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Chapter 4

Overcoming Impediments to Reform: Building a Sustainable Ecosystem for Educational Innovations

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In this chapter, we examine how we can sustain educational innovations from the ecological perspective, where multiple stakeholders at the leadership level can help new adopters of innovations to construct an ecosystem that is conducive to deep learning. From our studies, we established that schools could sustain educational innovations to achieve purposeful learning by leveraging *ecosystem carryover effects*, which are defined by Ron Adner (2012) as the process of leveraging successful elements in constructing one ecosystem to create advantages in constructing a new ecosystem. We found four types of carryover effects that can occur in self-renewing learning networks that engender new knowledge, namely: *structural, economic, socio-cultural and epistemic ecosystem carryover effects*. For the rest of this chapter, we will explain how we had identified these carryover effects and provide preliminary evidence for the impact of these carryover effects in sustaining educational innovations that move towards achieving life-long, life-wide, life-deep and life-wise learning in the schools.

INTRODUCTION

Generally, we know that some innovations come and go. The enduring innovations gain incremental momentum at a steady pace, while disrupters

displace their predecessors rapidly, catching up with the mainstream players at breakneck speeds. Others enter the market with a bang but fizzle out quickly.

To understand the variegated diffusion and adoption rates of innovations, we often need to look at not just the value propositions proffered by these innovations, but also at the wider ecosystem that influences their uptake as well. As an example, we can resonate with the advent of mobile application-based transportation technologies such as Uber and Grab which have threatened the viability of the traditional transportation market by offering an alternative system where "people are empowered to look for ways to meet their own needs" (Haxeltine et al., 2013, p. 4). These app-based platforms create a "minimal viable ecosystem" (Adner, 2012, p. 194) that streamline the processes of matching the demands of commuters to the aggregated supply of drivers seamlessly, without the need to go through a call centre that might not be reachable during high-volume peak periods. The whole process is well-supported by mature and sophisticated backend technologies that additionally provide a whole slew of complementary activities such as accurate location-based tracking, cashless transactions, and a comprehensive scheme of rewards and penalties for positive commuter experiences. To date, the synergistic interactions of these offerings have resulted in less frustrated commuters. It is, therefore, not surprising that a palpable wave of global uptake has ensued. The holistic convenience these innovations provide has proven to be irresistible to their targeted end-users.

Based on the above examples, we can better relate to the fact that we can better understand the success of Uber and Grab technologies from the perspective of an innovation ecosystem. Carayannis and Campbell (2009) remark that an innovation ecosystem "is a multi-layered, multi-modal, multi-nodal and multi-lateral system, encompassing mutually complementary and reinforcing innovation networks and knowledge clusters consisting of human and intellectual capital, shaped by social capital and underpinned by financial capital" (p. 202). According to the authors, innovations can be promulgated either in a top-down policy-driven or bottom-up entrepreneur-empowered fashion and technologies

can nurture and catalyse the uptake of innovations, as seen in the case of the transportation sector.

Intriguingly, such rapid and widespread diffusion of innovations is few and far between within the education sector. Many academics (Cuban, 2017; Halverson & Smith, 2009) have lamented that classroom configurations and instructional modes across the globe have not changed much over a century. Tyack and Cuban (1995) attributed this rigidity to the "grammar of schooling" which includes impediments such as timetabling, infrastructural investment, subject compartmentalisation and institutional routines that perpetuate traditions. To change any of the abovementioned components can be a costly endeavour that requires steely political will, careful calibration of resources, risk-taking cultural dispositions and support from multiple stakeholders, thus limiting the change agility in the education sector. In pursuing educational innovations in schools, we ask the following questions. *How then can we collectively overcome the impediments of innovations in our educational system? How can we nurture an innovation ecosystem that can sustain promising changes?*

UNPACKING THE INNOVATION ECOSYSTEM

Before attempting to answer the above two questions, we would first need to understand what constitutes an innovation ecosystem. In the parlance, it is a web of interactions amongst diversified innovators bounded by common purpose and context. More specifically, Adner (2017) defines the innovation ecosystem as "the alignment structure of the multilateral set of partners that need to interact in order for a focal value proposition to materialise" (p. 40), and where incumbent technologies will constantly be challenged by streams of nascent value propositions. This is similar to Geels and Schot's (2007) discussion on the typology of socio-technical transition pathways where niche innovations bubbling from the ground have to wrestle with countervailing forces stemming from powerful regime actors. These actors are inclined to maintain the stability of the system by having a strong foothold on cognitive routines, regulations and

standards. However, changes emanating from the broader landscape may also act as a window for these regime actors to be more receptive to alternative technologies so that they can respond in time to the change imperatives imposed by exogenous forces.

