríguez, P., Nussbaum, M., & Dombrovskaia, L. (2012). ICT for education: A conceptual framework for the sustainable adoption of technology-enhanced learning environments in schools. *Technology, Pedagogy and Education, 21*(3), 291–315.

Ruchter, M., Klar, B., & Geiger, W. (2010). Comparing the effects of mobile computers and traditional approaches in environmental education. *Computers & Education, 54*(4), 1054–1067.

Scherrer, J., Israel, N., & Resnick, L. B. (2013). Beyond classrooms: Scaling and sustaining instructional innovations. In *Proceedings of connecting computer-supported collaborative*

learning to policy and practice: CSCL2011 conference proceedings (pp. 1073–1080). Hong Kong: ISLS.

Sha, L., Looi, C.-K., Chen, W., Seow, P., & Wong, L.-H. (2012). Recognizing and measuring self-regulated learning in a mobile learning environment. *Computers in Human Behavior, 28*(2), 718–728.

Sharples, M. (2006). How can we address the conflicts between personal informal learning and traditional classroom education. In M. Sharples (Ed.), *Big issues in mobile learning* (pp. 21–24). Nottingham: LSRI, University of Nottingham.

Shih, J.-L., Chuang, C.-W., & Hwang, G.-J. (2010). An inquiry-based mobile learning approach to enhancing social science learning effectiveness. *Educational Technology & Society, 13*(4), 50–62.

Sloane, F. C. (2008). Through the looking glass: Experiments, quasi-experiments, and the medical model. *Educational Researcher, 37*(1), 41–46.

Smith, K., & Petersen, J. (2011). *Supporting and scaling change: Lessons from the first round of the investing in innovation (i3) program*. Boston: Bellwether Education Partners.

Song, Y., Wong, L.-H., & Looi, C.-K. (2012). Fostering personalized learning in science inquiry supported by mobile technologies. *Educational Technology Research and Development, 60*(4), 679–701.

Sun, D., & Looi, C.-K. (2013). Designing a web-based science learning environment for model-based collaborative inquiry. *Journal of Science Education and Technology, 22*(1), 73–89.

Thompson, M., & Wiliam, D. (2007). *Tight but loose: Conceptual framework for scaling up school reforms*. Washington, DC: American Educational Research Association.

Wong, L.-H., Boticki, I., Sun, J., & Looi, C.-K. (2011). Improving the scaffolds of a mobile-assisted Chinese character forming game via a design-based research cycle. *Computers in Human Behavior, 27*(5), 1783–1793.

Zhang, B. H., Looi, C.-K., Seow, P., Chia, G., Wong, L.-H., Chen, W., So, H.-J., Soloway, E., & Norris, C. (2010). Deconstructing and reconstructing: Transforming primary science learning via a mobilized curriculum. *Computers & Education, 55*(4), 1504–1523.

Chapter 9
Innovation Scale-Up of ICT in Education in China

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Abstract Information and communication technologies (ICT) in education have been regarded as playing an important role in the development of educational equity and quality. There are many successful cases in promoting educational quality and equity in different countries and regions; however, it is still a big challenge to scale up the use of ICT in education to achieve educational development across a system. This chapter introduces the policies about ICT in education and their implementation in China and shares the experiences of scaling-up ICT in education in a big developing country. The chapter also describes a few successful cases of scaled-up ICT-based innovations in China and analyzes their characteristics. The diffusion models of decentralization and centralization in Mainland China are discussed at the end of the chapter.

Since the 1980s, the public had become increasingly concerned with the rapid progress of technology and the promise it holds for the future in facilitating all aspects of life: work, leisure, and education. Information and communication technologies (ICT) during the past two decades have had many points of contact with education and training (Rezaei et al. 2011). Policy makers and educational stakeholders recognize the contribution of ICT to achieving the development of education, and more broadly, the role of ICT as a key enabler of innovation and creativity in education and training, and for learning in general (Kampylis et al. 2013). The use of ICT in education is an important element in many countries' educational development strategy, because ICT is often anecdotally associated with improvements in quality of classroom instruction, provision of innovative

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instructional opportunities by teachers for students, and improvements of the capacity at the administrative or policy level (Tolani-Brown et al. 2011). Many countries have initiated policies and strategies for the infusion of ICT into their schools, and they share the belief that a critical factor in the nation's economic success is how well their citizens can adapt and thrive in a global ICT environment (Looi and Hung 2005). Therefore scaling-up the ICT-driven innovation is commonly believed to be a key factor in the further development of education. Over the past 20 years, the application of educational technology has been considered one of the most important engines of education development in China. The application of ICT in K-12 education, vocational education, higher education, and teacher education facilitates the innovation of teaching principles, methods, tools, and resources (Yang 2013). This chapter is intended to share experiences concerning the policies and development of ICT in education in China which other countries and regions in the world can tap on as a reference point for their own scaling up of ICT in education.

Educational Development in Mainland China

Since initiating market reforms in 1978, China has shifted from a centrally planned to a market-based economy and has experienced rapid economic and social development. With a population of 1.3 billion, China recently became the second largest economy and is playing an increasingly important and influential role in the global economy.

Yet China remains a developing country (i.e., its per capita income is still a fraction of that in advanced countries), and its market reforms are incomplete. Official data shows that about 98.99 million people still lived below the national poverty line of RMB 2,300 per year at the end of 2012. With the second largest number of poor in the world after India, poverty reduction remains a fundamental challenge (World Bank 2014). Rapid economic ascendance has brought on many other challenges as well, including high inequality, rapid urbanization, and challenges to environmental sustainability.

Education has traveled the same path as the social development of China. The past 30 years of reform and opening up have resulted in major changes in the education system. First, China has provided free 9-year nationwide compulsory education in both urban and rural areas of the country. Second, the development of higher education has taken a historical leap and entered a stage of increasing availability. Third, the development of vocational education has been accelerated in the process of carrying out reforms and making innovations, and major breakthroughs have been made in improving the overall structure of education. Fourth, China has made major strides toward realizing equality in the development of the education system. Fifth, China has established the basic framework for a socialist educational system with Chinese characteristics and is following a path for the development of such a system.

As a developing country with the biggest population, China has built up the largest education system in the world, covering all types of education at all levels, such as basic education, vocational education, higher education, and continuing education. The system has benefited about 316 million people among the total population of 1.354 billion in Mainland China. All citizens must attend school for at least 9 years, known as the 9-year compulsory education. It includes a 6-year primary education, starting at age 6 or 7, and a 3-year junior secondary education (middle school) for ages 12–15.

According to the National Statistic Gazette of the Educational Development (2012), China's gross enrollment rate was 64.5 % for preschool education, 99.9 % for primary education (the 6–11 age group or 7–12 age group), 102.1 % for junior secondary education (the 12–14 age group), 85 % for senior middle school education (the 15–17 age group), and 30 % for higher education (the 18–22 age group) by the end of 2012 (MOE 2013).

China Ministry of Education (MOE) has released the National Plan for Medium and Long-term Education Reform and Development (2010–2020), which contains a number of strategies for education development and also proposes development goals for all levels of China education.

By 2020, 1-year preschool education will be provided for all the children, 2-year for most children, and 3-year for children in developed areas. The childhood development program for 0–3 year-olds will be improved with further efforts. By 2020, every school-age child will have guaranteed access to qualified education by expanding the coverage of compulsory education, improving overall education quality and leveling up education development of specific areas. By 2020, senior secondary education will be developed in a vigorous way to meet the needs of junior secondary graduates for further education. A well-structured vocational education system covering both secondary and postsecondary level will also be constructed, in coordination with industrial restructuring and the change of economic development models, to meet the social needs for high-quality workforce and skilled personnel. By 2020, higher education will be better structured, and it shall also go up a notch in talent or professional development, scientific research, and social service as a whole. A number of high-quality and world-known universities will come to the fore, some of which will be on the world-class list.

The Development and Challenges of ICT in Education in China

ICT in education refers to the process of applying modern ICT thoroughly and deeply to education to foster education change and education development; the result of ICT in education will definitely form a brand new kind of education: information education (Huang et al. 2006). In the course of applying ICT to education, the process of educational transformation is promoted gradually. The teaching

process will experience four changes in the process of applying ICT into education: changing of student perception, changing of some instructional principles, changing of instructional content and material, and changing of the relationship between teachers, students, and teaching materials (Huang et al. 2013). These four changes will happen not because of the application of ICT in education per se, but the development of the wider information society.

Along with the process of social transition, educational transformation, and spreading of ICT in society, the development of ICT in education in China mirrors its international development. If we consider the proclamation that "computer education should start from children" by Deng Hsiao-ping as the starting point of ICT in education in China, it can be divided into four phases: instruction of computing as a discipline starting from the end of 1970s, computer-assisted instruction and management starting from the middle and late 1980s, national initiatives of ICT in education focused on the construction of infrastructure since late 1990s, and national projects of ICT in education focused on improving capacity of using ICT since 2005 (Huang et al. 2006).

Since 1970s, a series of national projects and policies of ICT in education have been implemented, laying a solid foundation for its sustained development (Liu et al. 2009). By the end of 2013, 57 % of schools have internet access, 41 % of classrooms (1.6 million) in primary and junior secondary schools have ICT equipment, 50 % of schools have at least one multimedia classroom, and the ratio of students to computers in K-12 schools is 11:1 (MOE 2013). Eleven million teachers and students can obtain learning resources from National Public Service Platform for Educational Resources; over six million registered online learning spaces with real names are in service; 244 National Quality Courses that selected from the best of best courses have been built by filming micro lectures into video clips.

Although significant progress has been made in using ICT in education, there are also some challenges in the process of applying ICT in education and transforming education as the society develops. In the past 30 years, China has made tremendous development in information systems, but these systems are isolated from each other because of their different technology development trajectories and different standards (Huang et al. 2007). While different government organs administer different systems, the responsibilities of these organs in streamlining the use of these systems are not clear. Educational administration departments and schools have recognized the important role of applying ICT in education, but decision-making and administration barriers still exist thus hindering the overall educational transformation in administration, instruction, and scientific research. For example, the pace and effect of the process of applying ICT in education in colleges and universities largely depends on the chief information officer or even the president's understanding of ICT's influence on education which can be uneven. Similar condition exists in the schools.

The Chinese government has paid much attention to apply ICT in education in western China and rural areas to narrow the "digital divide." But the big obstacle is in the shortage of ICT talent and developing and maintaining personnel in villages and towns to support ICT in education is difficult (Orleans 2010). Establishing such personnel or staff in the county level is a good approach, but there are still challenges on how to integrate the local institutions such as the teachers' college for vocational studies, schools, and the educational technology center to support ICT in education.

The current teaching and learning situation is characterized by "examination-oriented, overloaded work," which is quite different from the new idea of "independence, exploration, and collaboration" that should be emphasized in the process of basic educational transformation currently stressed by the government. In the past, teachers were admired and adored because of their extensive knowledge, and thus classroom teaching was easy to organize. Today, students were born and grown up in the time of digital technology. They are called digital natives, and they are good at getting access to digital information. However teachers are digital immigrants who may have less knowledge in using different kinds of technology. Therefore, teachers no longer hold the authoritative position in the classroom because students may know more than their teachers, in particular learning objects as information which is becoming more and more symmetrical for the students. Furthermore, it is easy for the digital natives to develop some ICT literacy, but it is difficult for them to retain intensity for long or to think deep (Prensky 2001). In this sense, classroom organization for teacher is difficult, as teachers have to cater the different kinds of needs from digital natives.

The Development Goals of the Ongoing 10-Year Plan for ICT in Education

Since the government has realized that the core value of ICT in education lied in transforming learning and teaching under the guidance of modern educational philosophy, the *National Plan for ICT in Education (2011–2020)* was released in 2012 to state the overall development goals of ICT in education in China (MOE 2012). By 2020, the system for ICT in education will be constructed to match the objectives of education modernization, with the aim of providing everyone with quality digital learning resources, creating an ICT-based public service system to support life-long learning, and expanding the coverage of the broadband Internet connections to all schools and universities. ICT-based educational management and the infusion of ICT in education will also be greatly improved.

The development goals of the ongoing 10-year plan for ICT in Education could be termed as *ConnectSCS*, which stands for *connecting Schools* through broadband network, *connecting Classes* with quality digital resources, and *connecting Students* in cyber learning space, as shown in Fig. 9.1.

Connecting Schools Through Broadband Networks

The task of connecting schools is to provide broadband network to access the Internet and build ICT infrastructure for enabling each school to support teaching with technology. This could be illustrated in the following three aspects. First, providing broadband network for every school includes three aspects of construction: the construction of broadband network to make it available for every school, the construction of

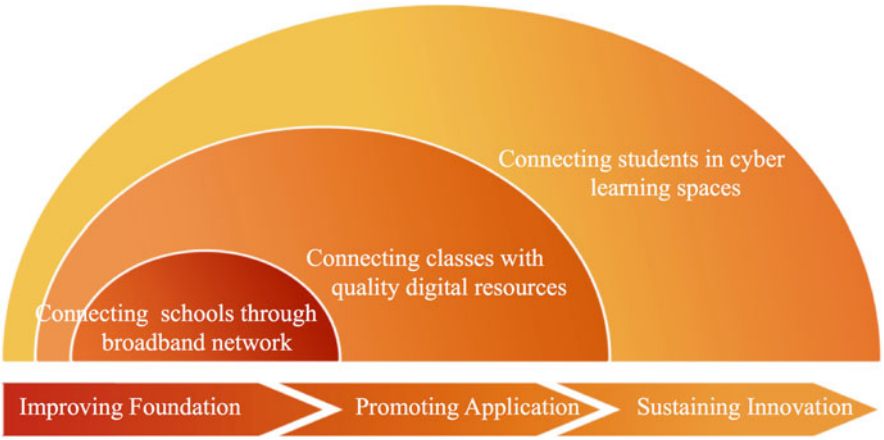

Fig. 9.1 The development goals of ICT in education: ConnectSCS

network infrastructure in school, and the construction of effective mechanism for supporting and maintaining ICT infrastructure. Second, providing hardware, software, and resources for every classroom includes three aspects: to equip every classroom with basic ICT facilities, to offer essential ICT-based instruction tools to every teacher, and to deliver rich digital learning resources to every class. Third, providing basic training for every teacher's teaching with technology includes three aspects: to allot computers and other devices for teachers, to encourage teachers to integrate ICT in teaching, and to offer teacher training in using ICT in education.

Connecting schools through broadband networks is the basis for ICT in education, which reflected not only in the infrastructure but also in the capacities of the teacher and the students to use ICT for learning. According to the 10-year plan for ICT in education, the government will carry out the overall planning and support policies to bring in telecom corporations to provide Internet access for schools. The building of the ICT environments in primary and junior schools in poor rural areas is mainly funded by the central government, and local governments fund other areas.

Connecting Classes with Quality Digital Resources

Connecting classes as a task is to provide quality digital learning resources for each class to normalize teaching using technology, which could be illustrated in the following three aspects.

First, it is about expanding the coverage of quality education resources through ICT to enable every teacher and student to easily access quality education resources. Teachers can use ICT skillfully to achieve teaching objectives and generate new resources. The application of ICT in teaching, research, and cross-school teaching will become a common practice for every teacher. Second, it is about maximizing

the effectiveness, efficiency, and benefits of teaching with technology to make students learn better with improved learning efficiency through ICT. Resource sharing can reduce education cost and learning load. Third, it is about innovating learning and teaching through the application of ICT in teaching and learning. To reconstruct learning and teaching process by ICT, to innovate teaching model in ICT environment, and to reform teaching and learning methods are the three key issues.

Connecting classrooms aims to use ICT and digital learning resources in daily teaching activities and innovation of classroom teaching. This helps to improve education quality and equity. Each teacher and school will be motivated to use ICT actively when available. Teachers using and sharing digital resources in daily teaching and research activities will then be pervasive.

Connecting Students in Cyber Learning Spaces

The cyber learning space is a type of controllable and manageable software platform, which can provide learning support, digital resource exchange, virtual interaction, and management to match personalized learning of students. The task of connecting students is to provide cyber learning space for each student, teacher, and administrator with real-name registration and to explore personalized learning environment for the new generation of students. This is illustrated in the following four aspects.

First, students can communicate freely in the learning community, and teachers can discuss their professional development in the professional development community through a web-based communication platform for students, teachers, and parents. The other important task is to realize seamless link between physical and virtual spaces. Second, students and teachers can easily access learning resources in cyber learning space with the support of different learning approaches and teaching models. The third is to build a flexible and convenient system for sharing learning resources to ensure learning resources are available on-demand and to ensure rights of stakeholders and to promote their interests and enthusiasm. The fourth is about building a real-name registered, organized, controllable, and manageable cyber learning space to ensure the effective management of cyber learning space and the security of personal cyber space.

Principles for Scale-Up ICT-Supported Educational Innovations in China

Owing to Chinese sociocultural and economic differences across regions, the process of using ICT in education to promote innovation and reform is quite different from other countries, thus creating a development pathway with Chinese characteristics.

ICT in education in China has made significant progress through a series of projects and policies in the last decade. National ICT infrastructure system for education has been established, schools in cities have accessed the Internet, and information

terminals have been equipped in most rural schools. Digital education resources are more easily accessed, and ICT are more and more integrated into the curriculum. ICT in education begin to play an important role in promoting education equality, elevating education equality, and innovating education mode. But the urban and rural areas still have digital divide in such a big county; the awareness of the important role of information technology in education remains to be deepened; ICT infrastructure needs to be enhanced to be universal for each school; the mechanism for sharing digital education resources among different regions and institutions demanded to be developed.

Based on special circumstances in China, the Chinese government has taken ICT in education as the decisive strategy for educational reform and innovation. The following three principles are derived from the basic experience of the policy makers.

Adhering to the Core Idea of Infusing ICT into Education

ICT brings new ideas and driving forces to the development of education, which profoundly transforms the educational contents, methods, and modes. This transformation goes with a process of mutual influence and promotion between ICT innovation and education development in the knowledge society. This is recognized as the essence and objective of ICT in education by the Chinese government. The value of ICT in education will appear only if ICT is integrated into education by changing traditional education ideology and models and by developing new teaching methods and patterns. The reform of education and the innovation of educational ideas require the support of advanced ICT, which promotes ICT development.

Adhering to the Basic Principle of Needs-Driven Application

Needs-driven application could be summarized in the following four aspects: first, focus on the application of ICT in education and concentrate on classroom teaching; second, promote the full infusion of ICT into various aspects of teaching process and various subjects; third, enlist the capability of ICT application in the certification system of teacher's capabilities; fourth, make routine the use of ICT in daily teaching activities.

Adhering to the Fundamental Policy of Innovation-Driven Mechanism Construction

This is firstly to motivate all sectors of society to take advantages of market-allocated resources and professional service provided by the enterprises and other institutions, so as to realize the development of all in promoting ICT in education. Secondly, a number of model schools, teachers, and courses need to be created through

experimentation to explore the teaching organization methods and effective teaching models in different ICT conditions and accumulate typical experience for wider promotion.

Experiences of Scale-Up of ICT-Supported Educational Innovations in China

Countries and regions have developed various policies to enhance the application of technology into education (Looi et al. 2011). Although there are some successful cases in some areas, there is still a problem of how to scale up these ICT applications at the national level. Equity and quality are the two main concerns for education development in each country. In big countries like China with unbalanced education development in rural and urban areas, educational equity and quality are also big challenges in educational development. The Chinese government believed that the integration of ICT in education and the scale-up of ICT-supported innovation could promote educational equity and enhance educational quality. The following two sections will discuss the experiences of the scale-up of ICT-supported innovation from promoting educational equity and enhancing educational quality.

Promoting Educational Equity

To improve equity in educational opportunities and to extend educational provisions are important national educational goals related to the use of ICT in education, especially in developing countries (Pelgrum and Law 2003). China has a large proportion of rural residents, with 50.5 % of its population living in rural areas (National Bureau of Statistics 2011). The poorly educated rural population will shackle further development of China and become a burden of the nation, because these people impose additional demands on public budgets to deal with the negative consequences of a lack of education, such as higher spending on public health, social support, and greater criminality (OECD 2012). It is a tough problem to provide the same quality education for all, especially the same quality teachers and quality resources.

The Chinese Central Government adopted a centralization policy in the education sector. Education was regarded as a key field related to social stability and development, and therefore the State exerted a strict control over education. The educational system is characterized by a unified system of planning, administration, curriculum structure, syllabus and textbooks, and student admission. The State assumed responsibility for formulating educational policies, allocating educational resources, and exerting administrative controls. For promoting educational equity by utilizing ICT, the Chinese government has conducted several important projects nationwide.

The implementation of the "all school connected" project which started in 2000 has smoothed the way for the sharing of quality teachers and quality resources and promoted the balanced development of teachers and resources for both urban and rural areas. The *National Schools Modern Distance Education Project in Rural Areas* which is organized and implemented by the Chinese government is aimed at sending quality educational resources and providing teaching support service for the rural areas and the western underdeveloped areas by ICT. At the end of 2007, great progress had been made in the infrastructure construction of ICT in education in rural areas and over 100 million school students had benefited from it; the severe shortage of quality educational resources has been alleviated; over one million teachers have benefited from distance training specially designed for teachers in rural areas (Zhang 2009b).

New types of classes and schools have emerged such as "elite teacher class," "elite cyber school," and "distance class." The purpose is to share quality digital material in schools, to improve the quality of education, and to enhance the balanced development of education. In "elite teacher class," elite teachers are invited to give cyber classes to students in remote areas, so the human resources of elite teachers can be shared. "Elite cyber schools" offer quality digital learning resources through cyber class to benefit more students. Through "distance class," schools in remote rural areas can access classes provided by schools in urban areas with rich digital educational resources.

Example of "elite cyber schools": In 2005, the High School affiliated to Renmin University of China sets up the "Union of Co-construction and Sharing of National Basic Education Resources" (UCSNB-ER, http://www.g12e.org) together with other 39 key secondary schools across the country. The union aims to build the platform and mechanism for developing, integrating, and sharing quality digital learning resources. Based on the national project "The Application of IPV6 Grid in National Basic Education," the union has established its own grid platforms of basic education to achieve the objective of "nodes for all schools, groups for all classes, and spaces for all teachers and students." All schools and individuals that have access to the network can apply for the membership, through which they can use all the digital learning resources and upload their own resources to the network for sharing.

Example of "elite teacher class": The Teaching and Research Institute of Basic Education in Jiangsu Province (http://www.jssjys.com/tv) invites elite teachers to offer classes of different subjects and topics and experts to give comments on their teaching in cyber classrooms. The elite teachers decide on the teaching topics, present their teaching design, and demonstrate their teaching. Other teachers watch the video and listen to the reflections given by the elite teachers and the comments offered by the experts, as well as online discussion with the elite teachers and experts. The elite teacher class has motivated more teachers to participate in teaching and research activities.

One-teacher school is the weakest part of the basic education in China. Most one-teacher schools are located in the remote places with inconvenient transportation, with no access to the network, and with few teachers. Teachers in these schools

always have inadequate educational background. So far, there have been over 67,000 one-teacher schools in rural China, among which 7,000 are in eastern China and over 60,000 in middle and western China.

Example of "distance class": In November 2012, the MOE and Ministry of Finance jointly initiated the implementation of the project of "Full Coverage of All One-teacher Schools with Digital Learning Resources" (http://jxd.cbern.gov.cn/cms), which equipped the one-teacher schools with ICT devices for receiving and running digital learning resources. Taking one county as a unit, designated central schools within the county play an important role in organizing one-teacher schools to use digital learning resources in teaching and in helping them to run all the national courses as required so that the school-age children in remote rural areas can receive quality education near their homes. By December 2013, 47,000 one-teacher schools had been able to teach with ICT devices and digital resources. Taohuagou one-teacher school in Yun County of Hubei Province is located deeply in Qinling Mountains with over 25 km away from the county town. It has only one class composed of seven students in Grade One, Two, and Three in the primary level, with one teacher, whose name is Liu. Liu made full use of the ICT satellite devices and digital resources provided in the project to offer all eight national courses as required for the seven students in the three different grades.

All in all, the educational equity has been promoted by the scale-up of ICT in education through several projects initiated by Chinese government. "Distance class," "elite teacher class," and "elite cyber school" were three prominent innovations in China that scale-up the utilization of ICT in education. They did this through sharing quality digital material and thus enhancing the balanced development of education in rural and urban areas.

Enhancing Educational Quality

Educational quality goes beyond its conventional concept of academic achievements, and it refers to the kind of quality that ensures knowledge, skills, and dispositions development that can meet the needs of the information age (Mu et al. 2013). In the information age, not only content-specific knowledge is needed, but information processing capacity, cooperative capacity, and learning capacity are also needed. To illustrate, critical thinking and problem-solving, collaboration and leadership, agility and adaptability, initiative and entrepreneurialism, effective oral and written communication, accessing and analyzing information, curiosity and imagination are listed as the seven basic survival skills in the information age (Wagner 2008). For enhancing educational quality, methods of integrating ICT into the curriculum are being studied and carried out in China, and the "student-centered and teacher-guided" model was improvised by Chinese scholars according to actual Chinese educational conditions (Yu 2004). According to the model, under the guidance of scholars, different ICT infusion models has been created by many elite schools, and they have been tested effective for improving educational quality.

No. 2 Middle School in Zhengzhou (http://zz2z.zzedu.net.cn) is one of the examples, which has innovated their own ICT-integrated self-regulated learning model. This school is typical in that it was constructed under the principles of "Adhering to the core idea of infusing ICT into education" and "Adhering to the fundamental policy of innovation-driven mechanism construction." The school received special attention and support from Apple (China) and established a strategic partnership with Henan Normal University, East China Normal University, and other research institutions. With the support of researchers and cooperation, this school has implemented a self-regulated learning model by infusing ICT into the whole learning process. It has 78 classes, 217 teachers, and nearly 5,000 students. The school has set up ICT innovation experimental classes, in which each student is provided with a free tablet. Students could log into a smart learning environment with the resources for instructional design, courseware, teaching cases, and reflection. Such an environment facilitated students' mobile self-regulated learning. Students regulate their own learning, and the teacher can track students' learning processes and performance.

The school provides "four types of lessons" which include prerequisite lessons, feedback lessons, reflection lessons, and practice lessons. The "four types of lessons" are actually the four steps of classroom teaching that reflect the cognitive regularities, from the unfamiliar to the familiar, from simple to complex. The process are described as the following: (1) teachers send resources package, including courseware and related learning resources to each student through students learning support service system; (2) students self-study the content according to textbooks and resources package; (3) students demonstrate their learning outcomes through tablets or demonstrate their learning results by taking tests in the students learning support service system; (4) teachers summarize the important and difficult knowledge points through guiding student's thinking, questioning, and discussing; and (5) final examinations will be administered on the learning platforms, and the student learning support service system will provide automatically generated statistical results to teachers and students. In this mode, self-study before class time is integrated as part of the learning process, and the students can select the content and resources independently by using software tools and Web resources.

Meanwhile, mobile, ubiquitous network environment, and learning systems provide students an opportunity to carry out an anytime, anywhere learning, which realized the combination of physical classroom and virtual classroom. Teachers can use the learning support system and the learning evaluation system to give one-on-one personalized guidance for each student to improve the efficiency of learning and teaching.

The innovation of infusing ICT in this school was developed with the assistance of academic researchers and IT companies. Through conducting academic research in collaboration with schools, academic organizations are promoting ICT in education by developing innovative teaching methods and materials and by providing academic and technical support in the process. IT companies and industries consider ICT in education one of the major markets. The cooperation between IT companies and academic organizations has given the school enough support for innovating teaching by integrating emerging ICTs into the whole learning process.

This is a researcher-led diffusion model of ICT in education, which is a common adopted innovation method of ICT in education that will be discussed in the next section. One of the typical cases based on the researcher-led diffusion model, is called "promoting leapfrog development in K-12 schools by integrating ICT" which started in 2002 in a primary school at Guangdong Province. Under the guidance from a team from Beijing Normal University, an integration model has been created to engage students in English language learning in networked classroom. An evaluation conducted in 2003 shows that the model has been effective for improving student's English listening skills, speaking skills, and writing skills. Till now, the team has implemented this model at more than 200 schools supported by the funding from local government. The scale-up of this mode has improved the educational quality in these experimental schools.

Discussion: Diffusion Models of ICT in Education

The basic principles and the experience for scale-up ICT in education in China that have been introduced in previous sections intend to provide some references for scale-up of the innovation of ICT in education. These principles and experiences were effective methods and practices in a big country like China with unbalanced educational development. In order to provide a more general principle for scale-up ICT in education, theories behind these practices will be discussed in this section.

The Diffusion of Innovation model of Rogers (1995) is concerned about planning and guiding organizational change processes to promote the adoption of new innovations. Understanding how early adopters will push organizational uptake of new products and processes, or how entrenched resistors or "persistent skeptics" can stonewall change, is important for change managers and will help to scale up the innovation of ICT in education.

There are two diffusion systems (models) in society: centralized and decentralized models (Rogers 1995). The former is a classical diffusion model, spreading from a central source of innovation to the adopters; the latter, by contrast, means that innovation may not come from the formal research and development system, but often emerges at the operational level within the system through invention by some major users of the system. The decentralized diffusion model is consonant with recent literature on diffusion of educational innovations (Developmental Education Task Force 2008). In the scale-up of innovative ICT in education, those two types of diffusion systems are in coexistence. We call the centralized model as researcher-led diffusion of ICT in education (shown in Fig. 9.2) and the decentralized model as practitioner-led diffusion of ICT in education (shown in Fig. 9.3) (Zhang 2009a).

The centralization diffusion system (researcher-led diffusion of ICT in education) is based on relatively linear, top-down, and one-way communication. Due to the long-term effects of the traditional educational model, the high pressure of enrollment and academic performance and the generally poor learning environments of the schools, educators including teachers, administrators of school, or regional

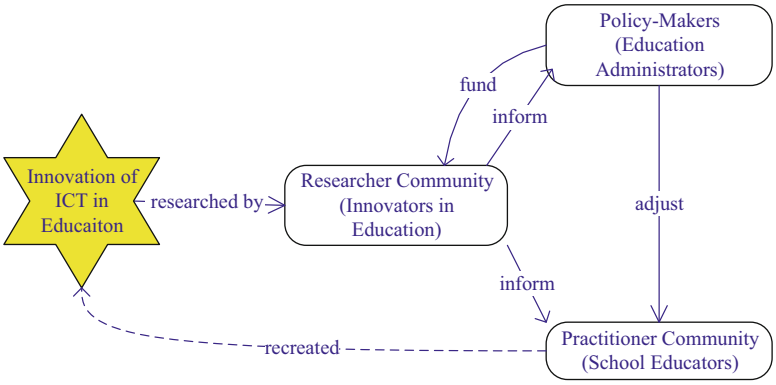

Fig. 9.2 Researcher-led diffusion of ICT in education

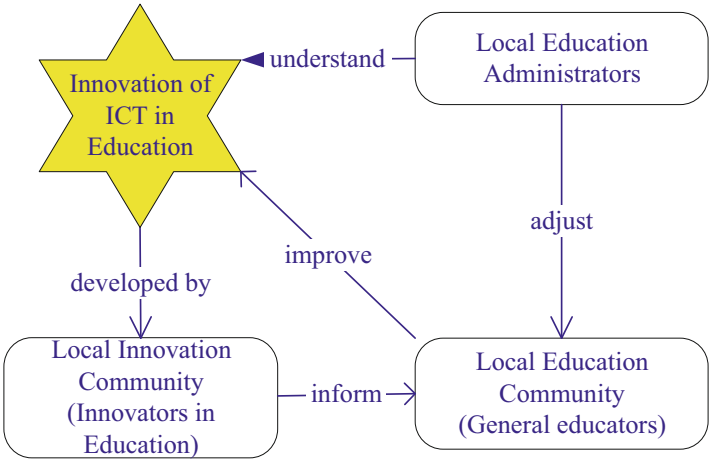

Fig. 9.3 Practitioner-led diffusion of ICT in education

education organization have no time to work on the new methods, technology, and applications. Therefore, educational institutions and organizations in China highly rely on researchers as experts to design and develop the innovations. The source of innovation is derived from the technical or educational experts in the field of ICT in education. In the research community through multiple channels, researchers create or recognize the innovations that are worth promoting and proliferating to the practitioners. Acting as innovation agents, researchers inform the policy makers and practitioners. Policy makers evaluate the value of the innovation, judge the feasibility of diffusion, control the funding (increased or reduced) by monitoring the diffusion process once they make the decision to promote, guide research community activities, or release new policy and regulations (such as incentive policies) guiding

practitioners' participation. In the process of adopting, implementing, and spreading the innovations, practitioners can also recreate or improve the innovation, thereby looping back to inform the next cycle of research.