To transfer these understandings to the context of the local education sector, we can equate the window for change as the urgent need to create knowledge-based learners who are equipped with 21st century learning competencies. The incumbent technology is the prevailing teaching practices in classrooms, and the nascent value propositions are the various interventions that aim to promote change in teaching and learning. The regime actors are policymakers in the education sector who are willing to perturb the current system to promote 21st century learning.

There are three types of innovation risks undergirding innovation ecosystems, as articulated by Adner (2012):

> *Innovation ecosystems are characterised by three fundamental types of risk: initiative risks — the familiar uncertainties of managing a project; interdependence risks — the uncertainties of coordinating with complementary innovators; and integration risks — the uncertainties presented by the adoption process across the value chain. Firms that assess ecosystem risks holistically and systematically will be able to establish more realistic expectations, develop a more refined set of environmental contingencies, and arrive at a more robust innovation strategy.* (p. 100)

In short, the ecosystem view allows all stakeholders to understand the explicit and latent inter-dependencies; opportunities and risks; as well as the resources available so as to create synergy for sustainability and cross-boundary competency for knowledge co-production (Adner, 2012; Hansson et al., 2014; Toh et al., 2016; Zhao & Frank, 2003). Another important concept related to the cross-boundary competency of knowledge co-production in an ecosystem is the notion of "ecosystem carryover effects". Adner (2012) defines this as the process of leveraging successful elements in constructing one ecosystem to create advantages in

constructing a new ecosystem". Such carryover effects can happen when tacit knowledge or market share embedded in one product can be spawned to other related products. These spawning effects can result in what Carayannis and Campbell (2009) term as the "co-existence, co-evolution and co-specialisation of different knowledge paradigms" (p. 203), arising from the interdependence of people, culture and technology. These interdependencies can span across academia, industry, government and media, thus forming a network that is "multi-layered, multi-modal, multi-nodal and multi-lateral" (p. 202) in nature.

SELF-IMPROVING NETWORKS FOR DIFFUSING EDUCATIONAL INNOVATIONS

In the preceding section, we have articulated the notion of innovation ecosystem and unpacked the tenets underpinning it. While the examples cited are drawn from the business sector, we find that these concepts can also be transferable to the education sector. Like the business world, there is also a compelling need for various stakeholders in the educational sector to co-create value propositions for change.

By educational change, we are referring to pedagogical practices that are predisposed towards student-centred learning and 21st century competencies such as self-directed and collaborative learning. From the literature, we know that deep transformation requires time, coherent planning and whole-school participatory effort (Bain, 2007; Coppola, 2004; Dimmock *et al.*, 2013). Specifically, David Hargreaves (2010) argues that for school reforms to be sustainable, they have to be premised on the development of ''self-improving school systems'' (p. 5) where schools are primarily accountable for their own improvement. Over time, it is anticipated that the learning embedded within the network will mature and each node, or what we refer to as a nodal school, in the network can help other schools attain similar achievement and expand individual schools' "repertoire of choices, moving ideas and good practices around the system" (Stoll, 2009, p. 12) and "transcending their individual capacities'' (Bain, 2007, p. 6). The caveat is that the social capital of trust, reciprocity, identity and collective moral purpose are present in these

networks (Hargreaves, 2012). Toh and colleagues (2014) postulate that the leaders of self-improving schools need to exhibit systemic and/or ecological awareness so that they can create the enabling conditions for both innovations and improvements to happen, within and across schools. The value proposition for participating in these school-to-school networks is that there will be greater potential to collectively circumvent innovation challenges and leverage strengths of innovating partners to build the capacity of change agents in a timely fashion.