Compared with the centralization diffusion system (Research-Led Diffusion of ICT in Education), the decentralization system of innovation can better meet the needs of users and help address their problems. In this decentralization system, users are able to feel the sense of ownership and control of the innovation, because they are in the center of the key decisions. For example, educators can decide which problems should be paid prioritized for attention and be resolved, what innovation can best meet their needs, from where and how to obtain the relevant information, and how to make appropriate amendments once implementing innovations in specific circumstances. The "Union of Co-construction and Sharing of National Basic Education Resources" of High School affiliated to Renmin University of China is an example of this diffusion model.

Since the *National Plan for ICT in Education (2011–2020)* was released in 2012, the main form of proliferation and diffusion of ICT in education in Mainland China has switched from *point diffusion* to *scale-up diffusion*. This means shifting the emphasis from local areas' individual, isolated pilots of "migration type" to regional expansion of purposeful, targeted, and hierarchical diffusion. Many districts are developing and promoting regional ICT applications, such as cloud-based learning system and online digital learning resource database, for a whole city or even a whole province. In specific situations, if the innovation complexity is not high and the user environment is relative to "heterogeneous," decentralization strategy will be effective; but if the user environment is "homogenous," centralization strategy of diffusion will be more effective.

In certain cases, integrating elements of decentralization and centralization can lead to the formation of a hybrid diffusion system. For instance, a diffusion system may combine a central coordinating role, with decentralized decisions being made about which innovations should be diffused and which user sites should be supported. Regional diffusion decisions may be made and implemented by using the centralization strategy, and users can be allowed to participate in local diffusion process of decision-making through adopting decentralization strategy. In the regional centralized diffusion system, government officials and technical subject-matter experts lead the construction and management of public infrastructure and service. Innovations in decentralized systems come into being through local experimentation by nonexpert users. Local units decide which innovations should diffuse through horizontal networks, enabling a high degree of autonomy.

Since 2012, the Ministry of Education launched the national pilot project of ICT in education, exploring the effective and deep integration of ICT into education. Every province's center for educational technology acts as a central coordinator responsible for evaluating the innovation, drawing and implementing guidelines, evaluating pilot implementations, and sharing information and experiences. But the schools, according to their own circumstances, explore and conduct research on specific promotion activities in their local areas. In the past 2 years, some best practices have been identified, translated, diffused, or recreated by higher level

administration organizations or academic institutions and then disseminated further in the education system. That is a typical hybrid model of diffusion which is likely to be more prevalent in the future.

Conclusion

In the past 30 years, ICT in education in China has witnessed great changes from the construction of infrastructure to building the capacities of teachers in applying ICT to improve educational practices. Progress has been achieved in promoting educational equity, educational quality, teaching training, and educational management. China is persistent in formulating and refining suitable policies and initiating projects to scale up the innovation of ICT in education in light of her own national conditions. The successful application of ICT in education is derived from knowledge of the diffusion model of ICT in education and the policy decision from the central government.

The development goals of the ongoing 10-year plan for ICT in education reflect the ambitions and goals of Chinese government. It also means that ICT in education in Mainland China has entered the stage of in-depth development. It is necessary to have comprehensive solutions to scale up the innovation of ICT in education. Her educational innovation of ICT in education is different from other nations, as it arises from the Chinese educational context and development status. Thus, the experiences of scale-up strategies and diffusion models may be different from those of other countries. The development strategies for ICT in education in Mainland China are not static but will be fine-tuned and improved continuously and progressively.

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References

Developmental Education Task Force. (2008). *Developmental education models and best practices*. Retrieved from http://www.sanjuancollege.edu/documents/FSPDocuments/PresTaskForces/DevEd/Dev%20Ed%20Final%20report_05_09.htm.

Huang, R., Jiang, X., & Zhang, J. (2006). Innovation and transformation: Focus on current *educational* informatization development. *Distance Education in China, 4*, 52–58.

Huang, R., Zhang, Z., Chen, G., & Xu, C. (2007). Online learning: Does learning really happens: *Comparison* of Chinese and British online learning in intercultural context (in Chinese). *Open Education Research, 13*(6), 12–24.

Huang, R., Chen, G., Yang, J., & Loewen, J. (2013). The new shape of learning: Adapting to social changes in the information society. In R. Huang & J. M. Spector (Eds.), *Reshaping learning SE – 1* (pp. 3–42). Berlin/Heidelberg: Springer. doi:10.1007/978-3-642-32301-0_1.

Kampylis, P., Law, N., & Punie, Y. (2013). *ICT-enabled innovation for learning in Europe and Asia* (pp. 1–147). Seville: European Commission. Retrieved from http://ftp.jrc.es/EURdoc/JRC83503.pdf

Liu, M., Lv, J., & Kang, C. (2009). Educational technology in China. *British Journal of Educational Technology, 41*(4), 541–548. doi:10.1111/j.1467-8535.2010.01094.x.

Looi, C., & Hung, W. (2005). ICT-in-education policies and implementation in Singapore and other Asian countries. In A. Aviram & J. Richadson (Eds.), *Upon what does the turtle stand?* (pp. 27–40). Dordrecht/Boston: Kluwer Academic Publishers. Retrieved from http://link.springer.com/chapter/10.1007/1-4020-2799-0_2

Looi, C., So, H., Toh, Y., & Chen, W. (2011, March). The Singapore experience: Synergy of national policy, classroom practice and design research. *International Journal of Computer-Supported Collaborative Learning, 6*(1), 9–37. Retrieved from http://link.springer.com/article/10.1007/s11412-010-9102-8

MOE of P.R.C. (2012). *Ten-year development plan for ICT in education in China (2011–2020)*. Retrieved from http://www.moe.edu.cn/ewebeditor/uploadfile/2012/03/29/20120329140800968.doc83c4d329.html

MOE of P.R.C. (2013). *Educational statistics 2012*. Website of MOE, China. Retrieved from http://www.moe.gov.cn/publicfiles/business/htmlfiles/moe/s7567/list.html

Mu, G. M., Zheng, X., Jia, N., Li, X., Wang, S., Chen, Y., He, Y., May, L., Carter, M., Dooley, K., Berwick, A., Sobyra, A., & Diezmann, C. (2013). Revisiting educational equity and quality in China through confucianism, policy, research, and practice. *The Australian Educational Researcher, 40*(3), 373–389. doi:10.1007/s13384-013-0113-0.

National Bureau of Statistics. (2011). *China statistic year book 2011*. Retrieved from http://www.stats.gov.cn/tjsj/ndsj/2011/indexeh.htm

OECD. (2012). *Equity and quality in education: Supporting disadvantaged students and schools*. OECD Publishing. http://dx.doi.org/10.1787/9789264130852-en

Orleans, A. V. (2010). Enhancing teacher competence through online training. *Asia-Pacific Education Researcher, 19*(3), 371–386.

Pelgrum, W. J., & Law, N. (2003). *ICT in education around the world: Trends, problems and prospects*. Paris: United Nations Educational, Scientific and Cultural Organization. Available at http://publications.iiep.unesco.org/ICT-education-world-trends-problems-prospects

Prensky, M. (2001). Digital natives, digital immigrants part 1. *On the Horizon, 9*(5), 1–6. doi:10.1108/10748120110424816.

Rezaei, M., Nazarpour, M., & Emami, A. (2011). Challenges of information and communication technology (ICT) in education. *Life Science Journal-Acta Zhengzhou University Overseas Edition, 8*(2), 595–598.

Rogers, E. M. (1995). *Diffusion of innovations* (4th ed.). New York: The Free Press.

The World Bank. (2014). *China overview*. Retrieved from http://www.worldbank.org/en/country/china/overview

Tolani-Brown, N., McCormac, M., & Zimmermann, R. (2011). An analysis of the research and impact of ICT in education in developing country contexts. In J. Steyn & G. Johanson (Eds.), *ICTs and sustainable solution for digital divide: Theory and perspectives* (pp. 218–243). New York: Information Science Reference. Retrieved from http://books.google.com/books?hl=zh-CN&lr=&id=dq6jpD9oNMkC&oi=fnd&pg=PA218&dq=scale+up+ICT+in+education&ots=Y4EXk3OHWg&sig=vXR8cI1GhzHCNZd6OMvlaDyjSb4

Wagner, R. K. (2008). *Learning to read: The importance of assessing phonological decoding skills and sight word knowledge*. New York: Scholastic Inc.

Yang, Z. (2013). On the application of ICT in education in China. In *2013 IEEE 13th international conference on advanced learning technologies*, Beijing, 4 p. doi:10.1109/ICALT.2013.6.

Yu, S. (2004). Looking for the informatization for China. *Distance Education in China, 20*, 39–41.

Zhang, J. (2009a). The characteristics and diffusion strategies of educational technology diffusion system in China. *China Educational Technology, 7*, 6–13.

Zhang, J. (2009b). The current status and future development strategies of ICT in Basic Education in China. *e-Education Research, 30*(1), 5–86.

Chapter 10
Pathways to Enhance Multilevel Learning for Scaling Up Systemic ICT-Enabled Learning Innovations: Lessons from 7 European and Asian Cases

Nancy Law, Panagiotis Kampylis, and Yves Punie

Abstract This chapter presents a meta-study of the implementation strategies of seven cases of *ICT-enabled learning innovations* (ICT-ELIs), with a particular focus on lessons learnt about their sustainability, scalability and systemic impact. Three of the cases come from Europe (*eTwinning*, *1:1 Learning* and *Hellerup School*) and four from Asian countries (*e-Learning Pilot Scheme* in Hong Kong SAR, *Knowledge Construction with Technology* (CoREF) in Japan, *Third Masterplan for ICT in Education* (mp3) in Singapore and *Digital Textbook* project in South Korea). Almost all the analysed cases have either been developed over a period of more than 10 years or have built on system-level initiatives that started years ago. The cases were analysed in terms of the context, scale and nature of the innovation, the intended learning outcomes, the role of technology and the leadership strategies. The synthesis of the case study findings reveals that the core dimensions of an innovation for learning—nature of the innovation, phase of implementation, access level, targeted stakeholders and impact area—interact and are interdependent. The contexts of the innovations are complex, and the starting points and pathways of change and scalability observed are extremely diverse. The observed characteristics are aligned with an ecological model of change and innovation rather than classical models where scaling up would involve the propagation of well-tested prototypes or solutions. Each of the seven ICT-ELIs is a dynamic system comprising hierarchically nested levels of actors and contextual factors, which interact and are hence interdependent. Analysis of the seven cases' learning outcomes—seen as changes that have taken place over time at individual, school, project and system levels—reveals that alignment of learning across these different levels is critical to the impact and scalability of ICT-ELIs and that this alignment requires the design and

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implementation of appropriate structures and mechanisms to scaffold learning through horizontal and vertical interactions within and across levels. This model has important implications for policies and strategies for the further development and progressive mainstreaming of ICT-ELIs.

Introduction

Education is widely recognised as one of the most important levers for ensuring competitiveness and prosperity in the age of globalisation, and nations around the globe are striving to modernise their education and training (E&T) systems in order to keep pace with the digital economy and society. Hence, *educational innovation* is regarded as top priority target to achieve '… dynamic change intended to add value to the educational process and resulting in measurable outcomes, be that in terms of stakeholders satisfaction or educational performance' (OECD/CERI 2010, p. 14).

In this context, information and communication technologies (ICTs) are playing an increasingly important role in fostering and driving educational innovation, and consequently, many policies at local, regional, national and international levels are promoting their use in E&T systems. For instance, many countries have launched master plans/strategies for ICTs in education as an integral part of aligning the school curriculum with the demands on education for the twenty-first century (Kampylis et al. 2013). The use of ICTs is also a key element in the European Commission's strategy for opening up and modernising E&T, and the need to scale up the use of ICTs in learning and teaching practices is emphasised in recent policy documents (European Commission 2012, 2013a).

However, computers in schools were found to be 'oversold and underused' (Cuban 2001), and they do not have significant impact on students' learning outcomes (Collins and Halverson 2009). Bocconi et al. (2013), report that the majority of schools in Europe are not reaping the benefits of new technologies as enablers of the modernisation of learning and teaching practices. In addition, only a few *ICT-enabled learning innovations* (ICT-ELIs) manage to survive beyond the early adopter stage and become fully embedded in educational practice. This is despite the fact that (1) ICTs are already embedded in many of the ways people interact, work and trade; (2) the infrastructure to promote innovative ICT use for learning is largely available; (3) there is a sound research base to guide the process; and (4) there are policies that promote the use of ICTs for learning and training.

International surveys and policy documents (e.g. European Commission 2012, 2013a, b; Eurydice 2011) describe the seriousness of this implementation gap and its negative socio-economic impact and emphasise the need to take immediate policy action to mainstream ICT-ELIs. To realise the 'transformative' potential of ICTs to support learning requires the redesign of teaching and learning activities so

that the new goals and processes targeted can be achieved (Oblinger and Hawkins 2006). The challenge, however, is not in the generation of innovative pedagogical practices, as studies conducted internationally in widely different economic and social contexts have consistently identified successful examples of classroom integration of ICT use by teachers (e.g. Shear et al. 2011). Where problems do arise is in the sustainability, impact, costs and mainstreaming of ICT-ELIs. Making ICT-ELIs work on a big scale with a wide scope involving large groups of learners and a wide range of stakeholders at system level has different enablers and barriers to small-scale pilots. Hence, success in initiating change does not guarantee that these changes can be sustained over time.

In this context, the Information Society Unit at the European Commission's JRC-IPTS[1] initiated a study on *ICT-enabled innovation for learning in Europe and Asia* (Kampylis et al. 2013) as part of the European Commission-funded project *Up-scaling Creative Classrooms in Europe* (SCALE CCR, http://is.jrc.ec.europa.eu/pages/EAP/SCALECCR.html). The goal was to study selected large-scale pilots in real-life environments in diverse education and training systems worldwide, particularly those that have already achieved significant scale and/or impact, in order to learn about how to speed up the transfer of innovation research into educational practice. This chapter provides a meta-study of the seven cases of ICT-ELIs at various stages of maturity and in different contexts in Europe and Asia that were included in the SCALE CCR study. These cases included formal and informal ways of learning and teachers'[2] continuous professional development (CPD).

The prefix *meta*[3] has been paired with a variety of design methods and generally denotes the aggregation of multiple research studies into a coherent whole to investigate the processes and results of previous research. The meaning of the term meta-study as it is used here is based on the description of Paterson and her colleagues (2001, p. 1): a study of this kind involves 'analysis of the theory, methods and findings of qualitative research and the synthesis of these insights into new ways of thinking about a phenomenon'. In this chapter, the *meta-study* comprises meta-analysis and meta-synthesis of the qualitative data of the seven cases, focusing on diverse pathways of scaling up ICT-ELIs with systemic impact. At the end of the chapter, the outcomes of the innovations and lessons learnt about the necessary conditions for sustainability, scalability and systemic impact of ICT-ELIs are discussed, and an ecological model of educational change as aligned learning across levels is proposed.

[1] The Institute for Prospective Technological Studies (IPTS) is one of the seven scientific institutes of the European Commission's Joint Research Centre (JRC). IPTS consists of six research units, one of which is the Information Society Unit.

[2] The term *teachers* is used in this report in its broadest sense as meaning school staff—such as teachers, head teachers, librarians and IT coordinators—affiliated with preprimary, primary and secondary education and also initial vocational education and training.

[3] The prefix *meta* comes from the Greek language and means basically 'after' or 'beyond'.

Theoretical Framework

For more than a decade, education researchers have pointed to the complex nature of educational change and sought insight from ecological studies (Davis and Sumara 2008; Davis 2008; Hargreaves 2003; Law et al. 2011). Most of these studies use ecosystems as a metaphor for understanding the multilevel interdependencies inherent in educational change, drawing analogies from change in diverse domains such as climate change and stock markets to illustrate the strong similarity across different forms of complex phenomena. Educational change is dynamic and non-linear and involves nested hierarchies of self-similar structures. Likewise, classrooms are nested within schools, which are in turn nested within districts, provinces and larger systems. There is complexity at each level, and the timescales for change are possibly different at different levels. Complex systems are characterised by the presence of many different feedback loops and interactions, so there is no simple causal relationship. Hence, in conducting this study, it is important to avoid simplistic linear models of change and scalability and accommodate a multidimensional approach to the adoption of learning innovation (e.g. Clarke and Dede 2009). Furthermore, history and context matter and therefore diversities in educational, cultural and socio-economic contexts must be studied to reveal the complex interactions between different contextual conditions affecting sustainability, scalability and impact.

Learning innovations are complex and dynamic phenomena as described above. In this chapter, and in the context of the SCALE CCR project, the term *ICT-enabled learning innovation* refers to profoundly new ways of learning which involve the use and creation of information and knowledge, made possible by the use of ICTs. Hence, the focus is on disruptive uses of ICTs as opposed to using ICTs to sustain or replicate existing practices (e.g. Christensen 2003). The disruptive use of ICTs can have a sustained impact on desired learning outcomes only when they are combined with appropriate pedagogical and organisational innovations (Kampylis et al. 2012).

In this study, *scaling up* of ICT-ELIs is not seen as a one-dimensional process, involving solely the expansion of numbers of schools implementing specific ICT-enabled teaching and learning activities (e.g. providing portable computing devices to all students). Neither does scaling up refer to recipes for replication of successful implementation nor to 'one-size-fits-all' models of innovation. In contrast, scaling up is considered to be a contextualised process that involves all the challenges of implementing a collective paradigm shift in practices at the system level (Bocconi et al. 2013; Clarke and Dede 2009; Law et al. 2011; Levin 2008; OECD/CERI 2010; Shear et al. 2011). Thus, scaling up ICT-ELIs should be an organic process that allows local autonomy and ownership of innovation. This is needed for continuous change and flexibility for future adaptations in order to address the shifting priorities and requirements of society. In other words, the sustainability of innovation is the necessary condition for its scalability and long-term impact. Last but not least, scaling up ICT-ELIs does not refer to future classroom scenarios but to changes in today's practices which have been made possible by taking advantage of existing and emerging technologies (e.g. Aceto et al. 2014).

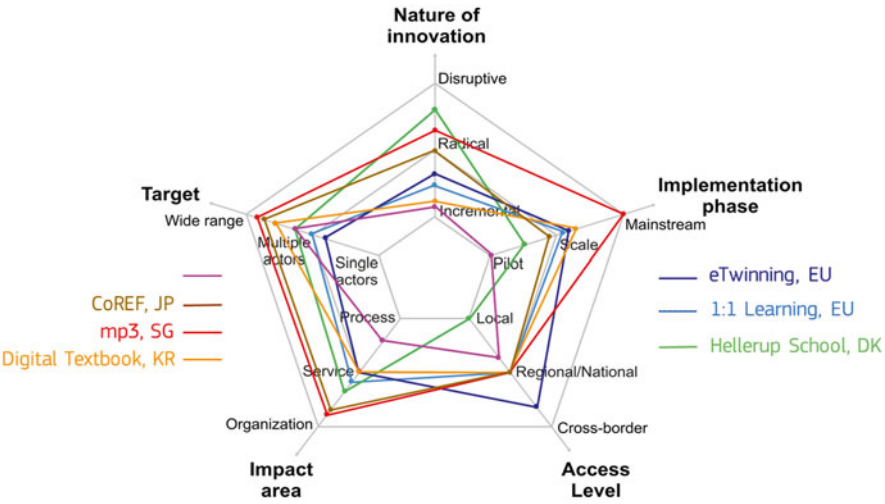

Fig. 10.1 The seven ICT-ELIs represented on the mapping framework (Source: Kampylis et al. 2013, p. 120)

A five-dimensional framework developed by Kampylis et al. (2012) is adopted here to characterise and chart the trajectories of change in the scale of impact of ICT-ELIs (see also Fig. 10.1 in section "Mapping and analysing seven selected cases from Europe and Asia"):

1. The *nature of innovation* captures the progressive levels of change from the introduction of some new elements (*incremental*), to a significant number of innovative elements (*radical*), to a profound and comprehensive change (*disruptive*).[4]
2. The *phase of implementation* describes the stage of development of an initiative, ranging from limited application (*pilot*), to more consolidated uptake (*scale*), to established use (*mainstream*).
3. The *access level* captures the geographical coverage of the innovation, from restricted (*local*) to broad (*regional/national*), up to international/worldwide (*cross-border*).
4. The *impact area* pinpoints the extent of innovation, from affecting the way different practices such as teaching and learning are being carried out (i.e. *processes*), to the emergence of new business models/services to support the use of ICTs for introducing new modes of teaching and learning (*services*), up to making organisational changes at different levels from schools to the entire system (*organisation*).
5. The *target* identifies the actors targeted by the innovation, from a specific group such as students (*single actors*), to a subset of key stakeholders (*multiple actors*, e.g. students and teachers), up to a wide set of stakeholders including most of the

[4]The term *disruptive* is used in the sense of being a game changer in established practice (Christensen 2003).

key actors such as students, teachers, parents, school leaders and experts (*wide range of actors*).

This five-dimensional framework is used in the next section to map and analyse the innovation characteristics of the seven cases in this study. These innovation characteristics will be used as the basis for further exploration of the policy and organisational strategies that contributed to the scaling up of ICT-ELIs with systemic impact.

Mapping and Analysing Seven Selected Cases from Europe and Asia

The seven cases of ICT-ELIs in Europe and Asia were deliberately selected to ensure diversity. Some of them have a long innovation history (a decade or more) or are continuations of initiatives that started years ago and have already achieved some level of sustainability and scale. Theoretical sampling was used (Eisenhardt and Graebner 2007) to select these diverse ICT-ELIs which have the potential to shed light on the different factors and conditions that affect their sustainability, scalability and systemic impact. They were selected according to the following key criteria:

1. They involve not only technological but also pedagogical and organisational innovations.
2. They are ongoing ICT-ELIs with reliable and relevant data available.
3. Each case has reached significant scale and/or impact and represents a distinct pathway of learning innovation in terms of nature of innovation, implementation phase, access level, impact area and target of innovation.

The three European cases of ICT-ELIs cover most European countries, whereas the Asian ones represent four specific countries that have (1) long innovation histories in education; (2) high ranking in international benchmarking on educational performance, such as the OECD's Programme for International Student Assessment—PISA (e.g. OECD 2013); and (3) ongoing large-scale ICT-ELI initiatives.

To provide a rigorous empirical basis for cross-case analysis and comparison, a case study report was compiled for each of the selected cases. These reports were written by European and Asian experts who have good knowledge of not only the cases themselves but also the local contexts. They follow a common case reporting template and have been published in a JRC-IPTS report (Kampylis et al. 2013), briefly summarised here in Table 10.1 for ease of reference. In order to ensure the interpretive validity of the seven cases, experts with knowledge on these seven cases were invited to participate in two workshops, one held in Seville and the other in Hong Kong. These two workshops and their participants are described in Chap. 1 of the JRC-IPTS report. To increase the interpretive validity of the meta-synthesis provided in this chapter, six out of the eight case report authors were invited to check and offer feedback on this chapter.

It is important to note that remarkable diversity was found not only across the seven cases—various levels of internal diversity were also found *within* them

Table 10.1 Overview of the cases

Case title	Implementation phase, scale and context	Short description and key focus of innovation	Key reason for case selection	Prospects for sustainability/scalability
eTwinning[a]	In its 10th year of development (January 2005–2014) More than 112,000 schools (preprimary, primary, secondary and initial VET) from 33 European countries[b]	A fast-developing teacher network with more than 223,000 registered users. The key focus of *eTwinning* is to offer a free and safe platform for teachers in Europe to network, conduct cross-border projects (involving their students) and develop their professional skills through CPD activities and peer learning	It was selected on the basis of its long innovation history (since 2005) and the recognition it has achieved as a Europe-wide initiative with significant scale and impact	Central Support Service and National Support Services provide multiple levels of top-down agency to support bottom-up innovation. Secured funding for 2014–2020 via Erasmus+. Expanding in six more countries through *eTwinning Plus*. Sustainability good at system level. Attempts to diffuse innovations locally through eTwinning school teams
1:1 Learning	It covers initiatives started no earlier than 2008 (or before but are still ongoing) involving mostly primary and secondary schools in 19 European countries.[c] The majority of the analysed initiatives have been scaled up or mainstreamed	It is actually a collection of 31 recent 1:1 initiatives, which equipped/have been equipping all students of a given class, school or age group with a portable computing device. Common foci are the increase of device/student ratios, the decrease of digital divide, the development of students ICT skills and digital competence and the expansion of learning opportunities outside classroom	These 31 initiatives were selected because they follow diverse pathways of innovation with a variety of implementation strategies and financing models that provide evidence on the conditions for scaling up ICT-ELIs	The sustainability of the analysed *1:1 Learning* initiatives is dependent on embedding the use of technology within innovative teaching and learning practices. Large-scale implementations are challenging due to the current economic climate in Europe, and new patterns of ownership and deployment models need to be adopted (e.g. bring your own device) for sustainable development and uptake

(continued)

Table 10.1 (continued)

Case title	Implementation phase, scale and context	Short description and key focus of innovation	Key reason for case selection	Prospects for sustainability/scalability
Hellerup School	In its 12th year of development (2002–2014). A public school (primary and low secondary) in Denmark, with ≈750 students and ≈50 teachers	An innovative public school that has successfully adapted its pedagogy and physical spaces based on students' needs to promote diversity, flexibility and creativity as well as to support a variety of learning strategies and styles. The main focus is to prepare responsible and 'community-oriented' citizens for a diverse and fast-changing world	The school selected as an example of a sustainable innovation at local level that has significant influence on other learning ecosystems in Denmark and beyond due to the wide media coverage of its radical (even disruptive) innovations at pedagogical, technological and organisational level	Success in building coherent school ecology, high teacher ownership, strong parent and community support and also partnerships with industry and academia contribute to the sustainability of innovation
e-Learning Pilot Scheme	*e-Learning Pilot Scheme* (2011–2014) is a collection of 21 diverse e-learning pilot projects involving 61 primary and secondary schools, which cover all districts of Hong Kong SAR territory in the context of the Third Information Technology (IT) in Education Strategy of Hong Kong SAR	A 3-year pilot scheme on e-learning in Hong Kong schools. The main focus is to develop, try out and evaluate e-learning solutions—in different curriculum and school contexts—that are sustainable, transferable and scalable for Hong Kong	Taking advantage of a long innovation history, *e-Learning Pilot Scheme* is expected to raise the baseline conditions for effective e-learning pedagogy in Hong Kong to achieve the targeted twenty-first-century learning outcomes	Top-down strategies (i.e. continuation of the funding, provision of teachers' CPD opportunities, monitoring of project implementation) contribute to the sustainability of the Pilot Scheme until August 2014 (currently, there are no plans on sustaining the scheme beyond the pilot phase)

Renovating Education of the Future Project (CoREF)	A pilot project (2010–2013) involving approximately 770 primary and secondary schools (around 20,000 students) throughout Japan	A university-driven project aims to change Japanese traditional teacher-centric education into more student-centred, socio-constructivist learning in classrooms from primary to secondary education. The fostering of students' twenty-first-century skills, the promotion of assessment for learning paradigm and the development of future-oriented, collaborative and knowledge constructive approaches for Japanese education are among the project foci	*CoREF* was selected due to (1) the specific pedagogical model it has adopted, i.e. the knowledge construction jigsaw, in order to guide the change at classroom level and (2) the notion of networks of networks to scale up the learning innovation	Japanese Ministry of Education, Culture, Sports, Science and Technology (MEXT) awarded University of Tokyo further support to continue *CoREF* from 2013 to 2017. In the coming 2–3 years, the project participants are expected to expand by 20–30 % each year. Reform movements in entrance exams of colleges and universities are in place providing *CoREF* with chances to expand its reform efforts
Third Masterplan for ICT in Education (mp3)	*mp3* (2009–2014) covers all the 362 schools in Singapore including primary and secondary schools and also junior colleges (preuniversity education)[d] for students with ages 7–18	*mp3* is a nationwide initiative building on the vision and outcomes of the 1st and 2nd Masterplans that go back as early as 1997. The main focus is to foster self-directed and collaborative learning, which will enable Singaporean students to meet the challenges of the twenty-first century, through the effective use of ICTs that support teaching and learning anywhere, anytime	Covering all Singaporean schools and based on a long innovation history, *mp3* was selected for providing evidence for sustainable implementation of ICT-ELIs with systemic impact	The top-down support, the existing ICT infrastructure and the professional sharing about the educational use of ICTs have raised the floor for the integration of ICTs into the curriculum. The availability of funds by the Ministry of Education (MoE), the early successes and the increased teachers' capacity to innovate on their own are also conditions for sustainability and scalability

(continued)

Table 10.1 (continued)

Case title	Implementation phase, scale and context	Short description and key focus of innovation	Key reason for case selection	Prospects for sustainability/scalability
Digital Textbook Project	A pilot project, which is part of the 4th and 5th phase of the South Korean Masterplan for ICTs in education. From 2007 to 2011, the development of digital textbooks and their implementation in 340 pilot schools (primary and secondary), from 2013 gradual nationwide application	This is a governmental pilot project to develop digital textbook contents that are more accessible and easy to use by leveraging the potential of mobile devices and social network service tools. The project focuses on providing students with more interactive, authentic and rich learning experiences that help them develop twenty-first-century skills	*Digital Textbook* project was selected to shed light on the step-by-step development of future-oriented learning environments that enables learner-centred learning anywhere and anytime	The technological rich environment (e.g. good Internet infrastructure in terms of penetration and bandwidth) both in and out of school contributes to the sustainability of the project. Moreover, the convergence of multimedia and e-learning resources can enhance the ways and effectiveness of the use of digital textbooks in classrooms

[a]See also Vuorikari et al., Chap. 11 this volume

[b]Find more about the 33 participating countries and statistics about registered users/schools and running/closed projects at http://bit.ly/1frMvTd. As part of the *eTwinning Plus* pilot project (http://plus.etwinning.net), selected schools from six additional countries have joined the eTwinning community since March 2013

[c]The 19 European countries with *1:1 Learning* initiatives are AT-Austria, CY-Cyprus, CZ-Czech Republic, DK-Denmark, EE-Estonia, FR-France, GE-Georgia, DE-Germany, EL-Greece, IL-Ireland, IT-Italy, LT-Lithuania, NO-Norway, PT-Portugal, SK-Slovakia, ES-Spain, SE-Sweden, TR-Turkey and UK-United Kingdom

[d]http://www.moe.gov.sg/education/pre-u

(Kampylis et al. 2013). The greatest internal diversity is evident in the case of *1:1 Learning in Europe*, which comprises a collection of 31 innovations, all involving the deployment of 1:1 portable computing devices to enhance students' learning outcomes. These 31 initiatives differ one from another in all five dimensions of the mapping framework (see section "Theoretical framework" and Kampylis et al. 2012).