METHODOLOGY

In this chapter, we examine the growth of three ground-up learning networks occurring in our education system. MOE's funding programme (eduLab) supported these exemplars that encourage bottom-up tinkering of innovations to surface good pedagogical practices. Table 1 shows the contexts of the three learning innovations. They are selected for discussion as they have a sustained innovation trajectory of at least five years. More importantly, each of these innovations has explicitly articulated a pedagogical orientation that is well-aligned with 21st century competencies.

We collected qualitative data based on interviews with school leaders, middle managers, teachers and champions of the innovations. To further triangulate the self-reported data, we also observed professional learning sessions and lessons occurring within and across schools. We conducted inductive coding with the overarching notion of ecosystem carryover in mind, where we strove to identify the epistemic brokers in each of these innovations and distilled how they help other schools to create an ecosystem that is hospitable for innovations to take root.

Table 1: Innovation Contexts and Data Sources

Innovation	**Context**
Learning across contexts with mobile technology (LxC)	Innovation started with the use of 1:1 mobile technology to promote primary school scientific inquiry-based learning and to connect learning moments across formal and informal learning contexts. The effort was championed by the Northern Learning School (NLS), and the innovation had been propagated to another ten affiliated schools. The innovation entails the re-design of school-based science curriculum to integrate the affordances of mobile technology.
Knowledge Building Across Disciplines (KBxD)	The innovation aims to advance idea-centric pedagogy that focuses on real ideas and authentic problems, and which leverages the different perspectives and expertise of a group of learners to collectively improve ideas and achieve knowledge advancement. Tapping on the powerful learning analytics embedded in the socio-technological platform, learners can see their learning patterns. A lead specialist from MOE championed the innovation.
Cross-context Trails (CCT)	The innovation focuses on using mobile technology to design learning trails to promote real-world data collection; collaborative learning and active knowledge construction across different disciplines. The effort was championed by Crescendo School (CS) and the innovation was adopted by interested schools across the nation. CS also facilitated the use of the innovation within its consortium schools from the same cluster.

INNOVATION RISKS

Adner (2006) postulates that innovation involves initiative risk, inter-dependence risk and integration risk. These risks are also pertinent for innovation-adopting schools of the three learning networks mentioned above. We outline these risks below:

Initiative Risk

The participating schools from the three learning networks are cognisant of the risks associated with the adoption of disruptive innovations. Said one of the principals from LxC school A:

> *Risk-taking culture is important. Not all innovations can be successful, and results may dip…Diffusion is not a simple transfer, but exposure will help raise awareness. However, the innovation must be relevant to the school. We need to be mindful of what is going on and choose innovations that are most likely to succeed.*

This sentiment is echoed by another principal from LxC school B who is predisposed towards innovation and is clear about the fact that innovation involves grit, and not about "flavour of the month". Additionally, she feels that collaborating with schools is a very powerful vehicle as "structured mentoring" enables teachers to achieve their potential, suggesting that the benefits of co-innovation outweigh the inherent initiative risk of innovation adoption. Another principal from KBxD articulates the initiative risk related to implementation dip:

> *…[O]n hindsight I would say that that big drop [in results] was a very good thing that happened. Because it made us re-examine certain practices, and it started us on a journey of improvement……so that's why I will say sometimes crisis failure is a spur to improvement.*

Here, we see that the initiative risk can be transformed into an important window of opportunity for enduring changes.

Inter-dependence Risk

In terms of inter-dependence risks, the champion school from LxC network outlines the various encumbered challenges that need to be ironed out before participation can be more efficacious. The challenges are wide-ranging and include different pedagogical focus, infrastructural readiness, implementation pace, curriculum sequence, resource accessibility, capacity to contextualise the innovations, as well as pupil and teacher profiles, to name a few. All of these challenges can impede school-to-school collaboration.

As the schools come together to solve persistent problems of practice, they have to make adjustments to their curriculum sequence so that lesson enactment can be more synchronised with other member schools. Discussion would be more productive when all teachers in the network have gone through the phases of design, enactment and reflection, before convening at the network level again for further reification of lessons. Another teacher from KBxD network emphasises the need to spend the time to analyse student-generated artefacts and learning analytics before discussing these learning evidence in the professional learning community. These inter-dependencies signal the need to make adjustments to the current logic of curriculum and teachers' workload, both within and across the schools in the various networks. Based on our observations, these inter-dependence risks are painful as it requires sophisticated orchestration of project and resources. However, it can also be extremely rewarding to teachers who can see how others have internalised the true spirit of innovation and be inspired to do the same for their own classrooms.