At the other end of the diversity spectrum in the set of seven cases is the *Hellerup School*, an innovative public school (primary to lower secondary) that has successfully adapted its pedagogy and physical spaces to suit students' needs, to promote diversity, flexibility and creativity and to support a variety of learning strategies and styles. This school-level innovation requires all stakeholders (teachers, students, parents, etc.) to subscribe to the disruptive vision and innovative practices of the school.

Figure 10.1 maps the innovation characteristics of the seven cases onto the five-dimensional framework (Kampylis et al. 2012) described in section "Theoretical framework". Some of the ICT-ELIs have in addition vast internal diversities which are not reflected in Fig. 10.1. This figure is simply a representation of the dominant characteristics shared by all of the innovations based on the respective case analysis. These diversities are further explored above.

Nature of the Innovations

As can be seen in Fig. 10.1, the seven cases cover almost the whole spectrum of innovations—from incremental to radical or even disruptive. In the case of the HK *e-Learning Pilot*, the learning innovations in most of its 21 projects are incremental, and only a few projects target inquiry-oriented and learner-centric pedagogy. Similarly, although the ultimate goal of the South Korean *Digital Textbook* is to transform the teaching and learning process, its pilot projects are still largely of an incremental nature. Similarly, the 31 initiatives in *1:1 Learning in Europe* can be considered to be mostly incremental, with some moving progressively to more radical approaches (e.g. by adopting 1:1 pedagogies).

On the other hand, an innovation is not static, but may change over time, depending on the contextual and policy environment. For example, *eTwinning* started as an incremental innovation with no requisite conditions on the pedagogical approaches adopted in the cross-national classroom collaborations. Overtime, however, it has become a more radical innovation as it offers more opportunities for professional networking and development (see also Vuorikari et al., Chap. 11 this volume). Also, an innovation may be incremental in some aspects and more radical in others as can be seen in the case of *CoREF*. The current innovative use of ICTs in these Japanese classrooms is still incremental, but the pedagogical changes implemented are radical. They have altered the balance between the roles played by teachers and learners and have targeted deep changes in educational policies, including school grading systems and the curriculum. In the context of the Singaporean *mp3*, different levels of innovation can be found, ranging from incremental (small changes to classroom and other practices at the system level) to more radical (e.g. curricular

innovations in the FutureSchools@Singapore) and to disruptive ones (intervention projects carried out in some schools as design research in partnership with university-based teams).

The *Hellerup School* case represents an almost disruptive innovation that redesigns virtually every aspect of the school ecosystem, including its physical and digital infrastructure, curriculum organisation, leadership and assessment practices, in order to provide a coherent learning experience that caters for learner diversity and that nurtures twenty-first-century competences.

Implementation Phase of the Innovations

As can be seen from Table 10.1, some of the seven initiatives are clearly pilots, such as the Hong Kong *e-Learning Pilot Scheme* and the South Korean *Digital Textbook* project. Both of these were set up by their respective governments to identify possible critical issues and concerns and also to find viable ways to scale up and mainstream the innovation concerned. *eTwinning* is at the scaling up phase, while *mp3* in Singapore has already reached the mainstreaming stage. In *1:1 Learning in Europe*, because of the diversities across the 31 initiatives included in this case, all of the different implementation phases can be found, although the majority are already scaled up or mainstreamed.

Access Level and Scale of the Innovations

The seven cases were intentionally chosen for their diversity in scale and access level of innovation, to provide us the opportunity to explore whether and how the scale of an innovation affects the conditions for its scalability and sustainability. Table 10.1 provides more detailed information about the scale of each innovation, which varies from a local, school-level initiative (*Hellerup School*) involving approximately 800 students and teachers to an international project (*eTwinning*) involving more than 223,000 teachers and their students (as of early 2014). All the four Asian case studies cater for a wide geographical coverage within their own country or region, with a scale that varies from 61 schools from all districts of the Hong Kong SAR to the entire population of 362 Singapore schools served by *mp3*. In the case of *1:1 Learning in Europe*, although the geographic coverage is wide, each of the 31 initiatives only serves teachers and learners at the regional or national level to which it belongs. The scale of these 1:1 learning initiatives also differs widely, ranging from local initiatives such as the *Vzdelani21/Education* project in the Czech Republic that covers approximately 275 students to nationwide initiatives such as the *Escuela 2.0* that covers around 635,000 Spanish students.

Given this diversity in terms of nature, scale, access level and phase of implementation, the impact achieved and target actors involved also differ widely across

the seven initiatives, as expected when the study was designed. These variations are presented and discussed below.

Impact Area of the Innovations

In the case of the HK *e-Learning Pilot Scheme*, although it builds on the previous two ITs in education strategies, it is still a pilot. Most of its 21 projects target changes in the learning *process*, while a few involve changes in the *service* through partnerships with external actors and organisations.

eTwinning impacts directly at the *service* level, offering an online collaboration platform, a pedagogical framework for project-based learning and network-based mechanisms for teachers' CPD. Through the services it provides, *eTwinning* also affects the teaching and learning practices of the associated teachers and students (*process*). However, it does not affect schools or other institutions at the *organisation* level.

The *Digital Textbook* project has an impact on both *processes* in classrooms and *services* provided to learners and teachers. The vast majority of the 31 cases of *1:1 Learning in Europe* made an impact at the *service* level, addressing issues related to the provision of equipment to schools and the development of system-level ICT infrastructure.

Hellerup School has adopted an almost systemic approach to innovation, which affects several key dimensions of the school ecosystem such as teaching and learning practices (process), connectedness and leadership and organisation strategies within the school (organisation).

In the *CoREF* project, *organisational* impacts were achieved through the restructuring of the teacher support sections and the on-the-job training sections of the participating regional education boards, so that these two sections can work together for better results. These organisational changes result in improved CPD services to teachers and contribute to changes in teachers' pedagogical practices.

The *mp3* initiative has an impact on all three levels, i.e. *process*, *service* and *organisation*. The most important impact is the enhancement of innovation capacity of agents across all levels of the education system through the explicit alignment of the different levels of change to transform practices in teaching and learning.

Targeted Actors in the Innovations

All seven initiatives focus on learning innovations in formal school settings, mainly in primary and secondary schools, although *eTwinning* also serves the vocational education and training (VET) sector (see Table 10.1). For innovations to be progressively mainstreamed and achieve impact at the system level, changes need to be propagated to the entire education ecosystem. Thus, impacts can be achieved beyond

the *process* level, facilitating innovative practices through the availability of new *services* and changed *organisational* structures. Hence, the range of actors directly targeted by an innovation and those who were reported to have actually participated actively have implications on its scalability potential. A wider range of actors not only affords a broader range of expertise and resources to draw upon to support an innovation but also allows the actors involved to gain a better understanding of the nature and benefits of the innovation. In this way, they become potential allies and advocates for the measures taken to scale up and sustain an innovation.

Table 10.2 summarises the range of actors targeted in the seven ICT-ELIs analysed, as well as the actual range of actors reported to have engaged actively in them. Six types of actors (often referred to as *stakeholders* in educational change literature) are included in the analysis. A type of actors is considered as targeted if the innovation plan explicitly includes them as key beneficiaries (e.g. students) or agents in the innovation (e.g. teachers). On the other hand, targeted actors will only be considered as having been actively involved in the innovation at hand if its nature or design is such that it would not have proceeded or happened in a particular site if that type of actors had not taken steps to be involved in and contribute to the innovation.

As shown by the in-depth analysis of the seven case reports (see Kampylis et al. 2013), the wider the range of actors directly targeted and actively involved (and also the more levels of policy support within the broader education ecology given to an innovation), the better the chances of its sustainability and scalability. However, the relationship is more nuanced than this and is further discussed in section "Outcomes of the innovations at multiple levels".

Table 10.2 Actors targeted (x) and actively involved (o) in the innovations

Initiative	Students	Teachers	Principals	Parents	Partners (industry/ research/other)	Policymakers
eTwinning	x	x, o			o	o
1:1 Learning in Europe	x	x	x/(x, o)[a]	x	o	x, o
Hellerup School	x, o	x, o	x, o	x, o	o	o
Pilot Scheme, HK	x	x	x, o		x/(x, o)[a]	x, o
CoREF, Japan	x	x, o	x, o		x, o	x, o
mp3, Singapore	x	x	x/(x, o)[a]		x, o	x, o
Digital Textbook, S. Korea	x	x	x, o		x, o	x, o

[a]There are within-case variations due to the internal diversity of the innovations within each initiative

Technology Used and Its Role in the Innovations

In all the seven cases studied, ICTs are a contributing but not sufficient condition for sustainable innovation with systemic impact. Educational technology is not an end in itself, but plays an important role as leverage and a conduit for mediating learning innovations within and outside of schools. The exception is the case of *CoREF*, where ICT only plays an optional and peripheral role.

There is noteworthy diversity in terms of the learning technologies used. The *1:1 Learning in Europe* and the *Digital Textbook* project in South Korea are mainly governmental (top-down) efforts to make productive use of a specific technology—1:1 portable learning devices in the former and digital learning resources in the latter. Hence, those two initiatives can be regarded as technology-driven innovations.

On the other hand, the Singapore *mp3* and the *e-Learning Pilot Scheme* in Hong Kong are both system-level efforts to leverage the potential of ICTs to transform learning. In these two cases, no single technology is prioritised. Instead, the selection and use of appropriate, and often multiple, technologies are encouraged. There are also attempts to build more integrated technology infrastructures, such as wireless networks and learning management systems, to better achieve the targeted educational goals. So, these two Asian cases can be considered as ICT-enabled, reform-driven innovations.

eTwinning can be seen to occupy the middle ground in that the innovations are all developed around one single online collaboration platform, which is the basis for teacher networking and CPD activities and also for the development of cross-border student projects. However, the real focus of *eTwinning* is not on the technology but on enhancing collaboration, communication and intercultural awareness among the school communities in Europe, facilitated by social networking mechanisms offered by a secure and established platform.

According to Miyake (see Kampylis et al. 2013, Case report 5, pp. 78–90), in *CoREF*, technology to support the innovation is introduced and encouraged, but ICT use is optional. Teachers may decide whether or not to use ICTs for the innovation. Hence, the role of technology is very much that of an additional tool. No single technology is advocated: teachers could use a range of technologies from robotic agents to different e-learning tools and resources as appropriate for the specific curriculum and pedagogical purpose. So, *CoREF* is clearly a pedagogically driven innovation.

Hellerup School is a technology-rich school with an advanced digital infrastructure, which was purpose designed to be embedded and integrated fully into the innovative physical infrastructure and curriculum of the school. The mission for technology use is to fully support diversity, flexibility and creativity in pedagogy and to cater for a variety of learning strategies and styles.

Irrespective of the role or specifics of the technology adopted, there is evidence that the technological, pedagogical and organisational aspects of the seven cases studied interact and co-evolve (Kampylis et al. 2013).

Outcomes of the Innovations at Multiple Levels

The diverse pathways to innovation followed by the seven ICT-ELIs provide a valuable set of authentic data to identify the conditions where significant impact on learning is observed. In analysing data collected from the different cases, we observe learning taking place not only at the individual level of students or teachers, but *at all levels*, including school, district, community and system levels. Here, learning is interpreted broadly as having taken place if changes are observed in knowledge, skills and/or dispositions, which are often linked to changes in structure and/or interaction mechanisms at the respective levels. In educational change literature, teacher learning and involvement are considered to be of primary importance for success (e.g. Clarke and Dede 2009). Sometimes, leadership development as learning at the school level is also considered to be a crucial factor. Other factors that have impact on change or innovation—such as the school infrastructure, school routines, legislation, accountability structures, etc.—are generally taken as conditions for change. Taking an ecological framework (e.g. Law et al. 2011) as the basis for understanding change, we propose here that it is more appropriate to see such 'factors' at multiple levels as contextual variables that can be changed through learning during the innovation process. In other words, changes in these contextual variables should be considered as 'learning outcomes' that result from interactions of different actors at different levels in the change process. We describe, in the remainder of this section, the learning outcomes observed at various levels in the seven ICT-ELIs and how they are similar or different in terms of the structures and mechanisms available to serve as conduits for feedback and learning alignment across levels. We will also discuss, in the section "An Ecological Model of Educational Change as Learning Across Levels", how the 'learning at multiple levels' model provides a more consistent and holistic framework for understanding the sustainability and scalability of learning innovations in general and ICT-ELIs in particular.

Student Learning

Hellerup School reported the most impressive advances in terms of future-oriented learning outcomes of students: creativity, personalised and self-directed learning, collaboration and intercultural awareness and community building. These have been achieved through reinventing the school, from physical design and digital infrastructure to curriculum and pedagogy, all of which are aligned to support child-centred and collaborative learning, grounded on the best knowledge derived from learning sciences research on how people learn. The two key lessons that *Hellerup School* delivers regarding critical conditions for ICT-ELIs to achieve significant impact on student' learning outcomes are the need to put pedagogy first and to ensure autonomy and support for teachers as agents of change.

For the other six initiatives, it is not easy to compare the learning outcomes achieved at the case level due to their wide diversity (even within the innovations themselves), as discussed earlier. On the other hand, a common theme that emerged

from the case analysis was the primacy of the pedagogical approach over the technology adopted in determining the nature and quality of students' learning outcomes. In other words, a technology-centric approach to the integration of ICTs is unlikely to have substantial impact on students' learning. It is also unlikely to foster learners' key competences for the twenty-first century, which is a common focus underpinning all the innovations. Where substantial learning gains were observed in the context of ICT-ELIs, implementation always leverages the use of technology to support learner-centric pedagogy that stimulates learner interest, empowers and encourages students to engage in self-directed learning and collaborative knowledge creation. These kinds of classroom scenarios tend to share radical and/or disruptive elements similar to those found in the *Hellerup School*.

Outcomes other than the development of key competencies and twenty-first-century skills have also been reported, including a reduction in the digital divide among students, increased learning motivation, enhanced academic achievement, digital literacy and ubiquitous learning.

Teacher Learning

Provisions for teachers' CPD can be found in all seven initiatives as it is widely recognised that implementing ICTs in education requires teacher learning. However, the outcomes and effectiveness of these provisions depend on their nature and the conditions for teacher learning.

In *Hellerup School*, teachers work in autonomous multidisciplinary teams of five to thirteen members (each team being responsible for three or four classes) codeveloping timetables, content, pedagogies, etc., in order to help students not only to acquire knowledge but also to develop key competences and twenty-first-century skills. Here, the model of teacher learning is grounded on the same learner-centred philosophy that emphasises self-direction, authentic and problem-oriented learning that has been adopted for student learning. Hence, *Hellerup School* staff participate in diverse training programmes as needed on a regular basis to advance their professional practice. The provision and organisation of teacher learning are dynamic and effective as there are tightly coupled feedback loops between student learning, teacher learning and the school leadership. The possibility for self-organisation to achieve close alignment between the school vision and priorities with student learning and teacher learning is facilitated by these feedback loops and an organisation culture that values creativity and provides flexibility for adaption and change.

eTwinning has undergone a transformation since 2008, when teachers' professional development provisions were added through various means such as *teachers' rooms*, *groups* and *learning events* (see Kampylis et al. 2013, Case report 1, pp. 21–35; see also Holmes 2013). These structures scaffold horizontal interactions among teachers. They provide opportunities for eTwinning teachers to engage in peer, collaborative and problem-oriented learning within a wide professional community of

practice, similar to the model of twenty-first-century learning envisioned for students in many education policy documents. Since 2012, *eTwinning teams* (Vuorikari 2013) have been added as a mechanism for interaction and alignment for teacher learning at the school level.

In the Singapore *mp3*, there are also diversities in terms of understanding and implementation of the vision and goals of *mp3* across schools and teachers. However, at the system level, much effort has been put into building structures and mechanisms to support teacher learning within and across schools. At the school level, ICT mentors play an important role in supporting teacher learning in school-based project teams. Teachers from different schools also meet in monthly professional learning teams to engage in various forms of collaborative CPD. One of the main professional learning activities is lesson study, where teachers work together to plan, teach, observe and discuss actual classroom lessons to deepen their technological, pedagogical, and content knowledge (TPACK, Mishra and Koehler 2006). The case report (Kampylis et al. 2013, case report 6, pp. 91–102) does not provide descriptions of specific schools, so it is not clear whether there are schools similar to Hellerup that have achieved such outstanding learning at student and teacher levels. The Singapore *mp3*, however, offers a model of teacher learning where there are structures and mechanisms connecting teacher learning not only to school-level learning as in the case of Hellerup but also to system-level learning. This allows much more effective feedback and alignment of learning across these different levels, as will be discussed below.

In the *e-Learning Pilot Scheme* in Hong Kong, pilot projects that have built-in mechanisms to scaffold cross-school collaborations in curriculum development, lesson co-planning, peer observations and reflection make much more progress in their ability to design and implement learning experiences that foster twenty-first-century skills. Teacher learning through small networks and the formation of a network of networks were also reported to be crucial to achieving higher-quality pedagogical practices in *CoREF*. In the case of the *Digital Textbook* project in South Korea, provisions for teacher learning focused on technical training on the installation and use of the learning management system for accessing the digital textbooks but also included opportunities for sharing best practice in their classroom use. In all these cases, there are structures and mechanisms for horizontal interactions to support teacher peer learning at the project level. Necessarily, however, there are local variations within each project that affect the nature, intensity and learning effectiveness of those interactions. These projects also work through schools to solicit participation and teacher engagement though they cannot stipulate school-level structures and mechanisms for school-based teacher learning as in the case of the Singapore *mp3*. On the other hand, as observed in the case of the e-Learning Pilot Scheme in Hong Kong, some school principals may be more proactive in setting up mechanisms for school-based professional learning. This learning also connects with school-level leadership learning, creating opportunities for adaptive alignment across levels.

The analysed *1:1 Learning* initiatives also report the importance of building networks of practitioners to support each other. There is great diversity across the

different initiatives in the various jurisdictions. It is expected that the variations in teacher learning observed in the four Asian ICT-ELIs largely capture the full range of scenarios in mechanisms for teacher learning and how these connect with learning at other levels.

To summarise, it was observed that teachers' autonomy and the presence of a supportive community of practice with a shared vision are important conditions for effective teacher learning for all the seven ICT-ELIs. However, the learning outcomes and their impact on scalability of the innovations depend on how structures and mechanisms for teacher learning are connected to learning at other levels.

School Learning

In the literature on change and sustainability, leadership and organisational learning at the school level has been identified to be of critical importance to the success and sustainability of innovations (Hargreaves and Fink 2006; Sherer and Spillane 2011; Stein and Coburn 2008).

In the previous two sections, *Hellerup School* stands out in terms of student and teacher learning achieved. There are also very rich descriptions of learning at the school level in the report on this case (see Kampylis et al. 2013, Case report 3, pp. 52–62). The raison d'être for Hellerup School was to innovate, and to build a school that is guided by a vision of the learner as self-directed, and learning as creative, inquiry-oriented, social and collaborative. There is an understanding and expectation that to achieve the vision of learning for students requires very different kinds of physical, digital, human and organisational school infrastructures. Everyone associated with the school expects new solutions to be developed to cater for the interests and needs of the learner. Everything at the school level and below was taken to be 'work in progress'. Not only were the physical learning spaces designed to be flexible, the whole school organisation and management structure was designed to give autonomy and agency to teachers to work in teams to contribute to the ongoing 'construction' of the school. The interactions and feedback through formal and informal channels across teacher teams and with the school leadership ensure alignment in learning across student, teacher and school levels.

The school-level learning outcomes at Hellerup can be broadly categorised into the following: the school-based curriculum and associated learning and assessment resources and practices, professional and leadership capacity, a culture for change and innovation, adaptive school routines and governance and a supportive school infrastructure. There was substantial adaptation of the national curriculum aligned with the school philosophy by autonomous teacher teams. This was achieved through bottom-up teacher-led curriculum design and implementation, demonstrating effective team collaboration and the increasing maturity of distributed leadership in the school. Over the years, the school also evolved a culture geared towards openness for creative ideas and innovative teaching and learning practices as well as tolerance for ambiguity and risk taking. This cultural change has been strengthened

by the school's efforts to engage the involvement, commitment and ownership of the many stakeholders. To achieve its educational vision, the school has developed organisations and routines such as timetabling, organisational and accountability structures and also physical infrastructures such as the school building, technology infrastructure, etc. to give priority and ease of implementation to the school-based curriculum. In fact, the key dimensions of the school ecosystem, including the prevailing teaching and learning practices, can be considered as learning outcomes at the school level.

As the focus and boundary of each of the case studies vary, the other six ICT-ELIs cover much larger granularities, and the extent of learning at the school level may vary greatly within each case. However, it is expected that the sustainability of student and teacher learning outcomes at the school-site level will remain fragile unless these are accompanied by the kinds of learning outcomes at the school level observed at *Hellerup School*.

Learning at Project/Community/System Levels and Beyond

While changes at the school level may still be recognised as organisational learning during the process of innovation implementation, changes taking place at higher levels of the education ecosystem tend to be seen as policy changes rather than as learning at those levels as an integral part of the innovation evolution process. However, policy changes at various levels relate to the innovations both as factors influencing change and as consequences of interactions during the innovation process. This can be observed in all seven ICT-ELIs, including the case of the *Hellerup School*, which is as a state-funded school and an initiative of the Gentofte Municipality, though changes at these higher levels are not reported systematically in the case report.

Reviewing *mp3* in the context of the overall ICT in education policy developments, Looi (see Kampylis et al. 2013, Case report 6, pp. 91–102) reports a clear strategic development trajectory in the three Singapore Masterplans, starting with *mp1* (1997–2002) to *mp2* (2003–2008) and *mp3* (2009–2014). These master plans clearly focus on learning at the system level. Each one starts with a set of goals to be achieved and ends with the identification of progress made and the focus for the next stage of development. Hence, *mp1* focused on laying the foundations for e-learning, *mp2* on seeding innovations and *mp3* on strengthening and scaling up. Collaborative learning and self-directed learning were the central pedagogical focus to align efforts towards the development of twenty-first-century competences. Strategic structures and mechanisms progressively established by the Ministry of Education—such as principal networks for experience sharing and collaboration in e-learning innovation, projects and incentives to encourage cross-school and cross-sector collaboration (including private sector partners such as publishers and technology providers)—are all tangible learning outcomes at the system level that contribute to more effective learning at the lower levels of the system.

CoREF was formed as a partnership project between university researchers (funded by MEXT at the national level) and local boards of education. The decision to participate starts at the district level. Schools and teachers within the participating districts can then decide whether to participate in *CoREF* or not. The leadership and organisation of *CoREF* are tiered in the form of a hierarchically networked community, with small, overlapping networks of teachers, schools, policymakers and researchers operating in different combinations, following the principle of constructive interactions. Teacher learning was organised in teacher project teams, working on the same subject and adopting *lesson study* methods[5] to systematically examine their own practice, with a view to developing their professional skills. Membership of these teams may be school based or assembled from different schools or even different districts. The project puts in structures and mechanisms at the project and district levels (1) to enable learning scientists from the universities to work with teachers, students and district education board leaders as a learning community and (2) to facilitate teachers' sharing of their teaching plans, learning materials, audio/video records of classes and their student performance records.

The Hong Kong *e-Learning Pilot Scheme* covers all geographic and administrative areas in the HKSAR. Multilevel learning outcomes in terms of structures and mechanisms to support e-learning implementation and pedagogical change similar to those reported in *CoREF* were observed. However, one significant difference from *CoREF* is the lack of a strong pedagogical underpinning or vision at the project level for the *e-Learning Pilot Scheme* and weak support mechanisms at the overall scheme level. It was found that projects involving multiple schools exhibited significantly higher levels of student learning outcomes in information literacy and self-directed learning (Law et al. 2013) as opposed to single school projects. The learning outcomes were particularly impressive in projects that have in place structures and mechanisms for joint school learning interactions such as lesson co-planning, peer lesson observation and participation of the principals in debriefing meetings after joint lesson observations. The scheme's requirement on projects to engage nonschool partners such as publishers and educational software developers reveals inadequacies in policy guidelines and regulations governing partnership matters, particularly intellectual property rights issues that are still to be resolved (as a learning outcome yet to be achieved). The project design appropriately brought in key actors at various levels in anticipation that to scale up these innovations requires change and adaptation across different levels. However, unlike the Singapore *mp3*, there is inadequate understanding of the need to design and build structures and mechanisms for learning interactions across sectors and levels. Hence, learning outcomes at the project and system levels are less evident. On the other hand, the evaluation study on this e-Learning Pilot Scheme currently underway may contribute to system-level learning through the Fourth IT in Education Strategy that is being prepared by the Education Bureau of the Hong Kong SAR Government.

[5] http://www.tc.columbia.edu/lessonstudy/lessonstudy.html

Both the South Korean *Digital Textbook* project and the Singapore *mp3* are national-level projects. The former is a pilot, and the latter is already at the mainstreaming stage. Han (see Kampylis et al. 2013, Case report 7, pp. 103–114) reports changes in operation and management structure and in everyday routines in schools as a consequence of the *Digital Textbook* project. In addition, as a result of the concerted efforts of the South Korean government and related organisations, the Korean Reprographic and Transmission Rights Association has approved free transmission of e-book contents for educational purposes. Legislation now states that once a printed textbook is officially approved, the publisher must develop and provide the corresponding digital textbook within a year, providing a firm legal and institutional basis for the development and implementation of digital textbook initiatives.

eTwinning as a cross-national project involving more than 223,000 registered users from more than 112,000 schools in 33 European countries involves teachers working primarily as individuals within their schools, as there is an average of only two teachers per registered school. It provides centralised top-down support at the European level (e.g. Central Support Service), national level (e.g. National Support Service) and the local/regional levels for bottom-up initiatives at the teacher level, without the need for school-level support. Multilevel evaluation/recognition/incentive mechanisms (e.g. various eTwinning quality labels and awards at national and European levels) have evolved progressively to promote aligned learning at all levels through clearly articulated quality criteria (see Kampylis et al. 2013, Case report 1, pp. 21–35).

The *1:1 Learning* case study is in fact a collection of 31 studies, some at regional and others at national/state levels. Hence, there is great diversity in terms of learning outcomes within this 'case' not only at the school level but also at the project and system levels. Bocconi, Kampylis and Punie (see Kampylis et al. 2013, Case report 2, pp. 36–51) report an increasing tendency in recent years in Europe for these initiatives to move their foci away from devices and infrastructure to learners and pedagogies. They conclude with a reference to the five principles identified by Hanleybrown and colleagues (2012) for initiating and leading collective impact initiatives, which are also of strategic importance for enabling innovation in 1:1 education: common agenda, shared measurement, mutually reinforcing activities, continuous communication and backbone support.

An Ecological Model of Educational Change as Learning Across Levels

In this chapter, we introduce the background to the European Commission JRC-IPTS study on *ICT-enabled innovations for learning in Europe and Asia* (Kampylis et al. 2013) and a brief description of the seven innovations included in this study. These seven cases differ widely not only in scale but also in all five dimensions of the mapping framework for ICT-ELIs developed by Kampylis et al. (2012): the

nature of innovation, implementation phase, targeted actors, access level and areas of impact. Furthermore, with the exception of *Hellerup School*, wide diversities are also observed within each of these innovations along all of these five innovation dimensions.

Though all of the cases are supported by centralised top-down strategic measures and involve bottom-up initiatives in their development (e.g. teacher-led or teacher-initiated innovation), the focal agency and pathways of development vary greatly. For example, *Hellerup School* is primarily a school-level innovation, while school-level support is not a necessary condition for a teacher to participate in eTwinning cross-border projects. In all of the other five cases, funding and policy commitment from the national/system level (Singapore *mp3*, S. Korea *Digital Textbook*, Hong Kong *e-Learning Pilot Scheme* and some of the *1:1 Learning* initiatives) or the regional/district level (*CoREF* in Japan and some of the *1:1 Learning* initiatives in Europe) were crucial to the initiation and launch of these projects.

The nature of the drivers that guide the development of these seven initiatives also differs. In *1:1 Learning* and the *Digital Textbook* initiatives, the key drivers are the national, regional or district governments that funded and developed the necessary infrastructure and implementation plans. In *CoREF*, the actual design of the innovation was the responsibility of the university-based learning scientists. In the *e-Learning Pilot Scheme*, it was the responsibility of the school (or school consortium for a multi-school project) to propose the specific focus and implementation plan for each of the 21 pilot projects selected for funding. In *mp3*, the Singapore Ministry of Education provided a variety of mechanisms such as stipulating the establishment of ICT mentors and incentive schemes such as FutureSchools@Singapore, Lead ICT Schools and teacher awards to stimulate and foster the agency for the design and development of innovation at various levels of the system: teachers, schools and university researchers. Ministry of Education officials still play an important role in the seeding of innovations in some schools, but they have increasingly placed emphasis on fostering the development of joint school communities.

The fact that all the analysed ICT-ELIs have demonstrated some level of sustainability and, in some cases, very impressive scaling up over the past few years, indicates that there are multiple ways of initiating, sustaining and scaling up ICT-ELIs successfully. On the other hand, the extent of the impact on student and teacher learning differs greatly even within each of the innovations, indicating that the specific pathway to change and innovation does not determine the success or scalability of an innovation. Furthermore, all of these innovations are organic, not static. These cases provide strong evidence that while the initial conditions of change frame the starting point of an innovation, how the change is then guided and managed determines its ultimate success and scalability. We need a model of change that can help us to conceptualise and conduct further research on the determinants of the change trajectory and scalability of innovations.

It is important to note here that the concept of scalability and innovation as referred to in this chapter only makes sense within an ecological model of change. It does not fit in with the concept of scaling up used in classical educational change literature. In the latter (e.g. Rogers 1995), there is a well-tested prototype or solution

that needs to be propagated. It may still be necessary to make changes and adaptations in the process of scaling up, but many of the specifics of the innovation are already developed, and scaling up means extending the implementation and impact of the prototype. On the other hand, the starting points of the innovations involved in all seven ICT-ELIs are guiding concepts and work in progress. All actors involved in the learning at different levels are engaging in something new, and all contribute to the innovation process. Nothing is static, and scaling up is not a process of replication. Learning from prior experience and the knowledge of others is important in an evolutionary sense as the basis for further knowledge building. It does not, however, provide solutions that can be adopted directly.

Each of the seven innovation cases is a dynamic system comprising hierarchically nested levels of actors and contextual factors, which interact and are hence interdependent, in alignment with the literature on ecological models of educational change (e.g. Hargreaves 2003; Law et al. 2011). By definition, any learning innovation necessarily introduces a certain newness to the education ecosystem and is hence a foreign species. Usually, the ambient environment does not have all the conditions necessary for a foreign species to prosper (e.g. physical and technology infrastructure of the school, teachers' competence and skills, flexible school timetabling, etc.), and hence, the sustainability and scalability of change and innovation are the critical hurdles to successful large-scale educational reforms.

To make the discussion more specific, we define the new (or foreign) species to be the learning innovation (i.e. the changed pedagogical practices) at the classroom level. We are interested in scaling up these learning innovations to produce the kinds of targeted learning outcomes in students and hence necessarily also of teachers. To achieve this in a sustainable manner, we need to increase the 'carrying capacity[6]' of the education ecosystem for these learning innovations. How can this be achieved? Building on Clarke and Dede's (2009) proposal that evolution is one important dimension for scalability, we argue that changes at different levels of the education ecology should be viewed as learning outcomes of the evolutionary process associated with innovation implementations. We present in our analysis not only the learning outcomes reported in the seven cases at student and teacher levels, which are outcomes normally reported and discussed in educational change literature. By identifying changes at the school, project, community, system and cross-national levels as learning outcomes, we also highlight the dynamic aspects of these 'conditions', as well as the cumulative characteristics and cultural/contextual dependence of these changes.

There are several important implications for learning innovation-related research, policy and practice, if we see the scalability challenge as primarily one of learning:

1. For classroom level innovations to be sustained and scaled up, learning at all the other levels needs to be supported and aligned. The process of innovation

[6]The carrying capacity of a biological species in an environment is the maximum population size of the species that the environment can sustain indefinitely, given the food, habitat, water and other necessities available in the environment. (Wikipedia)

implementation is not only a process of capacity building by actors at the various levels but also the construction of organisation structures/routines, interaction mechanisms and artefacts (or reifications) as tangible outcomes at these different levels.

2. The learning outcomes at one level become the contextual factors or conditions for learning at a lower level. Learning at all levels takes time, but the timescale for learning differs at the different levels. Hence, it is important to build in structures and mechanisms for interaction among actors from different levels to facilitate aligned learning through self-organisation.
3. If we see change at the different levels as outcomes of learning, then we should conduct research on the conditions which support aligned learning at the different levels. It is well documented in educational innovation/reform literature that what works in one context does not necessarily work in another if 'transferred' or duplicated. So perhaps the most valuable learning from 'good practices' is not what the innovation is about or how it is implemented, but how the learning at various levels is facilitated and aligned.
4. A comprehensive evaluation of innovations should not just focus on student and teacher outcomes, but on the learning outcomes at multiple levels of the system. The in-depth analysis of the seven cases from Asia and Europe reveals that the more innovative practices are, the more difficult is the alignment across all levels (i.e. from lower to higher ones) and scaling up.

We hope that the proposed ecological model of change will stimulate further research on the scaling up of ICT-ELIs, leading to more refined strategies and actions to be undertaken by policymakers to mainstream educational innovation with systemic impact. Further research is needed not only into cases of ICT-enabled learning innovation that have achieved a level of scale and sustainability but also into unsuccessful cases that mirror most aspects of the five-dimensional framework of ICT-ELIs. A comparison of successful and unsuccessful ICT-ELIs of this kind could provide valuable insights and evidence for scaling up ICT-ELIs and contribute to the modernisation of education and training systems in Europe and beyond.

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References

Aceto, S., Borotis, S., Devine, J., & Fischer, T. (2014). *Mapping and analysing prospective technologies for learning: Results from a consultation with European stakeholders and roadmaps for policy action*. Luxemburg: Publications Office of the European Union. EUR 26519 EN.

Bocconi, S., Kampylis, P., & Punie, Y. (2013). Innovating teaching and learning practices: Key elements for developing Creative Classrooms in Europe. *eLearning Papers, Special edition 2013*, 8–20. http://www.openeducationeuropa.eu/sites/default/files/news/SpecialEdition2013.pdf

Christensen, C. M. (2003). *The innovator's dilemma: The revolutionary book that will change the way you do business*. New York: Harper Business Essentials.

Clarke, J., & Dede, C. (2009). Design for scalability: A case study of the river city curriculum. *Journal of Science Education and Technology, 18*(4), 353–365.

Collins, A., & Halverson, R. (2009). *Rethinking education in the age of technology—The digital revolution and schooling in America*. New York: Teachers College Press.

Cuban, L. (2001). *Oversold and underused: Computers in the classroom*. Cambridge, MA: Harvard University Press.

Davis, N. (2008). How may teacher learning be promoted for educational renewal with IT? In J. M. Voogt & G. Knezek (Eds.), *International handbook of information technology in primary and secondary education*. New York: Springer.

Davis, B., & Sumara, D. (2008). Complexity as a theory of education. *Transnational Curriculum Inquiry, 5*(2), 33–44.

Eisenhardt, K. M., & Graebner, M. E. (2007). Theory building from cases: Opportunities and challenges. *Academy of Management Journal, 50*(1), 25–32.

European Commission. (2012). *Rethinking education: Investing in skills for better socio-economic outcomes* [COM(2012) 669 final]. Retrieved November 5, 2013, from http://ec.europa.eu/education/news/rethinking/com669_en.pdf

European Commission. (2013a). *Opening up education: Innovative teaching and learning for all through new Technologies and Open Educational Resources* [COM(2013) 654 final]. Retrieved November 5, 2013, from http://ec.europa.eu/education/news/doc/openingcom_en.pdf

European Commission. (2013b). *Survey of schools: ICT in education—Benchmarking access, use and attitudes to technology in Europe's schools*. Luxembourg: Publications Office of the European Union. doi:10.2759/94499.

Eurydice. (2011). *Key data on learning and innovation through ICT at school in Europe 2011*. Brussels: Education, Audiovisual and Culture Executive Agency.

Hanleybrown, F., Kania, J., & Kramer, M. (2012). Channelling change: Making collective impact work. *Stanford Social Innovation Review*. http://www.ssireview.org/blog/entry/channeling_change_making_collective_impact_work?cpgn=WP%20DL%20-%20Channeling%20Change

Hargreaves, A. (2003). *Teaching in the knowledge society: Education in the age of insecurity*. Philadelphia: Open University Press.

Hargreaves, A., & Fink, D. (2006). *Sustainable leadership*. San Francisco: Wiley.

Holmes, B. (2013). School teachers' continuous professional development in an online learning community: Lessons from a case study of an eTwinning learning event. *European Journal of Education, 48*(1), 97–112. doi:10.1111/ejed.12015.

Kampylis, P., Bocconi, S., & Punie, Y. (2012). *Towards a mapping framework of ICT-enabled innovation for learning*. Luxembourg: Publications Office of the European Union. EUR 25445 EN.

Kampylis, P., Law, N., Punie, Y., Bocconi, S., Brečko, B., Han, S., Looi, C.-K., & Miyake, N. (2013). *ICT-enabled innovation for learning in Europe and Asia: Exploring conditions for sustainability, scalability and impact at system level*. Luxembourg: Publications Office of the European Union. EUR 26199 EN.

Law, N., Yuen, A., & Fox, R. (2011). *Educational innovations beyond technology—Nurturing leadership and establishing learning organizations*. New York: Springer.

Law, N., Yuen, A. H. K., & Lee, Y. (2013). *Sharing on the research study for the pilot scheme on eLearning in schools.* Paper presented at the Learning & Teaching Expo 2013, Hong Kong.

Levin, B. (2008). *How to change 5000 schools: A practical and positive approach for leading change at every level*. Cambridge, MA: Harvard Education Press.
Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. *Teachers College Record, 108*(6), 1017–1054.
Oblinger, D. G., & Hawkins, B. L. (2006). The myth about online course development. *EDUCAUSE Review, 41*(1), 14–15.
OECD. (2013). *PISA 2012 results: What students know and can do* (Vol. I). Paris: OECD Publishing. doi:10.1787/9789264201118-en.
OECD/CERI. (2010). *Inspired by technology, driven by pedagogy: A systemic approach to technology-based school innovations, educational research and innovation*. Paris: OECD Publishing. doi:10.1787/9789264094437-en.
Paterson, B. L., Thorne, S. E., Canam, C., & Jillings, C. (2001). *Meta study of qualitative health research: A practical guide to meta analysis and synthesis*. Thousand Oaks: Sage.
Rogers, E. M. (1995). *Diffusion of innovations* (4th ed., p. 512). New York: The Free Press.
Shear, L., Gallagher, L., & Patel, D. (2011). *ITL research 2011 findings: Evolving educational ecosystems*. Redmond: Microsoft.
Sherer, J. Z., & Spillane, J. P. (2011). Constancy and change in work practice in schools: The role of organizational routines. *Teachers College Record, 113*(3), 611–657.
Stein, M., & Coburn, C. (2008). Architectures for learning: A comparative analysis of two urban school districts. *American Journal of Education, 114*(4), 583–626.
Vuorikari, R. (2013). *eTwinning School Teams—Case studies on teacher collaboration through eTwinning*. Brussels: Central Support Service for eTwinning & European Schoolnet.

Part III
International Networks for Scaling Professional Development of Teachers

Chapter 11
Scaling Up Teacher Networks Across and Within European Schools: The Case of eTwinning

Riina Vuorikari, Panagiotis Kampylis, Santi Scimeca, and Yves Punie

Abstract The aim of this research is to look at the key elements that help sustain and scale up a European-wide teacher network called eTwinning. eTwinning, which has more than 250,000 European teachers as members in April 2014, has become an incubator for pedagogical innovation in the use of Information and Communication Technologies (ICT) for cross-border school collaboration and for formal and informal teacher professional development. The chapter synthesises a series of studies on eTwinning – some of which are more qualitative case studies and others are based on social network analysis (SNA) – focusing on factors that contribute to the further development and mainstreaming of eTwinning. In particular, we look at the growth of the network and its reach among teacher population in Europe. Then, we move to observe deeper level collaboration through pedagogical projects and show how the network can be studied to understand its underlying structures. Finally, through case studies on eTwinning school teams, we also look at micro-level mechanisms for teacher collaboration within an institution to spread pedagogical innovation at the local level.

Introduction

The aim of this chapter is to look at the key elements that have helped sustain and scale up a European-wide teacher network called eTwinning (http://www.etwinning.net). Teacher networks are learning networks, i.e. technology-supported communities through which learners share knowledge with one another and jointly develop new knowledge (Sloep and Berlanga 2011). The ultimate aim of teacher networks is to encourage collaboration and knowledge exchange at both teacher and student levels

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in order to contribute to the quality of teaching and to the learning experience of students. This chapter introduces eTwinning as an example of a teacher network which promotes pedagogical innovation and intercultural awareness through Information and Communication Technologies (ICT). One of the main goals of eTwinning is to make it possible for all schools in Europe to build pedagogical projects with schools from other countries in order to encourage networking between schools and teachers in Europe. eTwinning teachers participate in pedagogical projects on a voluntary basis and take responsibility for shaping them as they see fit in their context. The eTwinning platform has an array of resources and services for upskilling and continuous professional development (CPD) to support teachers. This chapter, however, does not focus on the cross-border eTwinning projects or CDP provisions, but looks at the underlying network and its development, scalability and sustainability as a condition for transferring pedagogical innovation within and across schools in Europe.

In the rest of section "Introduction", we first explain what eTwinning is and how it has been previously studied. In section "Scaling up teacher network – getting the spread and the depth", we focus on measures related to scaling up the network and look into two different types of growth: scaling up the network horizontally (when new schools/teachers are added to the network) and vertically (when teachers are added from existing schools in the network). Last, we also focus on the long-term retention of participants. In section "Network properties of the eTwinning teacher network", we introduce a definition of teacher networks and then look at how collaboration among teachers creates networks and what kind of properties can be studied using Social Network Analysis. In section "Vertical growth to sustain innovation within a school", we go a step further and investigate factors that matter for sustaining vertical growth through interschool collaboration using an eTwinning school team case study. Finally, in section "Discussion and concluding remarks", we outline our final discussion and draw conclusions.

What is eTwinning?

eTwinning defines itself as 'the community for schools in Europe' which promotes cross-border school collaboration through the use of ICT. It started in 2005, though in terms of policy, it had already been conceived in 2002 as part of the European Council's decision to promote school twinning as an opportunity for all students to learn and practise ICT skills and to promote awareness of the multicultural European model of society (Fig. 11.1). At the end of April 2014, the eTwinning platform has more than 250,000 registered members from 32 different European countries. It is harder to estimate the number of students participating in eTwinning collaboration, but some estimates put the figure at between 600,000 and 1,300,000.[1] There is a

[1] The lower estimation is based on the members of the online collaboration spaces used for projects (TwinSpace); the higher estimation is an approximation based on the number of projects including

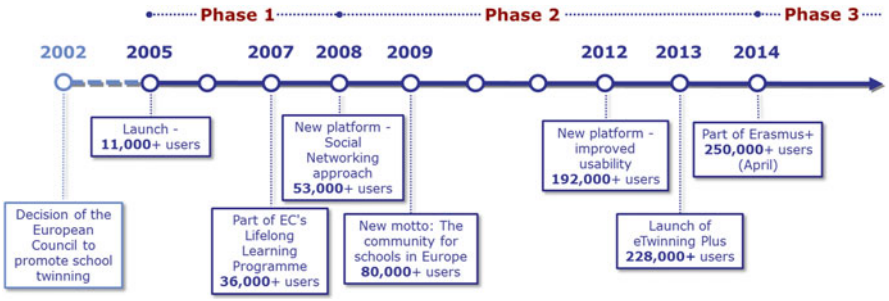

Fig. 11.1 The timeline and milestones of eTwinning development

strong international and multicultural aspect to all interactions and exchanges. Those involved represent many language and cultural contexts and are subject to different (regional or national) educational policies. Even though participation figures are already high, at the European level, they represent only about 4 % of the teaching population eligible for eTwinning. Therefore, a continued focus on scaling up and sustaining teacher participation in the network is important for its future development.

The main actors in eTwinning are eTwinners, i.e. the teachers[2] who participate in the initiative. eTwinning offers teachers the possibility of running pedagogical school collaboration projects and getting involved in CPD and an online platform to carry out these activities. eTwinning is designed to be an inclusive network: virtually any teacher from the eligible countries with a connected computer can take part. They themselves decide whether or not to participate. Therefore, eTwinning has a relatively low 'participation threshold' as all its support strategies and tools offer a relatively easy and cost-effective way of starting international cooperation and networking at the school level (Kampylis et al. 2013). While the key objective of eTwinning is to make it possible for all schools in Europe to build pedagogical projects with schools from other countries, these projects are not funded directly. The eTwinning management, however, is funded by the European Union to provide the online platform with tools, services, support and recognition for facilitating cross-border collaboration between schools.

On the eTwinning platform, teachers can find colleagues from other countries to run school projects[3] using a variety of technologies ranging from low-level ICT tools such as emails to more sophisticated tools such as learning management systems and social media tools. Although the collaboration between two schools

at least two schools/classrooms with an average of 20 pupils each.

[2] By teachers we mean all school staff such as teachers, headmasters and librarians who are eligible to join. The registered users need to be affiliated with primary (including pre-school) or secondary education or in initial vocational education and training.

[3] See 'my eTwinning cookbook' for the variety of pedagogical aspects in projects: http://files.eun.org/etwinning/cookbooks/EN_cookbook.pdf

from two European countries is the minimum requirement for an *eTwinning* project, there are projects that involve many more schools. An example is the award-winning Schoolovision[4] project, which was launched in 2009 and is still active. At the time of writing, 41 schools across Europe and beyond are taking part in this project. As explained in Law et al. (Chap. 10, this volume), in which *eTwinning* is one of the cases, the real focus of eTwinning '…is not on the technology but on enhancing collaboration, communication and intercultural awareness among the school communities in Europe facilitated by social networking mechanisms offered by a secure and established platform'.

A number of formal and informal CPD activities are offered to teachers. These include online 'Learning Events', distance courses for teachers and more informal CPD activities such as online interest 'Groups' and 'Teachers' Rooms' on various topics. In addition, on-site CPD is offered at national and European level, in both formal and non-formal ways. All in all, some 20,000 teachers every year participate in these CPD events (European Schoolnet 2013). Lastly, participating teachers can make use of a set of social networking tools offered on the platform. These include a profile page with personal and professional information, the possibility of displaying connections with friends (i.e. contacts) and posting on a personal journal (e.g. status updates) and also posting updates and comments in contacts' journals. In February 2012, for example, an average of 51 % of eTwinners used some of the social networking tools (Vuorikari and Scimeca 2013), a figure that can be taken as a proxy for actual participation in the network.

The strategies for implementing eTwinning are a combination of centralised/decentralised and top-down/bottom-up strategies (Fig. 11.2). The centralised top-down aspect is represented by the Steering Committee of eTwinning which sets

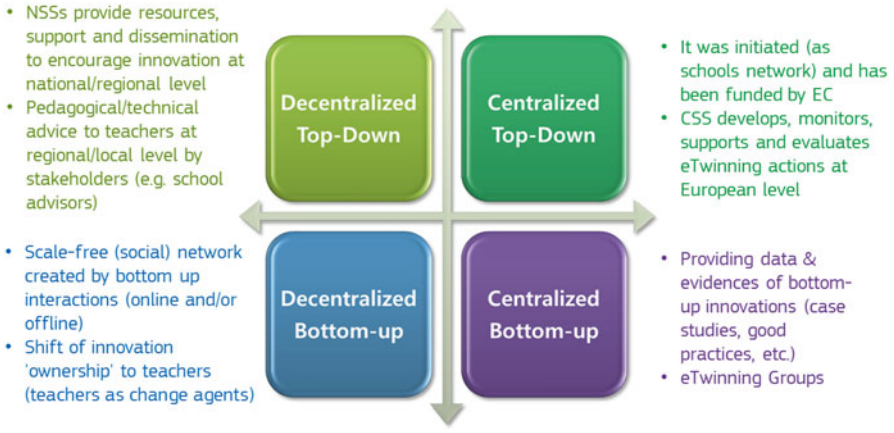

Fig. 11.2 Leadership strategies operating at different levels in eTwinning (Kampylis et al. 2013)

[4] http://schoolovision2014.blogspot.com.es

directions, monitors and manages and provides funds and resources. The Steering Committee is comprised of the European Commission and the Education, Audiovisual and Culture Executive Agency. The Central Support Service (CSS) is responsible for the eTwinning platform, the coordination of the National Support Services, the professional development activities that are run centrally, the monitoring of the action and the main communication strategies. The CSS is run by European Schoolnet,[5] and it also collects and processes data according to the data protection rules defined in the eTwinning privacy statement and keeps track of all communications and interactions among eTwinners (i.e. data processor). The decentralised top-down aspect, on the other hand, is represented by National Support Services (NSSs) that function in each participating country (or the region, in the case of Belgium). The NSSs are in charge of their countries' teachers directly, implementing a development plan for the schools under their jurisdiction and providing resources, support and dissemination to encourage innovation at the regional/national level. In other words, the NSS is there to avoid the 'replica trap', the erroneous strategy of trying to repeat everywhere what worked locally, without taking account of local variations in needs and environments (Wiske and Perkins 2005). Moreover, eTwinning Ambassadors[6] and other education stakeholders (e.g. school advisors) often provide pedagogical/technical advice to teachers at local/regional level.

The stable funding that eTwinning has received from the European Commission (EC) and regional/national educational authorities since its launch in 2005 has been a key factor for its development and sustainability. This funding scheme (i.e. EC and regional/national educational authorities) will continue through 2014–2020 via the Erasmus + programme[7] and is expected to contribute to eTwinning's further development and scaling up.

How Has eTwinning Been Studied

eTwinning has been the focus of various studies since it began. In Google Scholar, for example, a search with 'eTwinning' renders more than 1,100 results in various languages; only 37 % are in English (Google Scholar, January 2014). A more restricted search with eTwinning in the title still finds 71 results. 22 research articles appear in Springer alone.[8]

[5] European Schoolnet is a network of 30 European Ministries of Education. As a not-for-profit organisation, the aim is to bring innovation in teaching and learning to the key stakeholders: Ministries of Education, schools, teachers, researchers and industry partners.

[6] Ambassadors are experienced practitioners in eTwinning who are available to help and advise eTwinners.

[7] See, for instance, at http://ec.europa.eu/education/calls/s1013/invitation_en.pdf. The breakdown of EC funding per NSS is calculated by taking into account factors such as the resources necessary for the basic activities of each NSS, the population and the number of projects in each region/country covered by the NSS at hand.

[8] http://www.springer.com

Various types of research have been conducted on eTwinning ranging from small-scale personal studies and reports related to a PhD programme (e.g. Holmes 2013; Gouseti 2013) to the monitoring activities undertaken by the CSS and NSSs. Within the latter category, a number of studies focus on the development of eTwinning and its community-building aspects (Crawley et al. 2009, 2010; Wastiau et al. 2011). These studies can be called micro-level studies as they focus on the actions of individual teachers and students. An external evaluation reviewed the studies in this category and suggested that although they contain valuable case studies and information, only anecdotal evidence can be gathered from them (European Commission 2013, p. 40). Though these studies deal with active members and interesting cases, it is clear that they may not convey the full character of the larger community.

On the other hand, there are also studies on eTwinning on the macroscale: Vuorikari et al. (2011b) focus on the growth of the network using measurements such as 'eTwinning reach' to understand the spread of action within each country and Vuorikari et al. (2011a) elaborate on synergies between eTwinning and national CPD schemes for teachers. These macroscale studies also include the use of social network analysis (SNA) and information visualisation to study eTwinning (Breuer et al. 2009; Pham et al. 2012; Song et al. 2011; Vuorikari and Scimeca 2013). Within this category of studies, there are also research results from a project called Teachers' Lifelong Learning Network which studied eTwinning for a period of 3 years (e.g. Cachia et al. 2012; Vuorikari et al. 2012).

Table 11.1 shows seven research studies that were reviewed for the purpose of this chapter to investigate processes that focus solely on the measures for scaling up and sustaining teacher networks. Therefore, it is important to draw the reader's attention to the fact that this chapter does not deal with external reform implementation in schools and the consequent issue of sustaining practices or change at the school

Table 11.1 Synthesis of studies used for this research

Authors	Focus of the study	Method
Vuorikari et al. (2011a) and Vuorikari (2010)	Teacher professional development and eTwinning growth	Statistics, indicators and three country monographs
Pham et al. (2012)	Teacher networks	Social network analysis and information visualisation using authentic data from the eTwinning platform
European Commission (2013)	Impact of eTwinning on participating pupils, teachers and schools	Web-based survey on 5,956 eTwinners, 24 school case studies
Kampylis et al. (2013)	Conditions for sustainability and scalability of ICT-enabled learning innovations	7 case studies from Europe and Asia, out of which one was eTwinning
Vuorikari (2013)	eTwinning school teams	24 school case studies on eTwinning school teams
Berendt et al. (2014)	eTwinning analytics	Literature review and web analytics on eTwinning

level (for this see Law et al., Chap. 10, this volume). Rather, the chapter looks at teacher networks as a vehicle for this kind of change. The unit of study is therefore the network, not the individual organisation or the teacher. However, these factors are also addressed when they affect the growth and the sustainability of the network.

Scaling Up Teacher Network: Getting the Spread and the Depth

In this section, we look into different growth patterns in teacher networks, using the eTwinning network as an example. By growth, we mean engaging new members in the network. We first look at the development at the European level and then introduce an indicator called 'eTwinning reach'. Coburn (2003) refers to growth measures as 'spread', pointing out that scale is fundamentally multidimensional and that there is a need to simultaneously cultivate the depth of change necessary to support and sustain consequential change. Therefore, we also talk about scaling up the network both horizontally and vertically, demonstrating these concepts with some historical data. Last, we focus on retaining participants in the network.

A study conducted on the impact of eTwinning on participating pupils, teachers and schools compiled core statistics using the number of registered teachers, registered schools and participation in school collaboration projects at both country and platform levels (European Commission 2013). Using these absolute figures, it is easy to monitor how teachers engage in eTwinning. Figure 11.3 shows how the eTwinning network has grown annually in terms of new participants on the platform. The figures refer to the cumulative number of members since the inception of eTwinning in 2005. It can be observed that the growth rate increases over time,

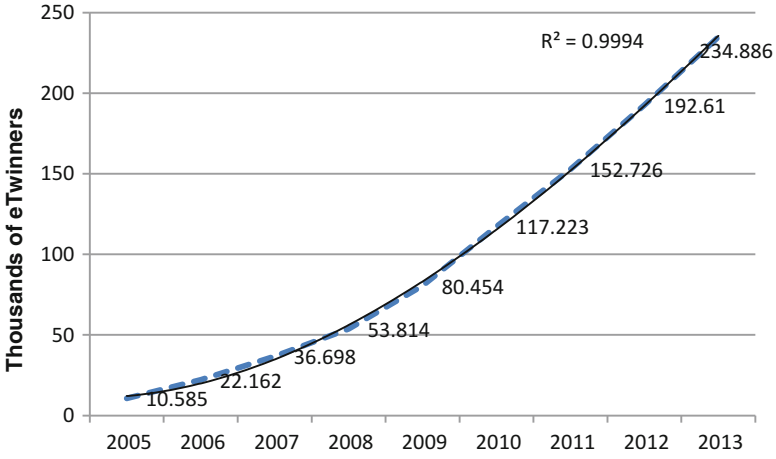

Fig. 11.3 Cumulative growth of eTwinners based on CSS data: the trend line follows cubic growth (R^2=0.9994)

indicated by the fact that growth in the numbers of eTwinners is quicker than simple linear growth. The curve in Fig. 11.3 (dotted line) closely fits a polynomial trend line (black line).

eTwinning Reach

Even though the growth of the eTwinning network in cumulative numbers as presented above is impressive, it does not help us to understand the spread and success of eTwinning across the entire teacher population in the eligible countries. Vuorikari et al. (2011b) gained new perspectives on the growth by introducing a proportional growth indicator called 'eTwinning reach'. This was done to show the percentage of teachers signed up on the eTwinning platform in a given country. The indicator is calculated by dividing the number of registered eTwinners of a country by the teacher population within this country. For the latter, OECD Statistics for educational personnel[9] are used. An annual 'eTwinning reach' has been used to monitor growth of eTwinning. In Fig. 11.4, we present numbers from May 2010 to

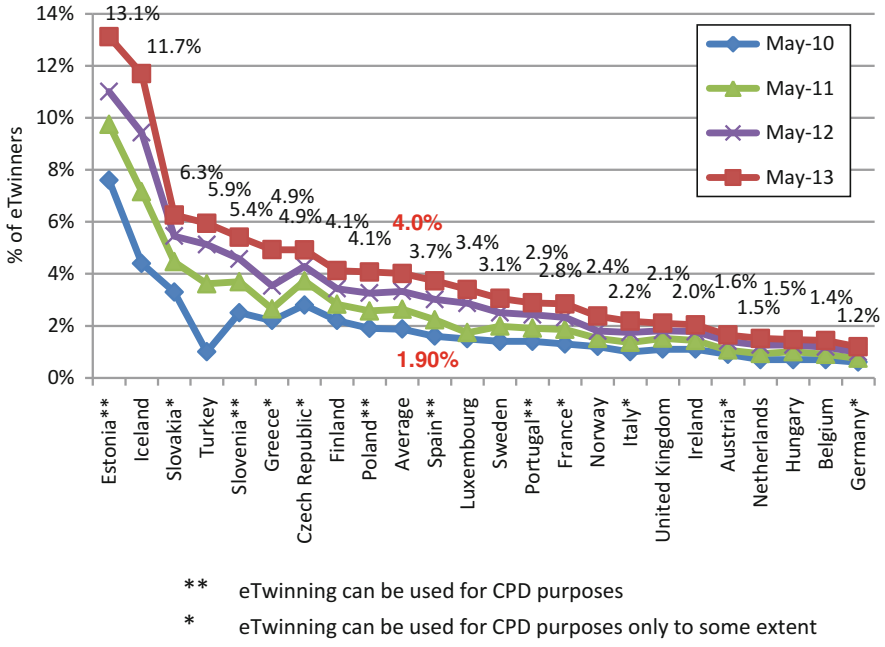

Fig. 11.4 eTwinning reach monitored in a number of eTwinning countries over a period of 4 years

[9] Data extracted on February 8, 2010, from OECD Statistics at http://stats.oecd.org/ (primary and secondary education, classroom teachers and academic staff, full-time and part-time for 2006–2007). No new data is available.

May 2013 when, on average, 4 % of the eligible teacher population was registered on the eTwinning platform.

As suggested by the authors in Vuorikari et al. (2011b), the indicator 'eTwinning reach' can also be interpreted using the popular idea of diffusion of innovations (Rogers 2003), 'a theory of how, why, and at what rate new ideas and technology spread through cultures'. Considering the growth of eTwinning in terms of Rogers' theory, eTwinning passed from the milestone of 2.5 % (Innovators) to Early Adopters in 2011 (ibid., p. 282). Apart from long-term monitoring, 'eTwinning reach' has also been used by the eTwinning Central Support Service and National Support Services as a strategic tool. To improve the strategic planning and marketing of eTwinning, a *persona approach*[10] was built loosely upon the idea of adopter categories (Rogers 2003). eTwinning Innovators, for example, could be described as self-driven and motivated to try new ICTs in their teaching. Most teachers, however, could be seen as more selective about which technologies they start using and less willing to embrace new technologies before they see how they fit into their teaching (e.g. Early Adopters and Early Majority). Through long-term ethnographic observation of eTwinners and their collaborative projects, Cachia et al. (2012) describe eTwinning personas.[11] Understanding the differences between 'groups of customers' helps segment the eTwinning market and reach beyond the obvious group of Innovators. This, in turn, could help eTwinning to cross the 'chasm' from Early Adopters to Early Majority.

As can be observed in Fig. 11.4, the average 4 % of 'eTwinning reach' does not translate to all the countries; the differences between countries are notable. In general, small- and medium-sized countries (in terms of population) show high percentages above 2.5 % (e.g. Estonia, Iceland, Slovakia, Slovenia, Finland, Luxembourg, Sweden and Portugal). 'eTwinning reach' alone does not explain why some small- and medium-sized countries do better in terms of 'reach' than others (e.g. see Ireland, Austria in Fig. 11.4). A survey of 5,956 eTwinners suggested 'that the impact of eTwinning on schools […] appears to be highest in smaller countries, where a school may feel motivated to get involved because of isolation and, perhaps, where the NSSs are also able to have a greater reach with their available resources to support and promote eTwinning' (European Commission 2013, p. 53). However, Fig. 11.4 also shows that countries with bigger populations have achieved more than 2.5 % penetration of their teacher population, e.g. Turkey, Greece, Czech Republic, Poland, Spain and France. In this context, eTwinning reach prompts the question 'why do such big differences between countries exist?' The demand for professional development within the country and opportunities to use eTwinning for that purpose could be a plausible explanation (see ** in Fig. 11.4). A statistical analysis, however, revealed no correlation. Vuorikari (2010) speculates that differences are probably related to intricate framework conditions at the national and systemic level, such as ICT provision in schools, curriculum opportunities for

[10] Personas consist of a narrative relating to a user's daily behaviour patterns using specific details.

[11] An example of eTwinning personas: http://www.slideshare.net/europeanschoolnet/etwinning-personas-12956565

project-based learning and school collaboration and how teachers' career paths are organised, to mention but a few. Additionally, as with networks in general, these differences can also be attributed to *network effects*, meaning that the service becomes more useful as more users join.

Scaling Up Horizontally and Vertically

When a new teacher signs up to eTwinning, they must be affiliated to an educational institution, i.e. a (pre) primary, secondary or VET school. This allows the verification process at the local level to check that teachers really are who they say they are (each National Support Service is in charge of this process). Over time, two different types of growth can be observed: one where new teachers and schools join the network (i.e. 'scaling the network *horizontally*') and another where a new teacher joins from an existing school (i.e. 'scaling the network *vertically*'). These two types of growth are discussed below in terms of getting the spread and sustaining the network.