Integration Risk

Integration risk is accentuated when schools attempt to embed innovations into their daily organisational routine, instead of just implementing them in a tokenistic or add-on manner. One of the principals from KBxC network highlights the importance of process, resource and expertise integration:

> *Very often for [innovations] to work, we have to integrate processes. Because it was not just about the curriculum design, very often you have to look into timetabling for them, funding, professional development, all these things. So it's about integrating resources. That's the implementation stage. But the earlier part would be, you know, we try to capitalise on strengths and strategic opportunities.*

Another school principal from LxC network succinctly summed up that teachers need "support, space and time" to integrate innovative practices into their daily pedagogical repertoire. Integration risk can also manifest in the form of resistance from peers, especially when we diffuse the innovation to more classes or schools. An experimental teacher from one of the CCT schools remarks:

> *……there are also many teachers who are very fixated with figures, so they cannot let go [of results]. They will, you know, think that if you want to use their precious time, you make sure it [the new method] doubles their [students'] learning.*

This entrenched culture of teaching to high-stake examinations can imperil innovations. When the culture of innovation is still nascent, integration risk can become amplified. However, we may need to integrate the innovations fully into the ecosystem before the benefits of innovations can be fully reaped. This "chicken-and-egg" dilemma has plagued many schools that aspire to traverse the path of transformation.

OVERCOMING RISKS THROUGH ECOSYSTEM CARRYOVER EFFECTS

While the above innovation risks may sound grim, the potential benefits of reform efforts can mitigate these risks provided that the ecosystem carryover effects are effected and sustained. Based on our studies (Toh *et al.*, 2016), there are four types of carryover effects that can occur in self-renewing learning networks that engender new knowledge: structural, economic, socio-cultural and epistemic. These carryover effects can be

propagated by teacher leaders, as seen in the LxC context; system players such as MOE specialists, as seen from the KBxC context; or middle managers from champion school, as seen from the CCT context.

Structural Carryover Effects

Structural carryover effects occur when the champions of respective innovations endeavour to help other schools create structures that catalyse the process of innovation. We can manifest these carryover effects in the form of helping other innovation-adopting schools build up architecture for on-going reflections, capacity augmentation and operationalisation.

Building Structures for Reflexivity and Capacity Augmentation

The LxC innovation is one such example where thoughtful structures of participation were put in place by NLS to optimise learning. The network adopts a multi-tiered peer-to-peer communication strategy where we fostered separate dialogues among school leaders, middle managers and technical assistants of the schools for more targeted discussions. There were also common sessions for all actors to come together for briefing and sharing. The participating teachers convened fortnightly to discuss lesson plans and enactment to further prime the ground for re-contextualisation of respective lesson plans after collective tinkering. The champion school also replicated the structure of open classrooms that they adopted in their own school to the other networked schools and welcomed the teachers from innovation-adopting schools to observe the lessons of the champion teachers in action. In turn, the champion teachers also observed the lessons of the experimental teachers of innovation-adopting schools — all of which constituted intentional planning.

For the KBxC innovation, Christine, the lead specialist from MOE, established structures of community sharing where the main actors of member schools, including school principals and teachers, came together to discuss issues related to change management and pedagogical issues of implementing disruptive innovations in respective schools.

In the CCT innovation, the champion school, CS, will organise international conferences, workshops, annual national competitions related to CCT and cluster sharing on their ICT-mediated pedagogies and innovations. CS also worked closely with industry vendors to devise creative solutions to pedagogical problems. The school-industry collaboration culminated into comprehensive professional development for teachers adopting the innovations: the school focusing on curriculum and pedagogical issues; and the vendor on technological usage. Such collaboration also afforded CS with the capacity to administer resources to allow ten consortium schools to partake in deeper pedagogical innovations in their respective schools.

Building Architecture for Operationalisation

We are also seeing evidence of how schools can play a pivotal role in helping other schools get started on the innovation by helping them to operationalise the process. For LxC, the school circulated their toolkits such as standard operating procedures related to equipment installation, deployment and maintenance, as well as documents related to research ethics and cyber-wellness. These were well-appreciated by the participating schools. We also installed a common suite of ICT tools across the schools for better orchestration of technological support by the ICT HOD and support staff of NLS.