Figure 11.5 shows these two different types of growth patterns. The solid green line shows '*horizontal scaling*' where new members come from schools that have not previously been part of eTwinning. In network terms, this means adding more nodes to a system. The dotted red line shows 'scaling the network *vertically*', where new teachers come from an existing eTwinning school. In network terms, this refers to adding resources to an existing node.[12]

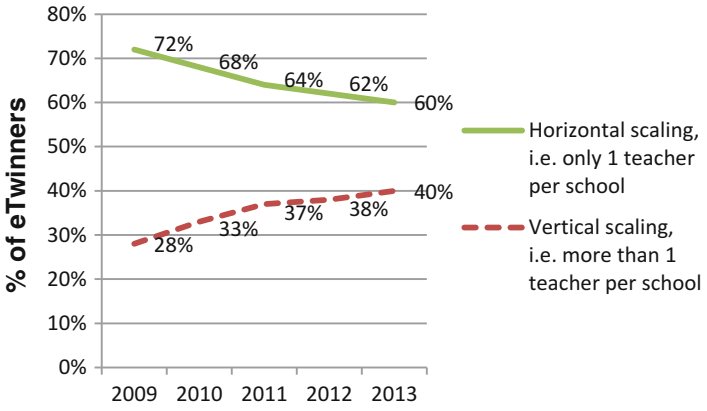

Fig. 11.5 Scaling up eTwinning network horizontally and vertically

[12] http://en.wikipedia.org/wiki/Scalability

Adding new countries to the network is also a type of horizontal scaling: we call it geographical scalability. In general, eTwinning applies to the member states of the European Union, though their overseas territories and countries are also eligible. Additionally, Iceland, Norway and Bulgaria have also participated from the beginning. In 2007, Romania joined eTwinning and, in 2009, Croatia. From 2009 to 2010, the former Yugoslav Republic of Macedonia took part and joined again in 2012. In 2010, Turkey became eligible. Finally, Switzerland joined eTwinning in 2011 and left in 2014. Behind this expansion, there is always a political decision taken by the European Commission. Each new country requires a NSS which is cofinanced by the EC and the country in question. Additionally, a new node in the network means increasing management complexity and cost for the CSS which runs the organisation and hosts the platform (e.g. a new translation of the user interface could be needed – it currently is available in 25 languages).

Pilots are also part of geographical scalability. eTwinning Plus,[13] for example, is a pilot for greater geographic distribution with limited participation of schools from Armenia, Azerbaijan, Georgia, Moldova, Tunisia and Ukraine. This pilot will end in June 2014, and it is likely that schools from these countries will fully join eTwinning. This geographical scalability of the eTwinning network implies that its underlying model offers a good base for horizontal scaling, although it must be remembered that a larger number of countries will increase management complexity.

Using intuitive indicators such as 'eTwinning reach' and horizontal growth allow easy measurability of the scale, but as Coburn (2003) points out, the problem of scale is fundamentally multidimensional. She argues that the attractiveness of measures such as those mentioned above lies in their simplicity and that there is a need to simultaneously cultivate the depth of change necessary to support and sustain consequential change. Therefore, over the years, it has also become clear that by solely focusing on horizontal scaling up, eTwinning will not achieve a more systemic level of pedagogical change in European schools. As seen from Fig. 11.5, in 2009, for example, 72 % of eTwinners were the only eTwinning actor in their educational institutions. There are two ways of interpreting this information. On the one hand, these teachers could be leading-edge pedagogical innovators in ICT use in their schools. On the other hand, they could be working in isolation in their school environments. Various campaigns have focused on the depth, intensity and ownership of eTwinning activities within an organisation. School year 2012–2013, for example, was the campaign year for 'eTwinning school teams'. As Fig. 11.5 shows, by the end of 2013, there was a 12-percentage point decrease in the number of schools with only one eTwinner. From the network point of view, we consider this to be good news. From a more systematic pedagogical change point of view, this vertical scaling of existing systems can also contribute to transferring and sustaining educational innovation within a school, a point we come back to later when we present the study on eTwinning school teams (see section "Vertical growth to sustain innovation within a school").

[13] http://plus.etwinning.net

Retaining Participation Over a Period of Time: Getting the Depth

In the section above, we focused on the growth of the network. Retaining the user base of eTwinners is equally important for the teacher network to properly function. In this section, we introduce a study on retaining participants in the network over a long period of time using an indicator called 'eTwinning retention rate' which was introduced first by Vuorikari and Scimeca (2013) and further developed by Berendt et al. (2014).

eTwinning has existed since 2005. It is therefore relevant to ask what evidence there is of teachers remaining with eTwinning over a long period of time. The 'eTwinning retention rate' is based on a web analytics measure used in online marketing to talk about the percentage of users who sign up for a service and come back within a certain period of time. The retention rate for eTwinning refers to the percentage of teachers who have registered on the platform and who continue to log in year after year. The retention rate is calculated once a year. Using the CSS data from 2011, 2012 and 2013, Fig. 11.6 shows that the eTwinning user retention pattern is very much the same year on year.

The x-axis represents the number of years since a member's registration on eTwinning. For example, for the data plotted in year 2013 (green line with triangles), 'Year 0' represents the eTwinners who signed up in that year, 'Year 1' represents those who have been in eTwinning for more than a year and so on. The vertical axis

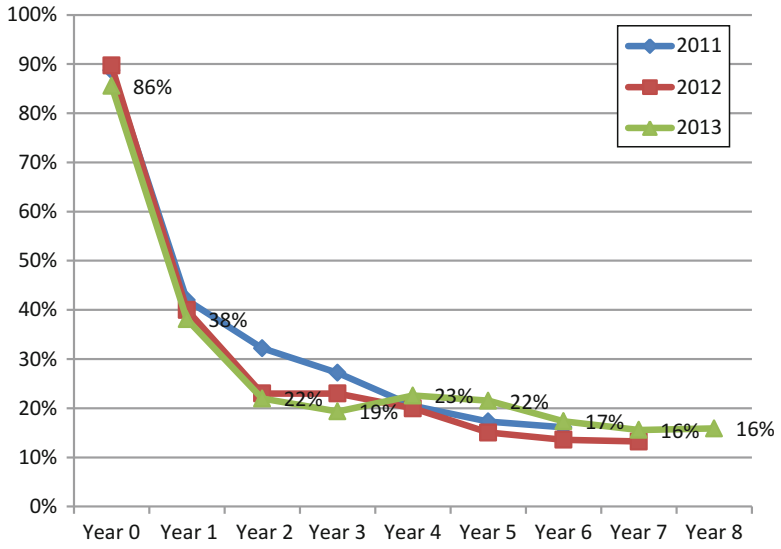

Fig. 11.6 eTwinning retention rate plotted in three consecutive years (2011–2013). Data on returning eTwinners by the year of their registration: '0 year' refers to eTwinners who registered in the given year, '1 year' = their first year in eTwinning, etc.

represents the percentage of eTwinners who log in at least once in that given year. For example, 86 % of users who registered on eTwinning in 2013 logged on again at least once during that year. For 2012 and 2013, a similar retention rate is observed, i.e. more than 86 % of first-year eTwinners return to the platform at least once during their first year.

A year after registration, however, there is a steep decline. Taking the example of year 2013, Fig. 11.6 shows that in Year 1, only 38 % of the users who registered on eTwinning a year earlier (i.e. in 2012) still log on to eTwinning. This trend is much the same in 2011, 2012 and 2013. After around the fourth year, Fig. 11.6 shows that around 20 % of eTwinners remain engaged. After 5–8 years, about 1 in 6 eTwinners remain engaged and continue to return to the platform. Using this indicator and the data collected from the eTwinning platform, Berendt et al. (2014) show that eTwinning has the potential to engage users over a long time period – i.e. 1 in 6 of teachers who registered in eTwinning 5–8 years ago remains engaged and uses the platform for school collaboration. These data, however, do not shed light on their reasons for doing so. For this purpose, in the following, we combine our results with more qualitative data from a large-scale survey on eTwinners (European Commission 2013).

The results suggest that the experience of being an eTwinner has incremental and cumulative positive impacts showing that those with years of experience in eTwinning are able to get more out of the programme. Similarly, those who are involved in school collaboration projects are more positive about eTwinning (European Commission 2013, p. 61). The survey results also suggest that teachers with several years' experience in eTwinning also tend to be more positive about eTwinning than those with only 2 or 3 years. For example, around 70 % of 'long timers' (i.e. Year 6 and more) said they had made new friends across Europe, had gained new ICT skills and were also positive about eTwinning's impact on pupils' skills or motivation (this figure was consistently about 15 % less for eTwinners with 2 or less years' experience). The survey results suggested that fulfilled expectations motivate teachers to continue their participation and interest in eTwinning. Paradoxically, according to Fig. 11.6, only about 20 % of those who sign up for eTwinning get to reap such benefits.

Why do so many teachers drop out in Year 1, only after a short involvement? This could be explored in various ways. One way of seeing the issue is through a well-known phenomenon that many social networking services experience: users sign up out of curiosity without further expectations and then never come back. For example, in 2011, Fig. 11.6 shows that 89 % of users who registered that year logged on again at least once during that year. This means that 11 % never did; we can speculate that these people may belong to this category; however, as the 'dropouts' are rarely reachable through surveys, essentially they have no voice. Another way to explore this is through the above-mentioned survey. It outlines the three most unfulfilled expectations of eTwinners in Year 0 and Year 1 as the following: difficulties in finding a project partner for their idea, difficulties in joining someone else's project idea and difficulties in exchanging experiences

and information with colleagues in other countries. These findings indicate that the platform did not provide sufficient support in getting these people connected with the right people at the right time. However, we do not know which percentage of 'dropouts' this group represents. Moreover, the survey also mentions other difficulties such as motivating pupils to learn with eTwinning and other unfulfilled expectations such as how eTwinning would improve pupils' language skills or knowledge of European cultures and countries in general. Coburn (2003) talks about 'deep change' as a dimension of implementing pedagogical innovation, meaning that the change goes beyond surface structures to alter teachers' beliefs, norms of social interaction and pedagogical principles, as was the case for the above-mentioned 'long timers' in eTwinning. Clearly, this group of 'dropouts' and 'disenchanted' teachers did not reach this point – understanding why is a crucial point for future research.

eTwinning keeps applying new strategies and best practices for supporting new users in a teacher community. However, from statistics as shown in Fig. 11.6, it is almost impossible to show their impact (year after year, the trend seems to remain the same). Each NSS, for example, has strategies for reaching out to newly enrolled members in their country to support them with their first steps. The platform also provides easy 'starter kits' for project ideas[14] and other elements to boost project work.[15] We already mentioned the on-site PD workshops that also focus on incubation of new projects. There are also more than 1000 eTwinning Ambassadors who are experienced eTwinning practitioners and can help and advise others. eTwinning Ambassadors can play important roles as they are in a position to easily connect newcomers to the existing network (horizontal growth). They can also assist existing schools with new collaborative pedagogical models such as project participation and the eTwinning school teams (vertical growth). Therefore, Ambassadors could be seen as 'change agents' as explained by Rogers (2003), namely, they bring innovations to new communities from outside the community. In the networking sense, Ambassadors also represent an important link between eTwinners and their NSS. Having Ambassadors as local contact points prevents the NSS, which have limited capacity, from being overrun by requests from eTwinners. Therefore, the system can expand without additional support (other than the Ambassadors themselves), a feature also known in peer-to-peer systems such as BitTorrent.[16]

In this section, we have discussed indicators for growth, reach and retention in the network. In the following section, we will look at the network from the perspective of cross-border school collaboration, to give more depth to the discussion.

[14] http://www.etwinning.net/en/pub/collaborate/kits.htm

[15] Modules are short activities which can be incorporated in any type of eTwinning project http://www.etwinning.net/en/pub/collaborate/modules.htm

[16] http://en.wikipedia.org/wiki/BitTorrent_protocol

Network Properties of the eTwinning Teacher Network

In this section, we first define teacher networks, the ultimate aim of which is to encourage collaboration and knowledge exchange at teacher and student level in order to contribute to both the quality of the teaching and to the learning experience of students. We then present a case study of the eTwinning cross-border school collaboration network, which has been studied using Social Network Analysis.

Vuorikari and her colleagues (2012) define the following three elements for teacher networks. Firstly, they are created *through teacher cooperation* which implies teachers working together in groups or teams to improve educational processes and outcomes (OECD 2009). Secondly, teacher networks may *exist on many levels*, for example, within a school or across schools at regional, national and international level. Finally, teacher networks are blended experiences combining online and offline networks, thanks to the use of technology-supported communication tools and social media. As Haythornthwaite and Kendall (2010) explain, the intersection between online and offline cooperation is changing, and the *physical world is increasingly mixed with the digital one*. These blended experiences are becoming the new norm and are now more common than previously studied 'online-only experiences'.

According to the above definition of teacher networks, their ultimate goal is to improve both the quality of teaching and the learning experience of students. As argued by Coburn (2003), it becomes clear that looking at growth and reach indicators does not explain how this improvement could take place. In eTwinning, for example, a teacher working in a school starts a school collaboration project with another teacher in another school in another country. How could that help contribute to the quality of teaching? Schlager et al. (2009) in their studies on teacher online networks stressed the need for 'reliable evidence of how, when and why online social networks do, and do not, advance learning' (p. 87). In the following section, we explain how our findings on the eTwinning network contribute to the understanding of the underlying structure, which, in turn, can help explain how and under what conditions learning in networks takes place.

eTwinning as a Network Structure

Using network theory terminology, a social relationship is seen as being made up of *nodes* and *connections* (Burt 2001). In an eTwinning cross-border school collaboration network (hereafter the collaboration network), the teachers are nodes, and their various joint activities create connections between them. Figure 11.7 is a visualisation of these multiple connections using authentic data. Each node is a school in its physical location in Europe. Each connection is an eTwinning project between schools, the tighter the mesh of connections, the more project collaboration. These structures change over time as people keep interacting. In 2011, 26 % of eTwinning members participate in projects.

Fig. 11.7 Visualisation of a teacher network: eTwinning project collaboration network connects schools across Europe (Pham et al. 2012)

The structure of connections defines the importance of the network for individuals within it, as they can obtain information, expertise and resources from the other members of the network. This is described as 'social' capital, in other words, individual's ability to derive benefits from such a context (Coleman 1994). These network structures function as conduits, for example, for sharing pedagogical practices. In eTwinning, the social capital is the professional benefits gained by teachers.

In order to better understand and eventually improve cooperation among teachers within these networks, we first need to explore their underlying structures. For this purpose, Berlanga et al. (2012) and Pham et al. (2012) applied social network analysis (SNA) techniques to the collaboration network to better understand the underlying mechanisms for the transfer of good practices and innovation from eTwinning projects. The data used for these studies was authentic user interaction data that was gathered from the eTwinning platform over 6 years. Previous studies using SNA methods on education communities have been conducted both online and in a physical setting, showing the value of these methods in supporting and promoting school change (e.g. Daly 2010; McDonald et al. 2005) and for a better understanding of how innovation is diffused within communities of educators (e.g. Penuel and Riel 2007; Penuel et al. 2006).

Firstly, to understand the structure of the collaboration network as a social network, Pham et al. (2012) showed that in over 6 years of existence, the network that teachers had created through collaboration in cross-border projects had evolved into a scale-free network with a power law degree distribution, more specifically that of a fat tail distribution. These networks are very suitable for social network analysis methods and studies, as the power law degree distribution indicates that super-connectors, or *hubs*, exist. Hubs are nodes that connect many other nodes (or

communities) to each other. They play an important role in ensuring connectivity, information spreading and behaviour cascading in networks. Hubs also have more power and control over the network than the other nodes which lie in the distribution tail. Moreover, a series analysis over 6 years showed that the development of the eTwinning network follows a model similar to other communities.

Figure 11.8 is another visualisation of the eTwinning project network. Each dot is an eTwinning teacher, and the connection between them shows project collaboration. The network consists of many separate clusters (hubs) which are interlinked over years of school collaboration. These interlinked clusters form the big component are illustrated by the tight connections in the middle. Though the above graph was computed in 2009, the current graph continues to evolve in a similar manner. In Table 11.2, Pham et al. (2012) detail the size of clusters within the

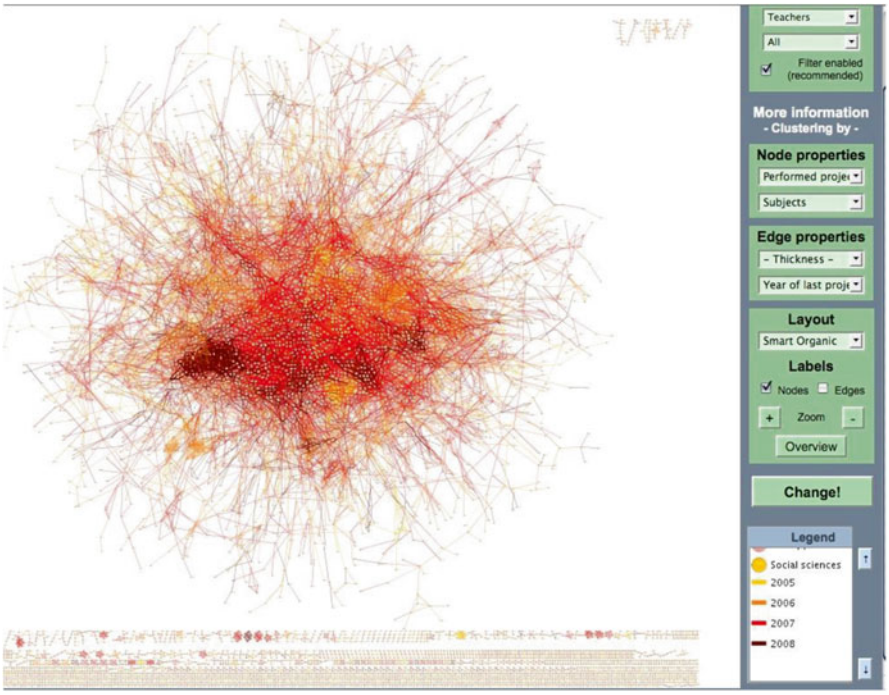

Fig. 11.8 An earlier visualisation of eTwinning teachers' network (Breuer et al. 2009)

Table 11.2 The number and the size of clusters created through eTwinning project collaboration

Cluster size (number of eTwinners)	10,567 (LC1)	6,277 (LC2)	4,362 (LC3)	2,372 (LC4)	100–1,000	10–100	2–9	Total	# of connected
Number of times identified	1	1	1	1	12	166	2,904	3,086	593

network using more recent data from the end of 2011. Table 11.2 shows a total of 3,086 components. Interestingly, the main core of the network is composed of four large communities ranging from the size of 10,567 eTwinners to 2,372, including a total of 23,578 eTwinners (see LC1–LC4 in Table 11.2). This means that 16 % of all eTwinners at that point in time were part of the *core* of the eTwinning collaboration network. This network has been formed over a long period through a large number of projects. Relating this information back to our study on the retention of eTwinners, we assume that this core represents the same groups of 'long timers' who remain involved in eTwinning for 6 years and more. Last, related to clusters in Table 11.2, the remaining 589 small connected communities are part of the core of four big clusters via many gatekeepers. Gatekeepers are teachers who are positioned at the interface of different communities. As mentioned above, they play an important role in ensuring connectivity, information spreading and behaviour cascading in networks.

Pham et al. (2012) also showed that not all eTwinners are connected to the main network (see Fig. 11.8 with unconnected components at the bottom of the image). Their analysis showed that while there is the *giant core* with many connected components (593), there are 2,493 disconnected ones. These disconnected components represent project partnerships of teachers who are engaged in project collaboration for the first time. Pham et al. (2012) speculate that none of them have yet collaborated with eTwinners who are part of the giant component, and therefore they remain disconnected from the core. Clearly, these eTwinners are deprived of the benefits of being connected to the larger network. However, we do not discount the fact that they may be connected to eTwinners via other types of networks that are created through other means such as the Contact tool, one of the social networking tools offered on the platform. The same authors, for example, show that the *average path length* through the Contact tool is about 4. This means that three intermediary contacts, for example, are usually enough to introduce anyone in the network to a random stranger. In other words, in relation to eTwinners who use the Contact tool, on average, a contact of your contact knows a contact of their contact.

Pham et al. (2012) also show that the *collaboration network* reveals a strong community structure with a clustering coefficient of 0.7308, much higher than other networks (e.g. Contact tool). In addition, these authors inspected the quality of clusters. Previous empirical observation indicates that a modularity greater than 0.3 corresponds to significant community structures. Modularity in the eTwinning network is 0.47, corresponding to a significant clustering of this network. These results accord with those of Berlanga et al. (2012) who showed that eTwinners' average sense of connectedness was 6.65 (on a scale of 1–9). According to Rovai (2002), this means that they 'feel connected to others' and they 'feel they are part of a community'.

To summarise the study findings above, we can show that social networks are created through cross-border school collaboration. Over a long period of time, clusters are formed, i.e. hubs of teachers that connect across communities and play an important role in ensuring connectivity and the spread of information through the network – in this case, sharing of pedagogical practices and gaining professional knowledge. Such hubs are important for sustaining the network and its social capital. Being part of a collaboration network can allow a teacher to access various

types of professional benefits in terms of social capital, which in turn can contribute to the quality of teaching and to the learning experience of students. Due to their limited capacity, however, SNA studies alone cannot answer all the intriguing questions that arise. Therefore, in the following section, instead of looking at collaboration across schools, we look at collaboration within a school. We revisit the notion of vertical growth through a set of case studies on eTwinning school teams. We consider eTwinning school teams to be a means of transferring and sustaining pedagogical innovation within schools. Sustainability refers to maintaining the depth of the innovation over time in the original and even subsequent contexts, making the necessary adaptions and changes (Clarke and Dede 2009; Coburn 2003).

Vertical Growth to Sustain Innovation Within a School

In a recent survey on eTwinners, 64 % of respondents said they had involved colleagues from their school in eTwinning activities (European Commission 2013, p. 68). Teacher collaboration within the same school was a focus of a report which was based on 24 case studies on eTwinning school teams (Vuorikari 2013). An eTwinning team is defined as two or more teachers from the same school working together on eTwinning activities (one cross-border project vs. separate ones). The aim of the study was to know more about the different characteristics of the teams and the conditions in which they work in order to better understand the necessary processes, adaptions and changes that take place. This will help to sustain innovation over time.

For the purpose of the study, eTwinning teams were considered as part of a pedagogical innovation process that takes place in the school environment. Pedagogical innovation is comprised of many interactions among different factors of varying levels and is a complex and gradual process. Forkosh-Baruch et al. (2008) define three levels of pedagogical innovation: namely, assimilation, transition and transformation.

Looking at the characteristics of eTwinning teams in schools, Vuorikari (2013) found that there is no single team model that could be described as ‘one size fits all’ and a wide variety of eTwinning teams exist in European schools. The author observed differences in institutional and human factors: the teams have been initiated by the teachers themselves and by the school management; leadership models vary, as do the time span and the size of the team. In the following section, an outline of these factors is given.

Mechanisms to Sustain School Teams

As one of the main objectives of eTwinning is project-based collaboration across schools, it is interesting to ask why eTwinning school teams have emerged and whether some common denominators across all cases can be found. Vuorikari (2013) outlined a number of common denominators which we summarise in the following paragraph.

In all the case studies on eTwinning school teams, there is a *lead teacher* or sometimes two or more of them. The term 'lead teacher' is used for someone who emerges as having a central role in the team's organisation and work. Lead teachers act in teams, exhibit solidarity and play a clear role in the dissemination of the innovation. Previous studies have identified these leaders' motivation as a vital component of the stability of the innovation (e.g. Nachmias et al. 2004) and one of the most influential factors in ICT-supported pedagogic innovation (e.g. Forkosh-Baruch et al. 2008). The eTwinning school team case studies underscored the existence of these leaders and their importance in bringing a 'breath of fresh air' into schools. They inspire others, and their sheer enthusiasm seems contagious. Therefore, the author underlined that finding ways to retain these people within the school organisation is important (e.g. recognition, rewards), as important as sustaining teams by building up leadership capacity and filling a leadership gap if, and when, it appears. Interestingly, the lead teacher was not always the initiator of the school team – the sample included a variety of teams from small teacher-initiated ones to whole school approaches initiated by the school management.

Another common denominator that emerges from all the case studies is related to a school's innovation history, i.e. how actively the school has sought collaboration and development opportunities inside and outside its own walls. What is common to all case studies is that the eTwinning team is part of the school's vision and it fits, in one way or another, with the existing process of innovation within the school. Vuorikari (2013) outlined two separate cases in this respect. Some of the schools had a very rich and varied history in various forms of school collaboration *before* turning to eTwinning. There are other cases, however, that show that eTwinning was *the first step* for the school to start collaborating at European level. The case studies therefore nicely illustrate that participating in a teacher network can offer ways for schools to adopt and/or maintain the depth of the innovation over a period of time, despite the differences in innovation history.

The case studies also show the different life cycles of eTwinning school teams. Some are in the very early stages of their journey (2/3 of the sample had been members of eTwinning for 2 years or less). Other teams already had a long history of collaboration and seemed to be a well-established part of the school structure. Interestingly, the author notes that a short lifespan did not always indicate the team's level of maturity and some comparatively new teams seemed well established. This was due to the fact that their schools already had an eTwinning history (albeit with only one teacher) or the fact that the teachers had a collaborative culture that facilitated the work of the team. This can be related to the school context or to the overall pedagogical innovation goal that the school is seeking. Educational innovation is usually not a one-off event, but rather a complex process, which evolves over time and involves many participants (e.g. Forkosh-Baruch et al. 2008; Law et al., Chap. 10, this volume). Therefore, the case studies also illustrate the fact that eTwinning activities performed by the team can have a place in the context of a school's pedagogical aspirations. They can either fit in with existing practices and bring only minor changes or introduce new practices with more radical, transformative innovation that brings major changes to the school's environment. The flexibility and

applicability of eTwinning, in general, support all levels of pedagogical innovation from assimilation to transition and transformation.

Last, the results also show that in all cases, some sort of *support from the school management* is crucial. This support has an important impact on the schools' time and space configurations allowing for more flexible planning and implementation of the team's work. Being able to modify timetables and classroom spaces facilitates collaboration among teachers, but also helps them arrange project work with pupils and, at times, even with parents and other external stakeholders. Management support is equally important in terms of rewarding and recognising teachers' work. These findings are important and worthy of further study.

The case studies also show interesting evidence of different *diffusion-of-innovation patterns* within schools. This can be seen as a form of vertical growth which sustains innovation within a school. All the accounts tell about lead teachers who work with a team of colleagues. In some cases, the team is rather loose and, in others, very well structured. Thus the innovation can catch on, as the people who work with the lead teacher(s) get the 'eTwinning virus'. This may lead not only to a pedagogical innovation being transferred within a school but also to it being sustained. These cascade effects are well known in networks and constitute a good example of vertical scaling of the network. However, in an educational environment, the diffusion process of innovation is often a time-consuming one and dependant on the context (see also Dearing and Looi in this volume).

Another interesting point related to the process of innovation diffusion and school teams is 'invisible' eTwinners. Vuorikari (2013) documented them as part of the case studies. 'Invisible' eTwinners work as part of the school team, but they are not registered on the eTwinning platform. They are called 'invisible', since in terms of monitoring eTwinning activities, there is no evidence of their existence (e.g. they are not included in measures such as 'eTwinning reach'; their participation in projects cannot be monitored through eTwinning management tools). However, their involvement in team activities is interesting and should not be neglected because of their 'invisibility'. On the contrary, it could be considered as example of the ripple effect, where passive bystanders in schools become the ones who are most susceptible to the pedagogical eTwinning virus.

A last point on school teams in general and on 'invisible' eTwinners in particular is that the case studies provide us with evidence of the strong offline existence of eTwinning activities at the local level. In this case, these activities take place in schools and involve their extended stakeholders. eTwinning defines itself as 'the community for schools in Europe'. These case studies nicely illustrate the fact that eTwinning can also seize local opportunities in schools, connecting the online community with the local offline one.

In this section, we have shown that physical interschool collaboration among teachers can bring about wider and deeper changes, which improve and sustain the quality of teaching over a longer period of time. In the following sections, we first discuss our results based on previous studies and then offer our conclusions and suggestions for future studies on teacher networks.

Discussion and Concluding Remarks

This study's focal concern was to explore the key elements that help sustain and scale up a European-wide teacher network, synthesising a series of studies on eTwinning. eTwinning is seen as an ICT-enabled learning innovation at classroom and/or school levels (Kampylis et al. 2013) that, through various forms of teacher collaboration, has evolved into a social network structure connecting thousands of students, teachers and schools together across Europe and beyond. In this synthesis of studies, the main unit of analysis was the social network and the conditions for its sustainability and scalability.

The issue of scaling up educational innovation is often discussed in the context of school reform and improvement programmes that aim to produce deep, transformative and consequential changes in teachers' beliefs and practices. As a result of these changes, instructional practices will also change, leading to improved education outcomes for students. Coburn (2003), for example, reviews the topic extensively and proposes a conception of scaling up that has four interrelated and interdependent dimensions: *spread*, *depth*, *sustainability* and *shift of ownership*. Clarke and Dede (2009), in their review of existing theoretical/empirical perspectives on the concept of scaling up, propose *evolution* as a fifth dimension.

In this chapter on eTwinning, a long-standing and well-established European teacher network, we have also discussed similar issues. We started by looking at the growth of eTwinning in terms of the number of teachers who register for eTwinning and contrasted this with the number of teachers in a given country. This indicator, called 'eTwinning reach', shows that on average, eTwinning has reached about 4 % of the teacher population within the eligible countries. However, numbers of registered teachers alone have little meaning if we do not know whether new schools are getting involved in the network. Therefore, the concept of horizontal growth (i.e. spread) was introduced as an additional indicator of eTwinning's scalability. This refers to new teachers from schools previously not registered to eTwinning becoming members of the platform and therefore joining the network.

The growth and spread as described above can give some indication of scaling up; however, they should not be taken as indicators of the existence of a teacher network. They should be interpreted as mere indications of interest, or intention, to participate in a teacher network. As outlined in section "Network properties of the eTwinning teacher network", an important element of the definition of a teacher network is that it is created through teachers working together in groups or teams to improve educational processes and outcomes. eTwinning projects, i.e. pedagogical school collaboration projects, offer opportunities for this kind of collaboration. From the SNA studies presented in section "Network properties of the eTwinning teacher network", we know that there are significant community structures created through project collaboration across various countries. As does the study by Coburn (2003), our synthesis of studies shows that most of the teachers who participate in teacher collaboration also experience other dimensions of scaling up such as change in their pedagogical beliefs, norms of social interaction and pedagogical principles.

This kind of change is described as 'depth' by Coburn (2003) who underlines the fact that depth may play an important role in a school's capacity to sustain change over a long period of time. In terms of sustained participation in eTwinning, we know that about 20 % of the registered teachers still use the platform after 4 years of participation.

Another way of creating teacher networks is through a school team. This is what we introduced as 'vertical growth', but it is very similar to Coburn's description of sustaining school reform though the 'presence of a supportive professional community of colleagues in the same school that reinforces normative changes and provides continuing opportunities to learn' (2003, p. 6). With eTwinning school teams, we see evidence that pedagogical innovations are being sustained and spread. As discussed in the chapter by Law et al. (Chap. 10, this volume), scaling up of *ICT-enabled learning innovation* on a systemic level 'is not seen as a one-dimensional process, involving solely the expansion of numbers of schools implementing specific ICT-enabled teaching and learning activities', but is considered 'to be a contextualized process that involves all the challenges of implementing a collective paradigm shift in practices at the system level'. Additionally, in terms of diffusion of innovation, the studies synthesised for this chapter also show that school teams are a great way to involve new people in the process of pedagogical changes locally (i.e. invisible eTwinners, namely, those in schools who participate in project work but do not have a presence on the eTwinning platform). eTwinning school teams also show evidence of how teacher networks increasingly mix both online and offline realms; even though project work across the schools takes place through ICT means, some of the collaboration between teachers happens in a physical location at the school level.