For KBxC, Christine, the lead specialist from MOE also set up a socio-technological infrastructure where she shared the resources related to Knowledge Building to participating members for easy retrieval, reification and critique. She also created a handbook where practitioners could refer to for better understanding of Knowledge Building principles and for gathering ideas to integrate scaffolds into KB classrooms. Similarly, the LxC innovation also created a repository to house the created artefacts to promote accessibility to resources. For CCT, the champion school worked with the vendor to ensure the learning trails were well-designed and functioned well on the mobile devices.

Economic Carryover Effects

When schools come together to pool resources, they may experience the benefits of economies of scale. Across these innovations, the three champions acted as resource brokers who absorbed the implicit cost of coordination work. Both NLS and CS had, at some point in time, loaned out mobile devices to interested schools when these resources were not readily available to the innovation-adopting schools yet. Christine also coordinated the upgrading and professional training matters whenever there were changes to the functions and interface of the socio-technological tool. NLS also managed to negotiate for a more favourable data plan package with service providers.

With the support from the MOE in most cases, these champions also absorbed the cost of coordinating conferences and inviting domain experts to enhance the depth of professional learning in their respective learning networks — all of which may otherwise be precluded to all due to the limited access to resources. These benefits were available not only to members of the network. Other schools beyond the three learning networks were also able to participate in some of the seminars and conferences, thus amplifying the multiplier effects of innovation tinkering.

Socio-cultural Carryover Effects

Both structures and economies of scale, although important, do not complete the picture of what goes on within an innovation ecosystem. Our observation is that socio-cultural underpinnings will exert a greater influence on how well organisations respond to change and how far these innovations can travel. Building a culture that is conducive to innovation generally requires longitudinal and concerted efforts of actors within the ecosystem. While schools within a network may attend the same professional learning sessions centring on a common pedagogical innovation, the outcomes of the implementation would still vary widely across the participating schools. Across the three learning networks, schools that fail to bring innovations to scale often suffer from these common pitfalls:

(1) Incongruence between the thrusts of school and innovation;

(2) Nascent professional learning culture within respective schools where lonely experimental teachers tend to work in silos and

(3) Lack of continuity in innovation culture which is disrupted by a leadership change.

To mitigate these challenges, the learning networks have emphasised localised accommodation and leadership practices that would nurture a healthy innovation ecosystem.

Localised Accommodation

To mitigate the misalignment between the thrusts of school and innovation, the champions of the three innovations had, in one way or another, encouraged localised accommodation of the innovations. They understand schools cannot supplant exogenous innovations into their own ecosystem without making adaption. The need for this kind of re-contextualisation work was clearly articulated by the champion school of LxC through disavowing of a blueprint model. The champion teacher from NLS spoke about the importance of school autonomy and customisation:

> *…[W]e wanted to leave it pretty much to the school on their level because I think (at) all schools you have different concerns, you have different areas of needs. So it's still pretty much up to the school to see how they want to roll it out.*

At times, the idea of localised accommodation is already embedded in the design of the technology itself. The ICT HOD of CS school explains the design rationale of the learning trail design app used for the CCT innovation:

> *……[W]e focus more on platforms, more on tools which are open tools, just like word documents, just like PowerPoint, just like FaceBook, all those stuff that anyone can use it and it's not tagged to a subject. It's not tagged to a level. It's not even tagged to secondary*

> *school. It can be used across and with that as the main vision, that's where we started to put certain new pieces together….. For example, for trails, schools have their own trails they want to design to fit into their particular program. So it's not a one size fits all.*

The focus of CS is to make the innovation scalable by providing, metaphorically, a canvas that allows endless possibilities in design and implementation. Schools can implement CCT either as an add-on or disruptive innovation. The mutability of the CCT innovation is more pronounced, compared to LxC and KBxC. For KBxC innovation, there is a need to ensure fidelity towards knowledge building principles. However, due to the design of socio-technological infrastructures, the tool can be easily adapted and be used across different disciplines and levels, thus making localised solutions feasible.