Above we gave two different examples for teacher collaboration creating network structures that can be studied in terms of Social Network Analysis. In these examples, teachers can tap into social capital within the network and have opportunities to derive benefits from this context. The structure of their connections (e.g. if they are situated in the centre in one of the tight-knit teacher clusters or in the intersection of the two as discussed in section "Network properties of the eTwinning teacher network") defines the importance of the network for them, as they can obtain information, expertise and resources from the other members of the network. The above-mentioned large-scale survey by the European Commission shows evidence of this; 74 % of responding eTwinners had been able to improve their personal knowledge, competences and skills, and 58 % said they had developed their teaching skills through reflection and dialogue with other teachers. Moreover, it was shown that around 70 % of the long timers (participation greater than 6 years) had gained 15 % more benefit from their participation in the network than those with 2 years' or less experience (European Commission 2013). Another benefit that they can get from participation in the project collaboration network is the recognition that teachers receive through eTwinning. In 2010, seven eTwinning countries recognised eTwinning project participation formally as part of teachers' CPD, and in 11 additional countries, this was possible 'to some extent'. 49 % of the respondents to the above-mentioned survey said that eTwinning had fulfilled their expectations of improving their professional prospects.

Though there are many similarities between scaling up school reforms and teacher networks, there are also differences, for example, in terms of shifts in ownership. Since participation in teacher networks is voluntary, there is no 'external reform' to be executed. From the beginning, the ownership of eTwinning and project collaboration has been with the teachers; however, it can also be seen as co-ownership between different levels of the top-down hierarchy (i.e. CSS and the local NSS). On the other hand, there is also evidence of transfer of ownership to learners (Wastiau et al. 2011). Another difference, which is also discussed by Clarke and Dede (2009), is related to effective transfer of an innovation to a new context. Since teacher networks are based on partnership and collaboration, this usually makes the partnering school a conducive site for adapting the new innovation.

Another dimension of scaling up school reform is evolution. Clarke and Dede (2009) define it as the following: 'when the adopters of an innovation revise it and adapt it in such a way that it is influential in reshaping the thinking of its designers. This in turn creates a community of practice between adopters and designers whereby the innovation evolves' (p. 354). This is also something that becomes evident through eTwinning project collaboration. For example, the project 'Schoolovision' has been run every year since 2009, and new schools join in, which in turn shape the project for the following years. Similarly, the shaping of the whole eTwinning could also be seen through the concept of evolution. Many of the support structures implemented by the CSS (i.e. designer) are a response to needs from the field by adaptors. A good practice example of such evolution is eTwinning school teams. In the beginning, they started appearing on their own, and only later in 2012–2013 did they become the theme of the annual campaign. Now, eTwinning teams are a permanent feature of eTwinning and a supported long-term activity.

Teacher collaboration through cross-border projects is a way of creating network structures. In eTwinning, we find plenty of evidence of teachers who conduct projects over many consecutive years either with the same partners or with new ones. This is a bottom-up way of sustaining and creating depth to educational innovation that takes place within a teacher network. We call this vertical growth, which is displayed in Fig. 11.9 (left end of x-axis). On the one hand, when a teacher joins an eTwinning project for the first time, they spread the teacher network. The right end of the x-axis shows where horizontal growth has taken place, i.e. new schools have become involved in the network regardless of their project participation.

In Fig. 11.9, we also outline the main strategies that have contributed to the vertical and horizontal growth of the eTwinning network (y-axis). As explained in section "What is eTwinning?", both top-down and bottom-up strategies are operating which are identified with three different layers in Fig. 11.9 (see different shapes). There is the top-down hierarchy of the management level starting with the Steering Committee down to the CSS and NSS (marked in red). They are all working towards both vertical and horizontal network growth and are therefore positioned in the middle of the x-axis. The graph helps us identify that certain issues, such as policies related to geographical spread and funding, are dealt with on a political level through top-down strategies. Other issues, such as CPD activities provided through the platform (e.g. Learning Events, Groups), are organised by the CSS with a view to

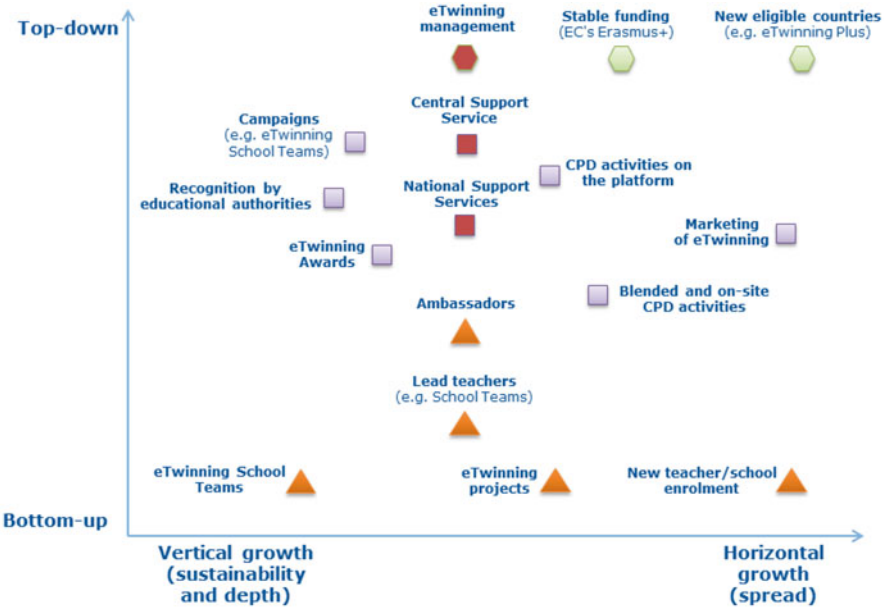

Fig. 11.9 Top-down and bottom-up strategies that contribute to the sustainability and scalability of eTwinning

improving skills and also getting new teachers involved in various forms of teacher collaboration (e.g. projects). The left of the x-axis shows some CSS strategies which are important for both the sustainability and the depth of innovation. eTwinning Awards are a good example at the European level, whereas the NSS also awards national prizes. Other formal recognition mechanisms through national, regional and local education authorities all contribute to keeping teachers engaged in eTwinning.

Figure 11.9 also shows the role played by eTwinning Ambassadors. They are aligned in the middle of the x-axis as they can link new teachers into the network (spread) and also help to deepen pedagogical innovation by introducing new ideas, among other things. 'Lead teachers' have a similar function at their school level. As discussed, they are important for vertical growth and also for getting new teachers involved in eTwinning activities at their local school level. Finally, it's worth keeping in mind that Fig. 11.9 is a simplification of the complex macro-level and micro-level structures that operate within eTwinning; however, it can be useful when examining various actors, structures and their interrelations.

We would like to end with some challenges for the future. As discussed above, there is a need for 'reliable evidence of how, when and why online social networks do, or do not, advance learning' (Schlager et al. 2009) and how individuals can benefit most from this context. Even if the results in "Network properties of eTwinning teacher network" help understand how, when and why social networks advance

learning, there still remain challenges. Though eTwinning can be seen as a social networking tool for teachers with its Web 2.0 features, its power really lies in the deeper connections that are created through teacher collaboration. This collaboration, in practical terms, deepens and sustains pedagogical innovation in teachers' practices in their classrooms and in their interactions with both their students and their peers. Moreover, the fact that eTwinning can retain its users over a long period of time shows evidence of sustained innovation that evolves and is codesigned by its adopters and designers. The support activities provided by the eTwinning platform (e.g. social networking activities, CPD), on the other hand, offer better chances for interaction which can in turn lead to project collaboration.

From a network study perspective, the social network analysis offered on eTwinning is just the beginning and only allows us to scratch the surface. Deeper questions should be asked in the future such as: Do teachers' encounters in teacher networks (such as eTwinning) cause them to rethink and reconstruct their pedagogical beliefs and principles? Do these encounters cause teachers to question underlying assumptions about how students learn, i.e. what constitutes effective instruction? If so, under which conditions does this happen? As shown in the studies analysed for the purpose of this study, it is clear that focusing only on what happens on the eTwinning platform (i.e. section "Network properties of the eTwinning teacher network") gives a limited picture of the network. For this purpose, more attention should be paid to the intersection between online and offline cooperation in future studies. Blended methods on a longitudinal scale that mix social networking analysis with rich case studies, such as the ones on school teams or eTwinning students, could offer more valuable information on how pedagogical practices are diffused and how they are changed in order to improve students' educational experiences.

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References

Berendt, B., Vuorikari, R., Littlejohn, A., & Margaryan, A. (2014). Learning analytics and their application in technology-enhanced professional learning. In A. Littlejohn & A. Margaryan (Eds.), *Technology-enhanced professional learning: Processes, practices and tools* (pp. 144–157). New York: Routledge.

Berlanga, A., Brouns, F., Fetter, S., Rajagopal, K., Sloep, P., Van der Vegt, W., & Vuorikari, R. (2012). *Social capital and peer support in learning networks – Deliverable 3.2 of the Teachers' lifelong learning network project*. Retrieved January 10, 2014, from http://tellnet.eun.org/c/document_library/get_file?p_l_id=10704&folderId=18137&name=DLFE-802.pdf

Breuer, R., Klamma, R., Cao, Y., & Vuorikari, R. (2009). Social network analysis of 45,000 schools: A case study of technology enhanced learning in Europe. In U. Cress, V. Dimitrova, & M. Specht (Eds.), *Learning in the synergy of multiple disciplines* (Vol. 5794, pp. 166–180). Berlin/Heidelberg: Springer.

Burt, R. S. (2001). Structural holes versus network closure as social capital. In N. Lin, K. Cook, & R. S. Burt (Eds.), *Social capital: Theory and research* (Sociology and economics: Controversy and integration series, pp. 31–56). New York: Aldine de Gruyter.

Cachia, R., Punie, Y., & Vuorikari, R. (2012). *Final report on the future of teacher networking. – Deliverable 4.3.2 of the Teachers' lifelong learning network project*. Retrieved January 12, 2014, from http://tellnet.eun.org/c/document_library/get_file?p_l_id=10704&folderId=18137&name=DLFE-817.pdf

Clarke, J., & Dede, C. (2009). Design for scalability: A case study of the river city curriculum. *Journal of Science Education and Technology, 18*(4), 353–365.

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

Coleman, J. S. (1994). *Foundations of social theory*. Cambridge, MA: Harvard University Press.

Crawley, C., Gilleran, A., Scimeca, S., Vuorikari, R., & Wastiau, P. (2009). *Beyond school projects – A report on eTwinning 2008–2009*. Brussels: Central Support Service for eTwinning & European Schoolnet.

Crawley, C., Gerhard, P., Gilleran, A., & Joyce, A. (Eds.). (2010). *eTwinning 2.0 – Building the community for schools in Europe*. Brussels: Central Support Service for eTwinning & European Schoolnet.

Daly, A. J. (2010). *Social network theory and educational change*. Cambridge, MA: Harvard Education Press.

European Commission. (2013). *Study of the impact of eTwinning on participating pupils, teachers and schools*. Luxembourg: Publications Office of the European Union.

European Schoolnet. (2013). Does the type of ICT training teachers pursue matter? *Observatory*, *3*, *Briefing papers.* Retrieved April 4, 2014, from http://files.eun.org/etwinning/bpaper.pdf

Forkosh-Baruch, A., Nachmias, R., & Mioduser, D. (2008). *Innovative pedagogical practices using technology: Cross-case analysis of the SITESm2 data.* Paper presented at the 3rd IEA International Research Conference. Retrieved January 15, 2014, from http://www.iea.nl/fileadmin/user_upload/IRC/IRC_2008/Papers/IRC2008_Forkosh-Baruch_Nachmias_etal.pdf

Gouseti, A. (2013). 'Old Wine in Even Newer Bottles': The uneasy relationship between web 2.0 technologies and European school collaboration. *European Journal of Education, 48*(4), 570–585. doi:10.1111/ejed.12051.

Haythornthwaite, C., & Kendall, L. (2010). Internet and community. *American Behavioral Scientist, 53*(8), 1083–1094.

Holmes, B. (2013). School teachers' continuous professional development in an online learning community: Lessons from a case study of an eTwinning learning event. *European Journal of Education, 48*(1), 97–112. doi:10.1111/ejed.12015.

Kampylis, P., Law, N., Punie, Y., Bocconi, S., Brecko, B., Han, S., Looi, C.-K., & Miyake, N. (2013). *ICT-enabled innovation for learning in Europe and Asia: Exploring conditions for sustainability, scalability and impact at system level*. Retrieved January 05, 2014, from Publications Office of the European Union at http://ipts.jrc.ec.europa.eu/publications/pub.cfm?id=6362

McDonald, B., Noakes, N., Stuckey, B., & Nyrop, S. (2005). *Breaking down learner isolation: How social network analysis informs design and facilitation for online learning*. Montreal: AERA.

Nachmias, R., Mioduser, D., Cohen, A., Tubin, D., & Forkosh-Baruch, A. (2004). Factors involved in the implementation of pedagogical innovations using technology. *Education and Information Technologies, 9*(3), 291–308. doi:10.1023/b:eait.0000042045.12692.49.

OECD. (2009). *Creating effective teaching and learning environments: First results from TALIS*. Retrieved January 10, 2014, from http://www.oecd.org/dataoecd/17/51/43023606.pdf

Penuel, W. R., & Riel, M. (2007). The 'new' science of networks and the challenge of school change. *Phi Delta Kappan, 88*(8), 611–615.

Penuel, W. R., Sussex, W., Korbak, C., & Hoadley, C. (2006). Investigating the potential of using social network analysis in educational evaluation. *American Journal of Evaluation, 27*(4), 437–451. doi:10.1177/1098214006294307.

Pham, M. C., Cao, Y., & Klamma, R. (2012). *Social network analysis methods for lifelong learning communities – Deliverable 2.2 of the Teachers' lifelong learning network project*. Retrieved January 10, 2014, from http://tellnet.eun.org/c/document_library/get_file?p_l_id=10704&folderId=18137&name=DLFE-803.pdf

Rogers, E. M. (2003). *Diffusion of innovations* (5th ed.). New York: Free Press.

Rovai, A. P. (2002). Building sense of community at a distance. *International Review of Research in Open and Distance Learning, 3*(1), 1–16.

Schlager, M. S., Farooq, U., Fusco, J., Schank, P., & Dwyer, N. (2009). Analyzing online teacher networks: Cyber networks require cyber research tools. *Journal of Teacher Education, 60*(1), 86–100. doi:10.1177/0022487108328487.

Sloep, P., & Berlanga, A. (2011). Learning networks, networked learning. *Revista Comunicar, 19*(37), 55–64. doi:10.3916/c37-2011-02-05.

Song, E., Petrushyna, Z., Cao, Y., & Klamma, R. (2011). Learning analytics at large: The lifelong learning network of 160,000 European teachers. In C. Kloos, D. Gillet, R. Crespo García, F. Wild, & M. Wolpers (Eds.), *Towards ubiquitous learning* (Vol. 6964, pp. 398–411). Berlin/Heidelberg: Springer.

Vuorikari, R. (2010). *Teachers' professional development – An overview of current practice* (A. Gilleran, Ch. Crawley, & S. Scimeca, Eds.). Brussels: Central Support Service for eTwinning & European Schoolnet.

Vuorikari, R. (2013). *eTwinning school teams – Case studies on teacher collaboration through eTwinning*. Brussels: Central Support Service for eTwinning & European Schoolnet.

Vuorikari, R., & Scimeca, S. (2013). Social learning analytics to study teachers' large-scale professional networks. *Open and Social Technologies for Networked Learning – IFIP Advances in Information and Communication Technology, 395*, 25–34.

Vuorikari, R., Berlanga, A., Cachia, R., Cao, Y., Fetter, S., Gilleran, A., Klamma, R., Punie, Y., Scimeca, S., Sloep, P., Petrushyna, Z. (2011a). ICT-based school collaboration, teachers' networks and their opportunities for teachers' professional development – A case study on eTwinning. *Advances in Web-Based Learning – ICWL 2011. Lecture Notes in Computer Science* (Vol. 7048, pp. 112–121). Berlin/Heidelberg: Springer-Verlag.

Vuorikari, R., Gilleran, A., & Scimeca, S. (2011b). Growing beyond innovators – ICT-based school collaboration in eTwinning. In C. Kloos, D. Gillet, R. Crespo García, F. Wild, & M. Wolpers (Eds.), *Towards ubiquitous learning* (Vol. 6964, pp. 537–542). Berlin/Heidelberg: Springer.

Vuorikari, R., Garoia, V., Punie, Y., Cachia, R., Redecker, C., Cao, Y., Klamma, R., Pham, M. C., Rajagopal, K., Fetter, S., & Sloep, P. B. (2012). *Teacher networks – Today's and tomorrow's challenges and opportunities for the teaching profession*. Brussels: European Schoolnet.

Wastiau, P., Crawley, C., & Gilleran, A. (Eds.). (2011). *Pupils in eTwinning – Case studies on pupil participation*. Brussels: Central Support Service for eTwinning & European Schoolnet.

Wiske, M. S., & Perkins, D. (2005). Dewey goes digital: Scaling up constructivist pedagogies and the promise of new technologies. In C. Dede, J. Honan, & L. C. Peters (Eds.), *Scaling up success: Lessons learned from technology-based educational improvement* (pp. 27–47). San Francisco: Wiley.

Chapter 12
The Knowledge Building International Project (KBIP): Scaling Up Professional Development Using Collaborative Technology

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Abstract Classroom-based knowledge building requires advanced pedagogies and collaborative technologies. It qualifies as disruptive innovation: progressively more impressive accounts of what students and teachers can accomplish alter beliefs regarding developmental, demographic, and cultural barriers. To establish knowledge-building communities requires effort from within as well as from outside the classroom. The Knowledge Building International Project (KBIP) has been rooted in school-university-government (SUNG) partnerships, along with their locally based networks of innovation. The chapter starts with a conceptualization of professional development in the digital era, and the main constituents of the Remote Networked School (RNS) initiative are presented. Next, a description of the SUNG

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partnerships follows. Emphasis is on agency, as it was observed in the RNS and in the SUNG dynamics of partnerships for classroom-based knowledge building: knowledge building as a shared vision, symmetric knowledge advancement, and multilevel, research-based innovation. Following is a descriptive analysis of the Knowledge Building International Project (KBIP 2007–2014) using Engeström's (1987) third-generation activity theory framework (Engeström and Sannino 2010). Referring to Engeström's expansive learning cycle (1987), further analysis is provided regarding the overcoming of double binds for KBIP expansion as an activity.

Introduction

Today's knowledge societies are raising expectations regarding teachers' work in the classroom. Schools and faculties of education are called upon to prepare teachers, while teacher educators are themselves experimenting and researching with digital tools and their contributions to teaching and learning. Three of the authors of this chapter began responding to this call almost 20 years ago. As educational psychologists studying socio-cognitive and classroom processes, collaborative technologies rapidly caught their attention as means to enhance human interaction for learning purposes. They engaged in the TeleLearning Network of Centres of Excellence (TL-NCE, Canada, 1995–2002) and researched within the strands Educating Educators and K-12 Knowledge Building Environments. Carl Bereiter was active in another TL-NCE strand (Bereiter 2002a).

Laferrière et al. (1998) codesigned a virtual community of support and communication for preservice teachers. The virtual community concept made sense across time and distance, but in brick-and-mortar settings, the notions of network-enabled classrooms/communities, be it at the primary, secondary, or tertiary level, appeared to be more appropriate concepts. Knowledge Forum®, a collaborative digital space of choice to enable classroom-based knowledge building, became the digital platform of choice. Year after year, preservice teachers developed views on what teaching and learning in a network-enabled classroom were like. The embedded search tool allowed successive cohorts to have access to artifacts of previous knowledge builders, and the virtual community concept took on its true meaning.

In 2002, the Quebec government mandated CEFRIO, a knowledge transfer agency with regard to the integration of information technologies in organizations, to create a model to enrich remote rural schools' learning environment. CEFRIO came to us, and we suggested that Knowledge Forum® be part of the Remote Networked School (RNS) model. It was the beginning of a sustained collaboration with colleagues Bereiter and Scardamalia for inclusive knowledge building, that is, aiming to transform schools to operate as knowledge-creating organizations in their own right. Focusing on professional development, this chapter relates how the RNS initiative has evolved over the past decade in terms of codesign and scalability and from local to regional to international pursuits. First, professional development in

the digital era is problematized. Second, school-university-government (SUNG) partnerships, which funded the professional development effort, are presented and analyzed. Third, the Knowledge Building International Project is described using Engeström's activity theory framework. Fourth, we refer to his expansive learning cycle to point to double binds that required agency for sustaining and scaling KBIP.

Professional Development in the Digital Era

Teacher professional development is meant to improve or transform classroom processes in ways that lead to more desirable student outcomes. For instance, the importance of helping students develop deeper understanding in order for them to thrive in the knowledge society has been argued (Bereiter 2002b; Bransford et al. 2000; Drucker 1993; UNESCO 2011). The contribution of collaborative technologies for deeper understanding (Sawyer 2006; Wiske 2005) and knowledge building/knowledge creation has been documented (Bielaczyc and Collins 2006; Seng et al. 2014; Sun et al. 2013).

Collaborative technologies that foster creative undertakings often remain scattered within education systems, and the innovation does not gain enough momentum and credibility for sustainability and scalability. At the low end of the professional development continuum, preservice teachers may hear about it but stay "unimpressed" as this is not what they usually see happening in classrooms. Regarding learning to teach, it is well known that preservice teachers give much credibility to the classroom teachers (cooperative teachers) where they do their early field experiences and student teaching. Wanting to get hired, likely by a local school, they are on a journey that resembles the "legitimate peripheral participation" process identified by Lave and Wenger (1991): aiming at becoming teachers, they observe those practitioners to whom they have access, and learn their ways of doing, and talking about their practice. At the high end of the professional development continuum, teacher educators who provide solid foundations for and describe classroom-based learning environments that are innovative do not have many local exemplars to convince teachers and student teachers whose professional project is to work in a classroom (Le Cornu and Ewing 2008).

As teacher educators and educational researchers, we see the potential of a distributed "critical mass" of teachers engaged in specific innovative practices, namely, knowledge-building pedagogies for an inclusive knowledge society – a society that takes maximum advantage of the new openness of information while at the same time promoting ways for everyone to find a valued and rewarding role (Scardamalia and collaborators 2014). For Rogers (2003), the critical mass is "the point after which further diffusion becomes self-sustaining" (p. 343). For teachers of an education system to adopt a pedagogical innovation and its technology, their working environment may be supportive or not. To understand teaching in context, we draw from the sociocultural perspectives on learning and knowledge building/knowledge creation

for uncovering forces at play at local/regional/national levels (Engeström 1987; Engeström and Sannino 2010; Virkkunen and Shelley Newnham 2013).

The present volume on educational innovations provides close-ups into the Singapore city-state context as a microcosm for better knowledge of scaling dynamics in larger contexts. Moreover, it reaches out to other exemplars from abroad. We are therefore pointing to a few initiatives. In Brazil, for instance, an innovative knowledge-building teacher professional development model takes advantage of the web and ministry educational policies to support 800 teachers in professional development (Nunes 2013). In Ontario (Canada), networks of school principals meet onsite/online, applying knowledge-building principles to their own work and that of teachers. In the United States, networks have proven valuable for educational reforms and sustaining and scaling innovative practices (Lieberman and Grolnick 1996). For example, the National Writing Project (www.nwp.org) is a solid teacher development network helping members deal with real problems, diversity issues, and changing needs of learning communities (Lieberman 2000). NWP fosters collaborative work, especially at a local/regional level, and is increasingly using web-based technologies.

There are successful networks that conduct totally online rather than combined online-onsite activity. One of them is Connected Educators (connectededucators.org), whose mission is to help educators thrive in a connected world. Anchored in the United States 2010 National Educational Technology Plan (NETP) and with the participation of many nationwide partners, it seeks to understand and promote educators learning and collaborating through online communities of practice and social networks. Learning Circles is another. It began in 1987 and circles were meant to be of international scope (Riel 1990, 2004a, 2013). They became part of iEARN in 1994 and are still growing around the world (www.iearn.org/circles/). The Learning Circles community provides teachers with social and technology support, and professional development, for cross-classroom collaboration (Riel 2004b; www.onlinelearningcircles.org). iEARN-Canada is a large and active network (www.iearn-canada.org). In Europe, the eTwinning teacher network is making headways in promoting school collaboration through the use of information and communication technologies (ICT) by providing support, tools, and services for schools (http://www.etwinning.net). The eTwinning network is connected to the European Schoolnet, a partnership modeled upon Canada's SchoolNet. The latter, an initiative of Industry Canada, did not sustain given that education is a provincial responsibility in Canada. The former, under the European Commission's leadership, now counts 30 ministries of education (see the Chap. 11 in this book on eTwinning).

Teacher development initiatives come and go, with policies driven by economic and civic forces. In the digital era, the principle of equity of access takes on new meanings and forms (e.g., online courses, online learning communities and communities of practice such as Math Forum in the United States or Sesamath in France, massive online open courses (MOOCs) which originate from one or a consortium of institutions). The list of teacher development initiatives at the local, regional, or national levels that are entirely or partly supported by the web gets longer almost every day.

Our own work as teacher educators and educational researchers has been situated both locally and in networks of national and international scope. Bereiter/Scardamalia contributions to technology-enhanced learning environments have served as inspiration and driving force as we engaged in onsite/online activity for innovative teacher professional development in the digital era.

The RNS Initiative: An Illustrative Case of Sustainability and Scalability

Quebec is a vast territory, and demographics reflect considerable change in the size and composition of villages due to the natural resources at the basis of their economies. The remote rural schools face many issues: lack of specialized resources for students, multilevel classrooms, small numbers of registered students, and professional isolation. Since 2002, the vision for moving forward has been one of the teachers and students interacting with other teachers and students through collaborative technologies to enrich their professional development and classroom environments. Teachers have been encouraged to connect their class, or a subset of students, with one or more classrooms from their school district and beyond. In 2013–2014, the RNS initiative involves 22 school districts, more than 200 schools, over 400 teachers, and about 6,500 students. Teachers are especially encouraged to engage students in collaborative learning and knowledge building. The combination of Knowledge Forum®, an electronic forum with substantive knowledge-building affordances, for written classroom discourse and Via, a web-based videoconferencing system for verbal exchanges, supports interactivity and systemic change at local, regional/national, and international levels.

Teacher Professional Development with a Focus on Knowledge Building

Over the years, numerous professional development sessions have been offered onsite/online to the RNS teachers regarding technology and pedagogy. Technical support is available onsite/online. The website (www.eer.qc.ca) contains information, including artifacts of the works of emerging knowledge-building communities (KBCs). Skilled resource people are available online for just-in-time help all day long regarding the planning of learning activities, reflection on the progress of specific collaborative activities, and the setting of goals for improving student writing and knowledge-building ability (Hamel et al. 2012). Each year, new teachers join in, and experienced teachers play an increasing role in their induction to being an RNS teacher.

Knowledge building (KB), which aims at engaging students in a collaborative effort directed toward creating and improving ideas (Bereiter and Scardamalia 1993), is distinctive in the RNS. The first KB-related challenge encountered is how to engage students in authentic and open questioning and collective knowledge building anchored in the school curriculum. Ideally, students will contribute ideas in

a form that will allow their emerging knowledge-building community (KBC) to identify problems of understanding, express initial conceptions (theories), gather and critique information from authoritative sources, and formulate explanations, historical accounts, novel problem formulations, and solutions.

Derived from the original 12 principles put forward by Scardamalia (2002), the following five principles inform and guide RNS teachers who engage their classrooms in knowledge building: (1) authentic problems explored through complementarity of ideas, (2) improvement and diversification of ideas through participatory discourse, (3) student empowerment in a democratic climate, (4) reference to reliable sources throughout the inquiry process, and (5) shared and in-context assessment, throughout the process. These principles are the results of seasoned RNS teachers reflecting back collaboratively on their involvement with researchers (Allaire and Lusignan 2011). The active engagement of teachers over an extensive period of time, with a focus on content, pedagogy, and local context, stands out in the literature on professional development (Fishman et al. 2013).

From day one, RNS teachers have been invited to participate in iterative cycles of codesign/implementation/evaluation of the activity of their local Remote Networked School(s). It is a form of professional development in itself (Laferrière and Breuleux 2011c; Voogt et al. 2015), one involving key education partners.

School-University-Government (SUNG) Partnerships for Classroom-Based Knowledge Building

The renewal of local practices and context, with or without the support of collaborative technologies, has to be a collective undertaking; partner agency is essential. In the RNS initiative, vertical agency was first sought: government officers accepted the initial model suggested by researchers; through CEFRIO's mediation, teachers volunteered; through school principal leadership and school district engagement, classrooms in their jurisdiction were connected with those of other teachers. The sustainability of the initiative in a given local context was compromised when agency at the intermediary level was lacking. Partners who shared agency for classroom-based knowledge building as part of the RNS initiative gave credibility to this innovation and helped the RNS innovation to scale. This section of the chapter is devoted to the evolution of the SUNG partnership of the RNS initiative and to other SUNG partnerships' agency that are making KBIP a knowledge-building oriented professional development activity.

The Agency of the RNS Partnership

The notion of "shared transformative agency," which means "breaking away from a given frame of action" (Engeström 1987; Virkkunen 2006, p. 43), reflects the design work of the RNS school-university-government (SUNG) partnership. Each party

exercised leadership and manifested openness to others' practices. Nonetheless, throughout its evolution, tensions arose and had to be resolved. Here are some illustrations.

Top-Down Moves

At its onset, the initiative was entirely top-down: a deputy minister consulted a knowledge transfer agency (CEFRIO) on the use of information and communication technologies as a solution to the challenges of small primary and secondary schools in remote rural areas in Quebec. CEFRIO, which has a mission to promote university-based research in different sectors including education, talked with two of the authors of this chapter to identify key elements of a best model to begin with. Design-based research was a known research methodology for the two researchers (Breuleux et al. 2002). At the technology level, they suggested two collaborative technologies, a multipoint desktop videoconferencing system (iVisit) and Knowledge Forum®. This was received as a top-down decision by local technical support teams. At the pedagogical level, knowledge building was what Knowledge Forum® best afforded, but it involved new ways of thinking and doing for practitioners. Nonetheless, the university-based researchers remained firm on the technology to be used for collaborative purposes between classrooms. They were well aware of the paucity of convincing student learning outcomes, beyond technology literacy, of many ICT integration initiatives. They knew that for the model to become sustainable and scalable, student achievement would be key. Moreover, CEFRIO demanded the formation, within each school district, of a monitoring committee, inclusive of representatives of all involved local partners, and presented the RNS initiative as being an action research. For university-based researchers, a design research process (Collins et al. 2004) had begun.

Bottom-Up Moves

Collaborative design occurred onsite/online and involved local participants (teachers, school principals, and school district personnel) meeting at the school/school district or online with a member of the university-based research and intervention team. After initial onsite launching of the RNS initiative, the research-intervention team has been providing constant online support by keeping open all day a room of the videoconferencing system that someone from any of the schools/school districts could access. After each online conversation, the research-intervention team member, usually a graduate student or a research professional, filled a form that summarized the content of the exchange. Another research-intervention team member could refer to it (1) when following up online with the same person and (2) when describing and/or analyzing the online support activity. Early in the year, technology-focused exchanges dominated. They helped establish a human connection, and pedagogy-focused conversations came next. Local counselors and

teachers developed at first simple plans regarding collaborative activities, ones privileging the videoconferencing system, and the research-intervention team was supportive: team teaching according to teachers' expertise or students' needs, teamwork between students from different remote classrooms, and interclass *exposés*. Some teachers preferred to engage students' work on Knowledge Forum® within their own classroom rather than between classrooms, and the research-intervention team supported the implementation process. Adaptation to local dynamics was a must, but research iteration results became the lever.

Basic analytics, adapted to each role within a school district, were provided regarding the use of the two collaborative technologies. What the school superintendent needed to know for his/her own decision-making regarding the RNS was different from what could help an RNS school team or an RNS teacher. The Knowledge Forum® analytic tools' results also provided helpful information to research-intervention team members for interacting online with participants (codesign of activities). Meanwhile, scaffolding volunteer teachers toward classroom-based knowledge building was on the research-intervention team's agenda. Innovation builds on innovation was the saying of a McGill's colleague. Therefore, local practitioners made self-determined "boundary-spanning" moves (Laferrière and Allaire 2010), and the research-intervention team kept aiming at mutual rather than local adaptation.

Engeström (2011) points that design research is more hierarchical than formative intervention – the participative approach he is suggesting for innovation purposes in a given context. He argues that design research is still captive of the linear view of interventions typical of the "gold standard" that "starts from the assumption that researchers know what they want to implement, how they want to change the educational practice. In other words, the intervention and its desired outcomes are well defined in advance. The task of research is to check whether or not the desired outcomes are actually achieved" (p. 599). For him, resistance and agency of learners are a source of surprise and novelty that cannot be ignored. We agree in theory, but argue that the sustainability and scaling of the RNS have been requiring both top-down and bottom-up moves, as is the case with much design research.

Attention to the Evolution of Roles Through Tension Reduction Between Activity Systems

When the RNS initiative entered its second phase (2004–2006) and began going to scale (13 school districts instead of 3 and 58 schools instead of 8), we engaged in analyzing top-down and bottom-up moves with reference to Engeström's activity theory framework. Role expansion (teacher, school team, monitoring committee, research-intervention team) was noticeable and indicative that the RNS as an innovation could become sustainable (Allaire et al. 2006): the teachers engaging students in knowledge building (emerging KBCs) had more intensive pedagogical discussions with research-intervention team members; school teams were taking action following iterative research results; and school district-based monitoring committees were in place. During the third phase (2006–2008), the number of

Table 12.1 RNS participants (2002–2014)

Participants	Phase 1 (2002–2004)	Phase 2 (2004–2006)	Phase 3 (2006–2008)	Phase 4 (2008–2010)	Phase 5 (2010–2012)	Phase 6 (2013–2014)
School district	3	13	22	23	23	22
Schools	8	58	116	149	122	207
Teachers	12	118	206	211	295	508
Students	300	1,500	2,500	3,000	3,800	6,500

school districts almost doubled, and the Ministry of Education did not encourage further scaling because of its available budget for each participating school district. Over 200 volunteered teachers engaged in the codesign of online activities using one or both of two collaborative technologies. During this and subsequent phases (2008–2010, 2010–2012), researchers analyzed practices at the activity, action, and operation levels in parallel; the process resembled that of Engeström's Development Work Research (DWR); the approach was collaborative, and local tensions reflective of contradictions within and between activity systems were identified and worked on iteration after iteration (Laferrière et al. 2008). Role expansion continued and emerging new rules and policies were established at all levels (Allaire and Lusignan 2011; Hamel 2011).

The RNS is now in its sixth phase research, and scaling is back on the Ministry of Education's agenda as illustrated in Table 12.1.

There are tensions that endure (Laferrière et al. 2012c). For instance, at the national level, the government keeps authorizing the RNS budget on a yearly basis, and this creates uncertainties at the school district level and tensions with school principals and teachers wanting to plan ahead; competition rather than collaboration remains between some small schools; IT personnel keep wanting to introduce new collaborative technologies (Laferrière et al. 2012b, 2013); and negotiation between research-intervention team's and RNS teachers' expectations continues to create tensions as regards knowledge building (KB). These tensions may also be seen as creative tensions, especially the last one. Without contest, the RNS partnership has created opportunities for introducing teachers and students to knowledge building: onsite/online codesign for the emergence of KBCs; financial support for experienced teachers to attend the Knowledge Building Summer Institute in Toronto (Canada), Mallorca (Spain), or Puebla (Mexico); administrative support for some students to attend the Toronto one; and planning for their participation in the 2014 summer institute to be held in Quebec City (Canada).

The Agency of the SUNG Partnerships for Knowledge Building

For knowledge building to become part of a student's experience in the classroom, university-school partnerships had been established for over 20 years. School-university-government partnerships, to which we give the acronym of SUNG in this

chapter, came next. The key role of the International Office of the Catalunya government (Spain) and the Quebec government was documented (Laferrière et al. 2010). Chan (2011) described the interrelated roles of the Hong Kong government (macro-context policies), the Knowledge Building Teacher Network (KBTN, meso-context initiative), and knowledge-building classroom innovations for change in the Hong Kong education system.

"Shared transformative agency" is manifest when the dynamics of partnerships (for classroom-based knowledge building) develop in parallel and interact laterally. Three components of such dynamics were identified: knowledge building as a shared vision, symmetric knowledge advancement, and multilevel, research-based innovation (Laferrière et al. 2010). University-based researchers exercised agency when introducing knowledge building at home or abroad. Hong Kong's and Catalunya's national concerns with thriving in the knowledge society and Quebec's demographic changes provided grounds for government public servants to exercise agency (education reform, research program) and envision knowledge building as classroom innovation. In the three SUNGs, all supported by governmental funding, symmetric knowledge advancement took the form of ongoing sharing of expertise within and among university-based teacher educators/researchers and school-based teachers for installing classroom-based knowledge building. Students' written behavior as budding knowledge builders was monitored and analyzed, and research results informed decision-making in the classroom and beyond.

Nonetheless, researchers had a sense of the fragility of the knowledge-building initiatives put in place. Were they adaptable or adaptive enough for knowledge building to become a sustainable and scalable innovation? The assumption is that agency was to be exercised at all levels of an educational system and events simultaneously and dynamically linked for change to be sustainable (Laferrière et al. 2012a). Would an international network be a good idea, thus creating new opportunities for teachers to exercise agency within and beyond their local context and giving visibility to their doings? During the 2007 Knowledge Building Summer Institute, held in Toronto by the Institute for Knowledge Innovation and Technology (IKIT), a teacher-researcher meeting was set to explore the need state regarding professional development through codesign with international partners. This was the beginning of KBIP – an activity distinct from the international influence the Dr. Eric Jackman Institute of Child Study (EJICS) was exercising with its leading-edge practice of classroom-based knowledge building.

Before engaging in the description of the KBIP activity, we present a fourth SUNG, one that reflects the growing attention of governments to the needs of society to address challenges of an inclusive knowledge society through multilevel partnerships. For example, the Literacy and Numeracy Secretariat, Ontario Ministry of Education, Canada, is partnering with the Institute for Knowledge Innovation and Technology, a center at the Ontario Institute for Studies in Education, University of Toronto, and an international virtual institute, and with the Provincial Principals' Associations (ADFO, Association des directions et directions adjointes des écoles

Franco-Ontariennes; CPCO, Catholic Principals' Council | Ontario; and OPC, Ontario Principals' Council). These partners are supporting school teams of principals, teachers, and school board senior staff, all committed to advancing knowledge building as a pedagogical framework. As well, the Leading Student Achievement (LSA) project, led by ADFO, CPCO, and OPC and in partnership with and funded by the Student Achievement Division of the Ontario Ministry of Education and supported by Curriculum Services Canada, is advancing the work by supporting multiple school boards engaged in research initiatives and production of case studies. The Provincial Principals' Associations have formulated an LSA Theory of Action (Leithwood 2014) that includes a knowledge-building component, along with professional development supported through school principals.

In all four SUNGs, funding has been provided through the combination of research grants and contracts with ministries of education, including in some cases subsidies to schools and school districts, especially for technology purchase and release time for teachers. The convergence of professional development and collaborative research is not that well spread in Canada and neither in the United States, though the Holmes Group (1990) promoted it through its professional development school strategy and later the National Council for Accreditation of Teacher Education (NCATE 2001).

In the next section, we present KPIP from the perspective of the third generation of activity theory on innovation (Engeström 1987; Engeström and Sannino 2010). According to Engeström (1999), the first generation of Cultural Historical Activity Theory (CHAT) centered on Vygotsky's (1978) concept of mediation for describing an activity system: cultural artifacts and human actions were linked in an attempt to resolve the individual/social dualism. Engeström points that the limit of this first generation of activity theory was that the individual remained the focus of analysis. The second generation was the result of Leontev's distinction between individual action and collective activity through an analysis of the evolving division of labor within communities. He offered a hierarchical view of the structure of an activity system: the developing object of an activity is related to the motive that drives it (object-oriented activity); an activity system produces actions that are driven by conscious goals (goal-directed actions); actions include automatic operations driven by prevailing conditions and tools. Thus, Leontev expanded Vygotsky's original triangle (subject(s), meditating artifact/tool, and object) by linking the individual to his/her community and arguing that this new gestalt was to be considered as the unit of analysis for studying activity systems (Daniels, Yamagata-Lynch 2010). Engeström offered a graphical representation of a collective activity system and related analytical tools (1987). This modeling effort of the complex interactions of the constituents of an activity system was the beginning of the third generation of activity theory, which stimulated the study of the coevolution of individuals and groups in a given environmental context and how they interact with one another. We will now apply this perspective to KBIP as a knowledge-building professional development activity.

The Knowledge Building International Project

The activity's object/motive of the new network/community was to create a socio-technological environment for the codesign of classroom-based knowledge building. The actions of the SUNGs aimed at moving their local networks beyond context-based practices while providing professional development to newcomers. For instance, school personnel and ministry officers offered guidance and encouragement regarding curricular requirements, and university-based teacher educators/researchers conducted onsite and online professional development workshops. At the operational level, partners set conditions for connecting classroom students from different sites and engaging them in knowledge building on problems of international importance.

The 2007–2009 Period

Originally, KBIP was organized like a web-extended academic conference, with onsite/online work throughout the year. The conference theme, climate change and sustainability-related themes, was chosen because it was of international concern and broad enough for emerging classroom-based knowledge-building communities (KBCs) to identify questions/problems of interest that would have some resonance with their school curriculum. Emerging KBCs were to work on their local Knowledge Forum® platform and later present/discuss their work using a web-based videoconferencing system (VIA, built in Quebec City using Adobe/Macromedia Flash). Two three-day online conferences were set, one at the end of November and the other at the end of April. English was chosen as the primary language to communicate across countries, and local participants, including researchers and bilingual students, were to help with translation.

In fact, online conference schedules were extended to accommodate over 20 different web-based videoconferences held among participants on different time zones (Table 12.2).

Coordination meetings occurred in October, during which volunteer teachers looked for matching their class with another of the same age group or studying the same subject matter. Ideally, matched classes were to enter one another's Knowledge Forum database and make contributions before a synchronous online conference

Table 12.2 KBIP participants who engaged in online interaction (2007–2009)

Sites	Students	Teachers	School principals	Ministry personnel	Graduate students	University researchers
Catalunya	500	20	11	3	1	2
Hong Kong	300	12	2	1	4	3
Quebec	300	18	4	1	4	3

was to happen. Students wrote hundreds of contributions on Knowledge Forum. During an online conference, emerging KBCs were to present their knowledge-building work, ask questions, and point to further inquiry. Minimally, one class was to hear what an emerging KBC would present. The schedule of each online conference needed adjustments until almost the last minute to resolve time conflicts or Internet connection problems. Some videoconferences turned out to be more social than knowledge-building events, and participating students were mainly from elementary schools.

One example of a genuine question asked by Quebec students from a remote school regarded the fact that wind turbines kill some birds. For students from a remote area and, therefore, not used to tall glass buildings or too many telephone lines that are known to kill many more birds than wind turbines, the question was a disturbing one, but it was not so for students from Barcelona. Another example of a challenge to intercultural understanding bound to geographical context was Barcelonian students' interest in the sustainability of cities as compared to Quebec students' interests in the sustainability of natural resources such as water and forest. However, along with Hong Kong students and giving one another space to lead a collaborative inquiry, they collected local data and shared their KBC's understandings. For instance, environmental effects on the water quality of a specific pond were investigated after another emerging KBC had inquired into the pH level in the water of the St. Lawrence River and its effect on the biodiversity level in the area. They understood that the water pH level had some effect on the quantity of fish on the south shore of the St Lawrence River (Quebec) than on the north shore. Two other KBCs agreed that animals' proximity to water was causing red tide in South Asia and too many blue-green algae in Quebec. The accumulations of planktonic organisms as they relate to red tide are still open questions for researchers. Another KBC came to the understanding that they had to speak with their parents as the latter did not know much about climate change as a problem and that they needed to be pushed into action. This was a rise-above contribution by one student that evidenced that students were thinking that they had collective knowledge of climate change that their parents did not have.

Could new roles develop and new knowledge-building routines develop in the KBIP socio-technological environment for the codesign of classroom-based knowledge building (new activity system) in spite of differences in language, culture, and time zone? There was acknowledgment that KBIP was acting as a boundary object, that is, an object that creates an interface between communities/networks. Researchers as well as teachers and students went beyond the limits of their individual contexts. Working primarily online across locally based communities and networks, they became boundary spanners. Up to then, there had been rare instances of attempting classroom-based knowledge building across KBCs. Becoming knowledge builders, be they school students, teachers, or graduate students, engaged in co-planning, tutoring, coordination, translation, and modeling roles of greater proportions than ever. Researchers and their close collaborators (graduate students, seconded teachers) were quite active in helping set up, analyzing Knowledge Forum databases, and organizing videoconferences. In the early months of 2009,

the Catalunyan teachers took on the initiative of codesigning the Tomorrow's Innovators (TI) program, a highlight of the Knowledge Building Summer Institute's program that was held that year in Mallorca, Spain (Laferrière et al. 2012a). The TI program was entitled Sustainable Development and the Drach and Campanet caves.

The 2009–2014 Period

KBTN teachers conducted mini-Tomorrow's Innovators (mini-TIs) programs in which students from one site traveled to the other to conduct joint fieldwork and exploration that build on their earlier online knowledge-building work. In 2009–2010, two mini-TI programs joined Hong Kong with Singapore schools and Hong Kong with Barcelona schools. Some KBIP teachers and students join the Tomorrow's Innovators strand during the annual Knowledge Building Summer Institute. Quebec teachers present at the knowledge transfer session held each October, and at times incoming KBIP teachers from other regions in Canada or abroad participated in these events. In less visible ways, teachers also express agency when they introduce knowledge building to a class, prompt students to improve ideas, organize a videoconference to plan with another teacher, or join a videoconference with their class when an emerging KBC present on a specific inquiry.

Central to KBIP is the understanding of the knowledge-building principles (Scardamalia and Bereiter 2003). Onsite and online conversations with teachers have dealt with the KB principles, thus stimulating teachers' thinking and doing for transforming a classroom into an emerging KBC. There has been a strong desire among participants to know how other teachers operate – with knowledge-building moments on pedagogy for knowledge building. Unlike learning, Scardamalia and Bereiter (2003) suggested that knowledge building is an intentional enterprise involving collective responsibility for knowledge advancement. In the RNS, for instance, it is collective knowledge that the three principles around which pedagogy centers in the early stages of engaging students in knowledge building are real problem, diversity of ideas, and authoritative sources. KBIP teacher educators/researchers know that teachers' epistemic agency is critical for engaging students in collaborative inquiry and knowledge building on climate change and sustainability-related themes. While satisfying their respective mandatory curriculum requirements, they codesign in boundary-spanning ways – see http://kbip.co.

The KBIP Activity as a Whole

Aiming at students experiencing the role of being knowledge builders, KBIP teachers, inspired by the knowledge-building principles with the support of local network members, engage students in productive interaction and collaboration across institutions and across countries. Teachers and students are central, and other participants of their local networks/partnerships are instrumental (Table 12.3).

Table 12.3 KBIP participants who engaged in online interaction (2007–2014)

Sites	Students	Teachers	School principals	Ministry personnel	Graduate students	University researchers
9 with 50 or more students	4,145	183	73	3	8	16

At the operational level, they use the same platform for written classroom discourse (Knowledge Forum) and discourse analysis (Knowledge Forum measurement applets) and the same videoconferencing system (VIA). At the action level, teachers bring to KBIP a whole ecology of practices. Data analysis shows a greater diversity of practices than many curriculum innovation initiatives focused around specific pedagogical designs. Therefore, KBIP goes beyond coevolution in practices and policies at school and system levels that are conducive to sustainability and institutionalization of change (Laferrière et al. 2012a). During classroom-based knowledge building, teachers and students exercise unusual roles (e.g., teachers codesign and jointly implement a collaborative inquiry engaging two or more classrooms; students explain local data to an online audience). Self-organization is apparent (e.g., over 4,000 students have written on Knowledge Forum; teachers take the initiative of videoconferencing with another teacher; emerging KBCs present their work on Knowledge Forum during a videoconference, including at times their next steps regarding a collaborative inquiry; emerging KBCs decide online on a next question to focus on). At the activity level, there is continual coordination for KBIP to exist as a socio-technological environment. The activity as a whole is subject to contingencies (e.g., administrative or research priorities, movements in school personnel).

Shifting the Locus of Agency for Sustainability and Scalability

For 7 years, KBIP has contributed to introduce classroom-based knowledge building to teachers and students. As an authentic and real socio-technological environment, it has provided a SUNG (a network, a community) that puts knowledge building at the center for teacher professional development and classroom-based collaboration within and across countries. It is an innovation steered toward a fascinating destination, one with some exchange value for an inclusive knowledge society. As any social innovation affords, the expansion of KBIP as an activity provides learning opportunities for its agents. In Engeström's terms (1987), it is a basic unit of expansive learning. In this section, we refer to the cycle of expansive learning – for further analysis that points to encountered double binds and agents' learning actions.

In his conceptual framework (1987), Engeström presents the cycle of activity expansion as corresponding to the phase structure of the zone of proximal development (ZPD) – "the teacher working his way 'from the inside' of the activity to be developed." Applied to KBIP, the first phase, teachers' need state, was to know how

other teachers operated. Knowledge building was not the primary ICT-supported innovation activity for these teachers; thus, their emerging KB activity was creating an inner or primary contradiction in their teaching activity (initial *double bind*). Participation in the KBIP activity "aggravated" this initial double bind, and as the activity expanded to its second phase, teacher educators/researchers faced a *double bind* of their own (secondary contradiction): conversations regarding the knowledge-building principles were restricting teachers' agency, and lack of emphasis on the knowledge-building principles was permitting KBIP practices lighter in substance or peripheral to the local curriculum.

The contradiction and its manifest tensions were addressed by the SUNGs (local networks/communities), with the exception of a few isolated teachers who came to KBIP on their own. Transitional actions, defined by Sannino (2008) as actions shifting sideways – i.e., across the boundaries between dominant and nondominant activities – were taken. For instance, it is considered acceptable, though disappointing for more advanced knowledge builders, for an emerging KBC to participate in a KBIP videoconference without their powerpoint presentation referring substantively to their current work on Knowledge Forum. It is also acceptable for an emerging KBC not to have entered one's KBC's KF database and be active in it (notes read and build-ons). It has been the main source of tension between partner classrooms.

The constructed models to move out of the double bind fitted local dynamics and manifested ownership of the innovation, a condition often mentioned in the literature on sustainability and scalability: for instance, shifting to a central KBIP server was a model meant to reduce time issues encountered by emerging partner KBCs when wanting to access one another's KF servers, but it has generated another double bind, that of crowding the database to the point that the Catalunya network "cannot stand it anymore" given the local actions they want to take in analyzing the written discourse of their emerging KBCs. Meanwhile, in Toronto, a new KF software is in the works.

Regarding the knowledge-building principles, two local networks adopted modified ones for making them more accessible to teachers and students. The Hong Kong network had already formulated the four following principles: working at the cutting edge, collaborative effort, progressive problem solving, and identifying high points (van Aalst and Chan 2007). The RNS in Quebec reformulated the KB principles as follows: collaboration and complementarity of work on real ideas and authentic problems; participation for the improvement and diversification of ideas; gradual empowerment of students in a democratic spirit; shared assessment in context, throughout the process; and consideration of any reliable sources throughout the process of collaborative inquiry. In each case, these transitional actions were meant to tap into teachers' agency by scaffolding their actions toward transforming their networked classes into knowledge-building communities. This intervention on the part of researchers refers back to Vygotsky's notion of double stimulation which is applied when expansive learning is the object of the activity. It means that a demanding task (first stimulus) and an external artifact (second stimulus) are both put in front of an individual or a group. The second stimulus is there to suggest meaning to the situation that the agents are in. The reduced sets of principles, which helped teachers and students move forward, were two successful models applied by

researchers for moving beyond the double bind (secondary contradiction) identified. Some teachers also used double stimulation with their students when they would shorten the KB principles and post them around the classroom in an artful manner.

Codesign has been the process (Laferrière and Breuleux 2011; Laferrière et al. 2011b; Voogt et al. 2015). Considered as improvable ideas, most models progressed, from year to year, toward classroom-based knowledge building. They introduced different pedagogical perspectives on knowledge building, and they continue to do so as agents voiced their understanding of the forms knowledge building may take in their local contexts and at the KBIP level. As a classroom- and school-based innovation, knowledge building requires a principled rather than a procedural approach to teaching (Zhang et al. 2011). It is an activity that consolidates through diversification, as Engeström would describe it (2006, pp. 9–10).

There were also other signs of tension (secondary contradiction) that involved local KBIP agents and their IT personnel and allies. Local networks'/partnerships' double bind was to stick with Knowledge Forum and its community and do with less local technical support or to adopt locally promoted collaborative technologies and reduce activity or abandon a collaborative platform showing evidence of students' gains. Agents negotiated locally and sometimes requested information from members of the KBIP community. Solutions differed, including moving all students' knowledge-building databases on a central server. This model (solution), pointed earlier as a solution to another tension, also simplified connections between emerging KBCs' written discourse and software updates. However, it has been a form of generalization that irritated local agents who felt a loss of control regarding the organization of their database (tertiary contradiction). The double bind that KBIP coordination agents have faced can be formulated as follows: to sustain and scale classroom-based knowledge building on a single server and loose local opportunities for knowledge building to "co-exist and interact within a local network of activities" (Engeström 1987) or turn KBIP into a hub that delivers tools and best practices to local networks/partnerships and loose codesign opportunities.

This is the phase KBIP is in as a professional development activity. Its agents want classroom-based knowledge building to unfold, sustain, and scale, and codesign is the preferred process, one that must take place at the local level and become a systemic innovation (Turcotte et al. 2009; Looi et al. 2011). It is not desirable to turn this complex innovation into a set of clear, simple, and interconnected tasks; this would be against the concept of agency itself by limiting proactive thinking and behaving and diminishing the creative power of teachers and students as agents. And it would be against principled practical knowledge (PPK), a new type of knowledge put forward by Bereiter (2014), and defined as "explanatorily coherent practical knowledge" (p. 5).

Moreover, it is not enough for KBIP to rally the agency of local innovators. Non-innovators are also agents having a role to play. KBIP agents manifest a disposition, a commitment toward continual idea improvement that makes them respectful of others' ways of thinking while developing collective knowledge. It is an innovation characteristic that has been also identified by Hartnell-Young (2009), and it illustrates Coburn's (2003) notion of a "shift in reform ownership."

The last phase of Engeström's whole cycle of activity generation (or expansive learning) is consolidation, one requiring, besides diversification, the resolution of quaternary contradictions resulting from the interaction between classroom-based knowledge building (the central activity) and its neighboring activities. Among such activities, there is collaborative research conducted by SUNGs. KBIP university-based researchers have pulled their own local innovation-oriented resources for making this innovation exist. They have had to face the following double bind: to seek long-term funding for staying with a SUNG dedicated to classroom-based knowledge building and miss opportunities for contributions to other questions of interest or move to new research and loose the capacity for collaborative research built with a particular SUNG. In the human and social sciences, the logic applied by research grant programs is often a short-term one, thus impairing continuous improvement of an innovation. Penuel et al. (2011) present a strong rationale for Design-Based Implementation Research. DBIR is aimed at transforming the dominant relationship between educational research and practice and emphasizes partnerships while also mentioning codesign and scaling as practices this approach may support (Fishman et al. 2013).

Back to Engeström' cycle of expansive activity, agents' learning actions at the consolidation phase extend to other activity systems related to their own activity system. For instance, whereas most KBIP activities are conducted in English, there are hispanophone and francophone subsets of emerging KBCs that conduct activities in their first language (Comconeixer and RIFCO, which stands for Réseau international francophone de coélaboration de connaissances). This is also saying that all agents have to learn something for the activity to expand and meet its co-constituted object outcome – in KBIP's case, a socio-technological environment for the codesign of classroom-based knowledge building. The KBIP activity system is not a closed system. On one side, it is serving well the RNS activity systems, and on the other side, it is interacting with the *Knowledge Society Network*, hosted by the Institute for Knowledge Innovation and Technology (http://ikit.org/ksn.html), and Knowledge Building International, a new association (http://ikit.org/kbi/knowledge-building). For overcoming the financing double bind mentioned a few lines above, the model currently explored under Marlene Scardamalia and Carl Bereiter's leadership is called Building Cultural Capacity for Innovation (BCCI). It combines grant partnership research funding at the coordination level with funding from local partners interested in moving schools beyond their primary activity as knowledge-telling organizations.

Conclusion

Collaborative technologies used in KBIP are put to the service of helping schools develop a capacity for operating as knowledge-creating organizations for an inclusive knowledge society. This requires innovative professional development. KBIP exemplifies a systemic and ecological approach to professional development at both

local and international levels. New trends or events such as social leaders' advocacy for twenty-first-century competencies, UNESCO's publication of its ICT competency framework for teachers, or OECD's inclusion of collaborative problem-solving assessment in the PISA add momentum.

In KBIP, scaling occurs through cross-fertilization, visibility of the local innovation in an increasingly socially recognized format (web conferences), and attention to newcomers who have no local colleagues with whom to share and advance their pedagogical vision.

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References

Allaire, S., & Lusignan, G. (2011). *Enseigner et apprendre en réseau: collaborer entre écoles distantes à l'aide des TIC*. Anjou/Montréal: Éditions CEC.

Allaire, S., Beaudoin, J., Breuleux, A., Hamel, C., Inchauspé, P., Laferrière, T., & Turcotte, S. (2006). *L'école éloignée en réseau: Rapport de recherche, phase II*. Québec: CEFRIO. Retrieved February 2014, from http://www.eer.qc.ca/publications.php

Bereiter, C. (Ed.). (2002a). Learning technology innovation in Canada. TeleLearning-NCE Special Issue of the *Journal of Distance Education, 17*(3).

Bereiter, C. (2002b). *Education and mind in the knowledge age*. Mahwah: Lawrence Erlbaum Associates Publishers.

Bereiter, C. (2014). Principled practical knowledge: Not a bridge but a ladder. *The Journal of the Learning Sciences, 23*(1), 4–17.

Bereiter, C., & Scardamalia, M. (1993). *Surpassing ourselves: An inquiry into the nature and implications of expertise*. Chicago/La Salle: Open Court.

Bielaczyc, K., & Collins, A. (2006). Technology as a catalyst for fostering knowledge-creating communities. In A. M. O'Donnell, C. E. Hmelo-Silver, & G. Erkens (Eds.), *Collaborative learning, reasoning, and technology* (pp. 37–60). Mahwah: Lawrence Erlbaum Associates.

Bransford, J. D., Brown, A. L., & Cocking, R. R. (Eds.). (2000). *How people learn: Brain, mind, experience, and school: Expanded edition*. Washington, DC: National Academy Press.

Breuleux, A., Erickson, G., Laferrière, T., & Lamon, M. (2002). Devis sociotechniques pour l'établissement de communautés d'apprentissage en réseau: Principes de conception et conditions de réussite résultant de plusieurs cycles d'intégration pédagogique des TIC/Building networked learning communities: Design principles and the conditions for successful pedagogical integration of ICTs in teacher education. *Revue des sciences de l'éducation, 28*(2), 411–434.

Chan, C. K. K. (2011). Bridging research and practice: Implementing and sustaining knowledge building in Hong Kong classrooms. *International Journal of Computer-Supported Collaborative Learning, 6*, 147–186. doi:10.1007/s11412-011-9121-0.

Coburn, C. (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.

Drucker, P. F. (1993). *Postcapitalist society*. New York: HerperCollins Publishers.

Engeström, Y. (1987). *Learning by expanding: An activity-theoretical approach to developmental research*. Helsinki: Orienta-Konsultit.

Engeström, Y. (1999). Innovative learning in work teams: Analysing cycles of knowledge creation in practice. In Y. Engeström, R. Miettinen, & R. Punamäki (Eds.), *Perspectives on activity theory* (pp. 377–406). Cambridge: Cambridge University Press.

Engeström, Y. (2006). *Interactive expertise studies in distributed working intelligence.* Helsinki: University of Helsinki, Department of Education, 1992 ISBN 951-45-6146-5. Retrieved February 2014, from https://helda.helsinki.fi/bitstream/handle/10224/3666/engestrom1-105.pdf?sequence=2

Engeström, Y. (2011). From design experiments to formative interventions. *Theory and Psychology, 21*(5), 598–628.

Engeström, Y., & Sannino, A. (2010). Studies of expansive learning: Foundations, findings and future challenges. *Educational Research Review, 5*(1), 1–24.

Fishman, B., Penuel, W. R., Allen, A., Cheng, B. H., & Sabelli, N. (2013). *Design-based implementation research: An emerging model for transforming the relationship of research and practice.* New York: Teachers College Press. http://nsse-chicago.org/Chapter.asp?uid=3062. Accessed 27 Aug 2013.

Hamel, C. (2011). *Prise de décisions individuelles et partagées des intervenants participant à l'École éloignée en réseau en matière d'innovation technologique, organisationnelle et sociale en région*. Doctoral dissertation, Université Laval, Québec.

Hamel, C., Allaire, S., & Turcotte, S. (2012). Just-in-time online professional development activities for an innovation in small rural schools. *Canadian Journal of Learning and Technology/La revue canadienne de l'apprentissage et de la technologie*, *38*(3). http://www.cjlt.ca/index.php/cjlt/article/view/641. Accessed 17 Feb 2014.

Hamel, C., Laferrière, T., Turcotte, S., & Allaire, S. (2013). Un regard rétrospectif sur le développement professionnel des enseignants dans le modèle de l'École éloignée en réseau. *Science et Technologies de l'Information et de la Communication pour l'Éducation et la Formation, 20*, Available: http://sticef.univ-lemans.fr/num/vol2013/20-hamel-cren/sticef_2013_NS_hamel_20.htm

Hartnell-Young, E. (2009). Learning for teaching: Building professional knowledge on a national scale. *Canadian Journal of Learning and Technology, 35*(1). Retrieved February 2014, from http://www.cjlt.ca/index.php/cjlt/article/view/516/246

Holmes Group. (1990). *Tomorrow's schools: Principles for the design of professional development schools*. East Lansing: Holmes Group.

Laferrière, T., & Allaire, S. (2010). Développement professionnel d'enseignantes et d'enseignants: les passeurs de frontière qui façonnent l'École éloignée en réseau. *Éducation et formation*, *e293*, mai, 102–120.

Laferrière, T., & Breuleux, A. (2011). Collaborative design (CODE) as a teacher professional development model in francophone and anglophone Quebec. In H. Spada, G. Stahl, N. Miyake, & N. Law (Eds.), *CSCL 2011: Computer-supported collaborative learning. Connecting research to policy and practice. Conference proceedings* (Vol. 3, pp. 1178–1181). International Society of the Learning Sciences & Center for Information Technology in Education, University of Hong Kong.

Laferrière, T., Breuleux, A., & Bracewell, R. (1998). TACT: The knowledge-building web of a TeleLearning community of support and communication for professional development. In *Worldwide network of learning: Opportunities, challenges, and contrasts. The fifteenth international conference on technology and education proceedings* (pp. 424–426). Sante Fe, New Mexico: International Conferences on Technology and Education.

Laferrière, T., Allaire, S., Breuleux, A., Hamel, C., Turcotte, S., Gaudreault-Perron, J., Inchauspé, P., & Beaudoin, J. (2008). *L'école éloignée en réseau: L'apprentissage des élèves: Rapport de recherche, phase III*. Québec: CEFRIO. Available: http://www.eer.qc.ca/doc/2009/EER_rapport-synthese_phase-3.pdf

Laferrière, T., Montane, M., Gros, B., Alvarez, I., Bernaus, M., et al. (2010). Partnerships for knowledge building: An emerging model. Second special edition on knowledge building, edited by M. Scardamalia & B. Egnetoff. *Canadian Journal of Learning Technologies, 36*(1), 1–20.

Laferrière, T., Hamel, C., Allaire, S., Turcotte, S., Breuleux, A., Beaudoin, J., & Gaudreault-Perron, J. (2011a). *L'école éloignée en réseau (ÉÉR), un modèle: Rapport-synthèse*. Retrieved February 2014. Quebec: CEFRIO. from http://www.cefrio.qc.ca/media/uploader/L_Ecole_eloignee_en_reseau_Phase3_Final_isbn.pdf

Laferrière, T., Perreault, C., Boutin, P. A., Law, N., Yuen, J., Montané, M., Hernandez, O., Boluda, P., & Blancafort, M. (2011b). Knowledge building international project: Designs for deep understanding. In *Proceedings of CSCL 2011* (pp. 414–421). Center for Information Technology in Education, University of Hong Kong.

Laferrière, T., & Breuleux, A. (2011c). Collaborative Design (CODE) as a teacher professional development model in Francophone and Anglophone Quebec. In *Proceedings of CSCL 2011* (pp. 1134–1138). Hong Kong: Center for Information Technology in Education, University of Hong Kong.

Laferrière, T., Law, N., & Montané, M. (2012a). An international knowledge building network for sustainable curriculum and pedagogical innovation. *International Education Studies, 5*(3), 148–160.

Laferrière, T., Barma, S., Gervais, F., Hamel, C., Allaire, S., & Breuleux, A. (2012b). Teaching, learning, and knowledge building: The case of the remote networked school initiative. *Problems of Education in the 21st Century, 40*(1), 96–113.

Laferrière, T., Hamel, C., Allaire, S., Breuleux, A., & Turcotte, S. (2012c). *The remote networked schools model for sustainable and scalable collaborative learning and knowledge building*. Paper short-listed for award, and presented at the annual meeting of the American Educational Research Association (AERA), Vancouver.

Laferrière, T., Hamel, C., & Searson, M. (2013). Barriers to successful implementation of technology integration in educational settings: A case study. *Journal of Computer-Assisted Learning, 29*(5), 463–473.

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge: Cambridge University Press.

Le Cornu, R., & Ewing, R. (2008). Reconceptualising professional experiences in pre-service teacher education… reconstructing the past to embrace the future. *Teaching and Teacher Education, 24*(7), 1799–1812. doi:10.1016/j.tate.2008.02.008.

Leithwood, K. (2014). *LSA theory of action.* Toronto: Leading Student Achievement: Networks for Learning. Available at https://sites.google.com/site/pqp2cat/the-principal-in-action---resa

Lieberman, A. (2000). Networks as learning communities: Shaping the future of teacher development. *Journal of Teacher Education, 51*(3), 221–227.

Lieberman, A., & Grolnick, M. (1996). Networks and reform in American education. *Teachers College Record, 98*(1), 7–45.

Looi, C. K., So, H.-J., Toh, Y., & Chen, W. (2011). The Singapore experience: Synergy of national policy, classroom practice and design research. *International Journal of CSCL, 6*(1), 9–37.

National Council for Accreditation of Teacher Education. (2001). *Standards for Professional Development Schools (NCATE).* Washington, DC: National Council for Accreditation of Teacher Education. Retrieved May 12, 2014, from http://www.ncate.org

Nunes, C. (2013). *Epic innovations in large scale: the search for excellence*. Retrieved February 2, 2014, from http://pt.slideshare.net/cesaraanunes/cesar-nunes-virtualeducacolombia

Penuel, W. R., Fishman, B. J., Cheng, B., & Sabelli, N. (2011). Organizing research and development at the intersection of learning, implementation, and design. *Educational Researcher, 40*(7), 331–337.

Riel, M. (1990). Cooperative learning across classrooms in electronic learning circles. *Instructional Science, 19*, 445–466.

Riel, M. (2004a). Learning Circles. In A. DiStefano, K. E. Rudestam, & R. J. Silverman (Eds.), *Encyclopedia of distributed learning* (pp. 281–284). Thousand Oaks: Sage Publications.

Riel, M. (2004b). Building communities of learners online. In G. Kearsley (Ed.), *Online learning: Personal reflections on the transformation of education* (pp. 309–320). Englewood Cliffs: Education Technology Publications.

Riel, M. (2013). *The learning circle model: Building knowledge through collaborative projects*. Retrieved on Feb 14, 2014, from https://sites.google.com/site/onlinelearningcircles/Home/learning-circles-defined

Rogers, E. M. (2003). *Diffusion of innovations* (5th ed.). New York: The Free Press.

Sannino, A. (2008). Sustaining a non-dominant activity in school: Only a utopia? *Journal of Educational Change, 9*(4), 329–338.

Sawyer, R. K. (2006). Analyzing collaborative discourse. In R. K. Sawyer (Ed.), *Cambridge handbook of the learning sciences* (pp. 187–204). New York: Cambridge University Press.

Scardamalia, M. (2002). Collective cognitive responsibility for the advancement of knowledge. In B. Smith (Ed.), *Liberal education in a knowledge society* (pp. 67–98). Chicago: Open Court.

Scardamalia, M., & Bereiter, C. (2003). Knowledge building. In *Encyclopedia of education* (2nd ed., pp. 1370–1373). New York: Macmillan Reference.

Scardamalia, M., & collaborators. (2014). *Societal human resource development in an open informational world: Opening doors and closing gaps*. Knowledge Building International, internal document.

Seng, C. T., So, H. J., & Yeo, J. (2014). *Knowledge creation in education.* New York: Springer.

Sun, D., Looi, C.-K., Y. C. J., & Phua. (2013). *Design and Evaluation of a Collaborative Inquiry Environment to Enhance Science Learning*. ICCE 2013, Bali.

Turcotte, S., Laferrière, T., Hamel, C., & Breuleux, A. (2009). Multilevel innovation in remote networked schools (RNS). *Systemic Practice and Action Research, 23*(4), 285–299.

UNESCO. (2011). *ICT competency framework for teachers.* Paris: Author. Retrieved from http://unesdoc.unesco.org/images/0021/002134/213475e.pdf

United States Department of Education. (2010). *National Educational Technology Plan (NETP)*. http://www.ed.gov/technology/netp-2010. Accessed 25 Oct 2013.

van Aalst, J., & Chan, C. K. K. (2007). Student-directed assessment of knowledge building using electronic portfolios. *The Journal of the Learning Sciences, 16*(2), 175–220.

Virkkunen, J. (2006). Dilemmas in building shared transformative agency. *Activités, 3*(1), 44–66, http://www.activites.org/v3n1/virkkunen-en.pdf. Accessed 2 Sept 2013.

Virkkunen, J., & Shelley Newnham, D. (2013). *The change laboratory: A tool for collaborative development of work and education* (p. 4). Netherlands: Sense Publishers.

Voogt, J., Laferrière, T., Breuleux, A., Itow, R., Hickey, D. T., & McKenney, S. (2015). Collaborative (re-)design as a form of professional development: Teacher learning by design. *Instructional Science*.

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. Cambridge, MA: Harvard University Press.

Wiske, M. S. (2005). *Teaching for understanding with technology* with Kristi Rennebohm Franz and Lisa Breit. San Francisco: Jossey-Bass.

Yamagata-Lynch, L. C. (2010). *Activity systems analysis methods: Understanding complex learning environments*. New York: Springer.

Zhang, J., Hong, H.-Y., Scardamalia, M., Teo, C., & Morley, E. (2011). Sustaining knowledge building as a principle-based innovation at an elementary school. *Journal of the Learning Sciences, 20*(2), 262–307. doi:10.1080/10508406.2011.528317.

Part IV
Closing Chapter

Chapter 13
A Synthesis: Expanding the Reach of Education Research and Reforms

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Abstract Stemming from the wide-ranging discussions in this book of issues, strategies, approaches, and trajectories for achieving scalability and sustainability, this closing chapter presents a synthesis of various crosscutting themes that have emerged or serve as rise-above for a higher and deeper level of understanding of the happenings and trends in educational reforms. We look into the themes related to framing the challenges of scaling, models of scaling from other disciplines, alternative approaches of scaling in different settings and the challenges that ensued, learnability of scaling and diffusion concepts, macro vs micro perspectives, and top-down vs bottom-up approaches. We envisage such a synopsis will lead to a systemic picture that is informative in creating a new scholarship of understanding the complexity of educational scaling matters.

Introduction

This collection of chapters reflects a vivid discussion of the challenges of scaling up educational reforms and innovations from the multiple perspectives of researchers, practitioners and policy-makers. Researchers studying scaleup explore what the factors which take to expand and sustain an intervention in real-world settings are and attempt to place them in a theoretical framework. Practitioners have stakes in the interventions and innovations they embarked on as it involves them to embrace, support and enact new practices. They give practical meaning to the interventions and innovations which will bring out positive impact on students. Policy-makers are interested in visions, strategies and processes to inform the scaleup of educational reforms or to maximise the impact of successful research interventions to benefit a wider audience.

Different chapters articulate the challenges of scaling in different settings, with many commonalities and yet also in ways that differ. One obvious difference is that the goals of scaling are posited somewhat differently in different contexts.

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Issues and challenges addressed are also at different levels of the education system, spanning the diverse levels of students, teachers, schools, districts, states and countries and international networks. To achieve scaling, different strategies are also proposed, described and discussed.

As can be seen from the book chapters, the entity to be scaled up – the 'innovation' – is defined rather broadly: it may refer to a whole-nation language curriculum reform programme (as in the STELLAR programme in Singapore), a macro plan to implement ICT innovations in schools in countries and regions (whether they are in big countries like China or in smaller countries and regions), a researcher-initiated curricular innovation (as in the ICT-enabled Group Scribbles and Seamless Learning interventions), a professional development initiative (as in the networks of teachers in e-Twinning and in KBIP) and public health innovations (as in spreading health interventions in Australia). The scaling-up journey narrated in these chapters shares a common element, i.e. spreading an innovation that has been shown to work in a small number of settings to a larger number of settings. For instance, the massive e-Twinning network that supports teachers sharing innovation stories and experiences is about scaling up the network of teachers who can benefit from such sharing. The various cases described in the book also differ in terms of the kinds of scaling and the dimensions (including the more typical notions of breath and depth) being focused upon.

Several notable common themes have emerged from this diverse collection of chapters.

Framing the Challenge of Scaling

One of the most cited references of scaling in the literature as well as in the chapters of this book is Coburn (2003) which defined scale as encompassing four interrelated dimensions: depth, sustainability, spread and shift in reform ownership. Clarke and Dede (2009) added a fifth dimension, namely, evolution, in which the innovation, as revised by its adapters, is influential in reshaping the thinking of its designers and creating a community of practice that changes and improves the innovation. These dimensions are very useful in unpacking what scaling entails with implications of how to approach the complex notion of scaling and what the pitfalls to look for are.

Sabelli and Harris in their chapter posits that a productive view arises when scaling is seen as the transformation of practices supported by research where researchers become intermediaries who work with practitioners to improve the education system. This is contrasted with the view of scaling as merely the transfer of research to practice or finding the right conditions (i.e. best fit) for the transfer. The core goal of scaling up is therefore not expanding the use of a specific educational innovation but to improve education through continuous progress towards improved performance goals over time, by adopting a working innovation. In this sense, scaling up a proven intervention is but a means and a tool to achieve sustainable, iterative and evolutionary improvements in learning and not the end per se (Chap. 2 by Sabelli and Harris, this volume).

Models or Learning from Other Disciplines: Health Innovations

What can actors in education learn from the models of scaling in noneducation sectors? Milat and Bauman articulate a staged model for spreading health innovations (Chap. 4 by Milat and Bauman, this volume). They pointed out that history shows that the standards of evidence needed before a health intervention is deemed ready to be scaled have evolved over the decades. Within the health sector, the approach to scale up public health programmes is different from that to scale up health-related clinical interventions that target individual patients. In the clinical setting, there needs to be clear rules about evidence-based medicine, such as the need for robust evidence from randomised control trials, before an intervention can be expanded to eligible populations and be acceptable to target groups and settings, at an acceptable cost. There must also be good understanding of the context in which the interventions operate. In contrast, in public health settings, such as in community-wide interventions (such as to prevent or reduce smoking, improve healthy diet or disseminate immunisation programmes to a large region), less clear 'evidence' is usually offered (Chap. 4 by Milat and Bauman, this volume). In this respect, scaling up in the education sector may be closer to scaling up public health programmes than scaling up interventions in the clinical setting. However, it should also be mentioned that there is scaling research in education that seeks more rigorous measures of evidence, such as the scaling up of SimCalc in the state of Texas in the USA that uses randomised experimental-control studies to evaluate the efficacy over large samples of teacher implementers (Roschelle et al. 2010).

Milat and Brown critique current models of scaling up health interventions as frameworks that are not informed by comprehensive empirical examinations of how scaling up decision-making occurs in the real world. Therefore they propose a scalability framework which incorporates the steps to assess the suitability of an intervention for scaling up, develop a scaling-up plan (with a vision of what the scaled up intervention will look like), prepare for scaleup (how to secure resources and build a foundation of legitimacy and support) and effect the scaling-up intervention (including establishing evaluation and monitoring systems). This model is potentially relevant for scaling up in education, as the scaling of public health programmes and of education innovations shares similar challenges in that it is key to find the right balance between fidelity and local adaptation in implementation. The challenge of maintaining this balance between fidelity of the innovation and adaptation to local contexts has also been emphasised in the other chapters by Dearing et al. (Chap. 5, this volume); Pang et al. (Chap. 6, this volume); Looi, Xie and Chen (Chap. 7, this volume); and Looi et al. (Chap. 8, this volume).

Ecological Models: Learning at and Across Different Systemic Levels

Ecological models of scaling have often been discussed in the literature on scaling. Law et al. in their meta-level analysis and synthesis of seven case studies of scaling distil a recommendation for learning across levels of the system. Using an ecological model for understanding change, they interpret factors at multiple levels as contextual variables that can be influenced and can lead to the adoptability and adaptability of the innovations. These levels reside at the levels of the student, the teacher, the school, the project, the community, the whole education system and beyond.

Hung et al. (Chap. 3, this volume) postulate that it is vital to work at these different levels as leverage for change and to support each level to take up innovations. They argue for a satisficing model where good enough innovations can be readily scaled up productively at different levels of the system depending on the contexts in which scaling is to take place and not on the demonstrated efficacy of the innovations in pilot studies, per se. In their model, scaling can progress without following a specified order – this differs from models of scaling in other chapters of this book. They propose that scaling does not require the innovation to meet the gold standard but to meet satisficing standards. They highlight that even in the case of Singapore, which is a centralised system, a silver bullet that is effective across different schools is also hard to come by. From their perspectives, the researchers' role is to engage in research to understand an innovation, especially its underlying mechanism, to engage in partnership with stakeholders to make the innovation work in different local contexts and to study patterns of growth, spread and implementation of innovations across these contexts.

Scaling can also be studied at a level that is beyond national boundaries, that is, at the international level. Two chapters discuss scaling up teachers' professional development through international sharing networks. Similar to some of the earlier examples, the KBIP for scaling up professional development for knowledge building also exemplifies a systemic and ecological approach to professional development at both the local and international levels. The key elements in KBIP are 'cross-fertilization and visibility of the local innovation in an increasingly socially recognized format (web-conferences) and attention to newcomers who have no local colleagues with whom to share and advance their pedagogical vision' (Chap. 12 by Laferriere et al., this volume). The e-Twinning project with its horizontal and vertical supports for sharing teacher innovations also exemplifies another ecological approach to professional development (Chap. 11 by Vuorikari, Kampylis, Scimera and Punie, this volume).

Learnability and Application of Scaling and Diffusion Concepts

Dearing et al.'s case studies show that it is possible for educational innovators in US community colleges to familiarise themselves with diffusion and scaleup concepts and apply them in their own settings (Chap. 5 by Dearing et al., this volume).

Although some concepts are too complex to apply and sometimes contradict other concepts, innovators have acted in creative ways to operationalise them. Also, technology provided leverage for increasing depth and spread. This narration provides confidence that educational innovators and practitioners can apply principles of diffusion of innovation and concepts in frameworks for designing successful educational innovations that scale (Coburn 2003; Clarke and Dede 2009; Rogers 2003; Dearing 2009). The three cases of scaling innovations in US community colleges demonstrate the importance of not only allowing for reinvention by later adopters and users but also actively encouraging their responsible adaptation or reinvention of innovations. An interesting key outcome of the diffusion is that the first-generation 'creators' of innovations also learned a great deal from their second-generation 'implementers' of innovations who found new and productive ways to adapt these innovations to meet their needs.

Top-Down Approaches

In the process of sustaining and scaling educational innovations, different strategies are adopted and applied. In the scaling strategy framework of Looi and Xie (2014), four quadrants of scaling models and strategies can be characterised with reference to its sustaining and scaling purpose/outcome (as centralised vs. decentralised) and its methodology/process (as top-down vs. bottom-up). In the 'centralised' model, an entity like the government has a prominent role in enacting directions/policies, taking initiatives and playing driving forces. The agents in centralised sustaining and scaling can either be assigned (top-down) or motivated (bottom-up) to spread certain innovations for certain outcomes, purposes or themes. In 'decentralised' models, there is no predefined or definite central theme to make all the agents unite together. Instead, competition and symbiosis for different scaling themes or factions are encouraged. In decentralised bottom-up sustaining and scaling, for instance, the agency really springs from the ground (grass roots) and the government has a minimum influence. Sustaining and scaling is about the building up of constituency. It can be achieved by collaboration with industry partners or driven by technological or business initiatives.

In the STELLAR scaleup, centralised planning by the Ministry of Education on intended outcomes, processes and implementation support strategies features prominently. In this centralised top-down model, spread is coordinated and driven from the top. Different levels of prescriptiveness and different types of disseminations using a variety of mechanisms such as programmes (e.g. workshops), materials and ministry staff as resources, can be engaged. A new English language curriculum was designed and studied centrally by the education authorities and was eventually implemented in almost 190 primary schools (Chap. 6 by Pang et al., this volume). When mentoring which was initially provided was gradually withdrawn, the schools continue to sustain the implementation of this curriculum. This chapter shows that a top-down model of scaling can work in the city-state of Singapore, with its unique

context of a centralised education system, as long as the needs of actors at different levels can be taken into consideration in the design and implementation of the innovations and the scaling process.

The STELLAR scaling-up model emphasises that human and organisational capabilities need to be and can be scaled up as well. This top-down scaling model incorporates the confluence of many elements, namely, ensuring and maintaining the quality of the innovation, especially curriculum coherence, planning and implementing strategies to ensure sustainability and providing strong central support. These are the elements which would provide some of the essential supports for running and sustaining any innovation over time. A summative evaluation study was also conducted to assess the efficacy of the innovation.

In contrast to scaling a curricular innovation in a small country like Singapore, the chapter by Zhang et al. (Chap. 9, this volume) paints top-down approaches for scaling ICT innovations in a large country. The goals of the scaling include improving the quality of education and promoting equity, and the latter is especially relevant in a vast diverse country like China. Some unique features of the Chinese model include centralised planning and support via conceptualisation, planning and participation by experts and researchers and scaleup diffusion being driven by practitioners as decentralised models of scaling.

Design-Based Research Approaches

In the centralised bottom-up model (Looi and Xie 2014), policies are set in place to encourage innovations, pinpoint directions, provide resources and funding, aggregate lessons learned from implementation to iterate the innovation and support the innovations initiated and advanced by the ground-level agents. The scaling up of GS and SL utilises bottom-up strategies, in particular, partnership strategies through DBR and DBIR approaches to bring about the sustaining and scaling of educational transformations.

The scaling up of GS shows that it can be adapted to meet the needs of a collection of schools, with different contexts, which demonstrates the local adaptability and interpretation for the pedagogical innovation of Rapid Collaborative Knowledge Improvement (RCKI). Two principles for scaling up are distilled: the focus in the invariant aspects and the variability of the innovation and the balance between assimilating innovations into existing structures and accommodations of the structures to integrate the key elements of the innovation and to demonstrate local consequence and utility on the other. The scaling of GS to schools with different contexts shows that through a collaborative and iterative process of partnership with schools, it is possible for an innovation to be adopted and adapted with sufficient fidelity for teachers and students to enjoy the benefits of the innovation. Successful teachers develop an innovation mindset and treat the technology and other supporting structures as resources for them to design their own learning activities using GS.

The critical aspects of the scaling up of GS and SL are the 'set of ideas and principles behind the intervention and the process of implementing those principles that will allow new implementers to do justice to the intentions of developers and researchers' (Chap. 2 by Sabelli and Harris, this volume). In GS, it is the set of RCKI principles; in SL, it is about the notions of seamless inquiry learning. The scaling of SL innovation which progresses from one school to five schools depicts a stage by stage curriculum development and scaling, according to the needs of local innovation context. In this scaling example as in many other studies, professional development of teachers is key. The seeding and seeded teachers in the schools not only transfer technology but also serve as innovation guides.

In the GS and SL scaling, the researchers are the key agents and they internalise the scaling concepts when working and codesigning with teachers. While the scaled innovation implemented in the schools worked to some extent at the point when the chapters were written, it is envisioned that there will be greater shift of ownership when the teacher innovators are given more agency to carry out their own implementation and scaling, leading to greater sustainability. In the scaling of innovations in the US community colleges, the researchers explicitly taught the innovators the scaling and diffusion concepts to increase their capacity to plan and to execute scaling (Chap. 5 by Dearing et al., this volume).

The GS and SL innovations are examples of efforts that involve long-term, collaborative partnerships with schools. These partnerships are anchors which ensure the presence of factors like professional development and school leaderships to support scaling. Researchers adhere to principles of design-based implementation research (Penuel et al. 2011) to focus on persistent problems of practice, commit to iterative codesign of learning, commit to developing capacity to sustain change and concern with develop theory on student learning and implementation. As demonstrated in the design-based GS and SL implementation and scaling, researchers conducted rigorous evaluation that informs the next cycle of implementation or scaling and also took into account the local contexts of the implementation.

International Networks for Scaling Up Professional Development of Teachers

In their argument for proposing a social reorganisation of the research infrastructure for addressing enduring problems of improvement in schools and colleges, Bryk et al. (2011) introduce the idea of a networked improvement community to guide the efforts to bring about sustained collective action towards solving complex improvement problems. This is motivated by insights from successful research and development activities outside of education: in industries like the semiconductor industry, the Linux development community and efforts in broad-scale quality improvements in health services, large networks have organised around complex problems and brought about remarkable change. Two chapters in this book discuss network improvement communities centred around teachers' professional development.

Vuorikari, Kampylis, Scimeca and Punie (Chap. 11, this volume) narrate the scaling up of a network of teachers across countries in Europe. The e-Twinning project incorporates both top-down and bottom-up strategies. As noted by the authors, while there are many similarities between scaling-up school reforms and teacher networks, there are also differences, for example, in terms of shifts in ownership. Since participation in teacher networks is voluntary, there is no 'external reform' to be executed. e-Twinning serves as a conduit to help teachers share innovations and experiences across countries and across large distances tapping on the power of the network. There is sharing at the horizontal level within a site such as a school, and vertical support is needed for teachers to adopt and adapt new innovations.

Coburn's and Dede's dimensions of scaling have often been used to analyse scaling qualitatively; for a complex network, new methods need to be deployed. The e-Twinning chapter also proposes the use of social network analysis as a methodology for studying and analysing the growth of teacher networks. e-Twinning's power lies in the deeper connections that are created through teacher collaboration which help teachers to codesign innovations. This collaboration 'deepens and sustains pedagogical innovation in teachers' practices in their classrooms, and in their interactions with both their students and their peers'. The support activities provided by the e-Twinning platform (e.g. social networking activities, continuous professional development), on the other hand, offer better chances for interaction which in turn can lead to project collaboration.

An international network of researchers and practitioners can provide the structures and support to help scale up a disruptive pedagogical innovation. The KBIP is a classroom-based knowledge building initiative, with its base in Canada, which requires the teacher to embody progressive epistemological beliefs and advanced pedagogies. Research has shown that teachers are more likely to embrace knowledge building if they can share progressively impressive accounts of what students and teachers can accomplish regarding developmental, demographic, and cultural barriers (Chap. 12 by Laferriere et al., this volume). Establishing knowledge building communities requires effort from within as well as from outside the classroom. The support from outside the classroom comes in the form of the international teacher network KBIP.

In KBIP, the strategies for scaling up PD include the use of collaborative technologies, a systemic and ecological approach to PD at local and international levels, scaling through cross-fertilisation, visibility of local innovation, attention to incomers with no local colleagues and strategies for overcoming the double binds (secondary contradictions from the perspective of Engestrom's third-gen activity theory framework) to enable KBIP expansion as an activity.

The common theme in these two chapters on international teacher networks is that scaling up is not just about expanding the impact of an innovation and reform but about building capacity in people and organisations to enact and adapt an innovation at hand and also future innovation improvement efforts. The outcomes of scaling up must be both knowledge and people. The agents for implementing scaling can and must cultivate an innovation mindset.

Conclusion

The work reported in all the chapters of this book attests that scaling is complex and there is no universal model applied to all contexts. We have to develop deeper understanding of the various scaling models as well as the sociocultural factors involved in the creation of new knowledge for scaling practice and research. The models of scaling in the Singapore context as discussed in some of the chapters may not be directly applicable for other national contexts where the system may be bigger with many more levels in the education system such as at the levels of the country, the state/prefecture, the city, the school district and the school. However, there may be ways for the Singapore models to be adapted productively in the other national contexts. For example, these models could be applied to jurisdictions of similar size as Singapore (or smaller) in these nations. Additional top-down supporting processes, structures and systems can then be designed and put in place by these nations at levels beyond these jurisdictions, and this will result in a new scaling model. Different scaling models have different virtues. While a more top-down approach could demonstrate the result of scaling faster, a more bottom-up diffusion approach might result in greater sustainability.

Drawing from the various threads discussed in this chapter, the issues of scaling can be conceived from both the macro and micro perspectives. Scaling from the macro perspective (systems level) needs to consider the purpose or goal of the scaling agenda, the planning for the process of systemic scaling and the overall strategy to be taken and the policies that need to be put in place in order to realise the purpose. Scaling from the micro perspective (ground implementations) needs to consider the partnerships, including networks both local and international, between parties such as researchers and teachers in the design-based research to advance the scaling process, projects with sound interventions for pedagogical change, programmes that enable the supporting conditions for sustainability to occur, professional development for practitioners and other stakeholders and provisions in terms of equipping and resourcing needed to achieve the goals at hand.

Importantly, it is critical that the macro and micro levels of scaling are in constant alignment and a dialectical interplay is needed. This is to be achieved through constantly making visible the ground implementations to policy-makers in any particular system and introducing top-down policies to plug systemic gaps that may arise during the local enactment of the scaling and translations.

As the chapters in this book show, there are some principles and strategies of scaling up which are invariant across systems. Scaling is correlated with various challenges in education, such as education policy, school improvement, teacher professional development and ICT advancement. We would like to offer two principles. First, implicit or explicit in the chapters, there is emphasis to balance attention between idealistic research to advance theory and realistic problems of improving practice. This is yet another timely call to shift towards Pasteur's quadrant (Stokes 1997) to address 'applied research that can advance fundamental understanding', not just 'basic research that is use-inspired'. Scaling research makes sense within a

movement in the field to emphasise adoption, scale and sustainability more – to shift from pure invention to a 'diffusion of innovation' perspective.

Second, the approaches/strategies for scaling span ecological models (Chap. 10 by Law et al., this volume), diffusion models (Chap. 5 by Dearing et al., this volume), top-down or centrally planned approaches (Chap. 6 by Pang et al., this volume; Chap. 9 by Zhang et al., this volume), design-based research approaches (Chap. 7 by Looi, Xie and Chen, this volume; Chap. 8 by Looi et al., this volume), integrated top-down and bottom-up approaches (Chap. 11 by Vuorikari, et al., this volume), satisficing approach (Chap. 3 by Hung et al., this volume) and identifying and addressing contradictions amongst multiple interacting activity systems (Chap. 12 by Laferriere et al., this volume). They are applicable in their own context of use with respect to the goals of their scaling. All these models of scaling deserve more inquiry.

These invariant principles and strategies for scaling up can galvanise educational researchers from different disciplines like policy and leadership studies, implementation research, learning sciences and organisation studies to work together with policy-makers and practitioners to conduct more implementation and scaling research in order to resolve the challenges that limit the potential of learning in our next generation. We hope that this book can contribute to the pursuit of this endeavour in a small way.

References

Bryk, A. S., Gomez, L. M., & Grunow, A. (2011). Getting ideas into action: Building networked improvement communities in education. In *Frontiers in sociology of education* (pp. 127–162). Dordrecht: Springer.

Clarke, J., & Dede, C. (2009). Design for scalability: A case study of the River City curriculum. *Journal of Science Education and Technology, 18*(4), 353–365.

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

Dearing, J. W. (2009). Applying diffusion of innovation theory to intervention development. *Research on Social Work Practice, 19*, 503–518.

Looi, C. K., & Xie, W. (2014). Sustaining and scaling research-based ICT in education innovations in Singapore. In R. Huang, J. Price, & Kinshuk (Eds.), *Emerging global trends in the use of ICT in education* (pp. 85–100). Beijing: Springer.

Penuel, W. R., Fishman, B. J., Cheng, B., & Sabelli, N. (2011). Organizing research and development at the intersection of learning, implementation, and design. *Educational Researcher, 40*(7), 331–337.

Rogers, E. M. (2003). *Diffusion of innovations* (5th ed.). New York: Free Press.

Roschelle, J., Shechtman, N., Tatar, D., Hegedus, S., Hopkins, B., Empson, S., Knudsen, J., & Gallagher, L. (2010). Integration of technology, curriculum, and professional development for advancing middle school mathematics three large-scale studies. *American Educational Research Journal, 47*(4), 833–878.

Stokes, D. E. (1997). *Pasteur's quadrant: Basic science and technological innovation*. Washington, DC: Brookings Institution Press.