Leadership Practices that Promote Innovation

We also witnessed other forms of socio-cultural carryover effects from the three exemplars. For LxC, the principal and vice-principals of the champion schools shared the importance of risk-taking dispositions and succession planning strategies such as seeding at least two champions within their own school to keep the innovation going. This provides a critical mass to form a professional learning community within the school where teachers can brainstorm and bounce off ideas together, thus overcoming the feeling of isolation experienced by the sole experimental teacher who would have to do all the heavy lifting alone.

CS also explicated how they had formed a dedicated and willing team to look into diffusion work while sheltering other teachers from having to dabble into this aspect of service work to the system. This practice was adopted by some consortium schools. For KBxC, when Christine convened the schools during the end of the year seminar, school leaders and teachers had the opportunity to hear about the socio-cultural strategies employed by different schools to get buy-in from various stakeholders. Most importantly, one of the KBxC teachers felt that the learning network was able to provide her with an alternative microcosm to support her social learning. Her

poignant account of the mounting challenges that she faced in implementing the innovation at her own school is a reminder that networked learning communities can connect individuals with common experiences with other like-minded folks. This is critical especially when the environment in her own school had become increasingly inhospitable to innovations after a leadership change. This alternative microcosm, could perhaps, to some degree, help innovative teachers alleviate the issue of adverse changes occurring in localised contexts, and provide "respite" as they wait until the ground is favourably primed again to continue their innovation work.

Epistemic Carryover Effects

Perhaps the most important, but difficult aspect of educational change is to enable epistemic carryover effects. Teachers must be able to reframe their belief on how knowledge can be acquired and internalise the spirit of student-centred learning whole-heartedly. Without the requisite mindset, change cannot be sustained and will be fleeting at best. The innovation may even go through the phase of "lethal mutation", which is the antithesis of the desired outcome.

Epistemic Shift in the Classroom

When it is apparent that the epistemic authority in the classroom has shifted from the teacher to the students and classroom discourse becomes increasingly dialogic, with both teachers and students actively co-constructing knowledge in class, we have good reasons to believe that changes have occurred at a deep level. For LxC, the champion teachers from NLS exhibited what we termed as "apprenticeship leadership" (Hung *et al.*, 2015) where they scaffolded the process of lesson co-design, enactment, and reflection. Professional development was situated and longitudinal, building up teachers' confidence in leading the innovation in their respective schools. One of the school leaders from LxC schools explained how capacity transfer could occur in the network:

> *Every school has its own pedagogical niche.…there is a transference of expertise…less about resources but more about PD [Professional*

> *Development]…less about skills of LxC but more about the mindset of our teachers.…It is not just application of old knowledge. It is a certain thinking approach here. If teachers have this…it will scale to other things. They will share it with other people [when they have the mindset].*

Similarly, KBxC also had this element of intensive apprenticeship where Christine endeavoured to build up a group of core expertise in every KBxC school. She was involved in every professional learning community of the various schools to examine the student artefacts together with the teachers. She probed the teachers' lines of inquiry in a deeper fashion to develop their understanding of the philosophical stance of KB through inquiry-based learning. She also modelled how to use the affordances of technology to improve interactions and to help students improve their ideas.

The intensive apprenticeship that we have been alluding is not foregrounded for the CCT innovation. Rather, the innovation "hinged upon the use of domain-independent technological application as a common epistemic tool that encapsulates pedagogical change and self-directed learning" (Toh *et al.*, 2016, p. 1259). For some CCT secondary schools, there were attempts to shift epistemic authority from teachers to students by inviting students to design the learning trails themselves and this promoted self-directed and collaborative learning (Suppiah *et al.*, 2013).

Investigating Learning Evidence

We observed that the ability to internalise the spirit of student-centred innovations would be highly desirable. Above that, being able to demonstrate the learning evidence that these innovations can accrue will buttress longer-term support from stakeholders.

The champion school of LxC innovation (NLS) had an entrenched culture of working with university researchers who acted as analytic investigators to distil learning evidence. Such a culture of collaborating with researchers

was also spread to the other ten schools. For KBxC, Christine actively modelled how the learning analytics embedded in the technological tool can powerfully aggregate and distil students' patterns of learning, and the dynamics of online interactions among students and teachers. Teachers used the visual analysis to inform them about the learning gaps of students so that they could design activities to alleviate said identified learning gaps.

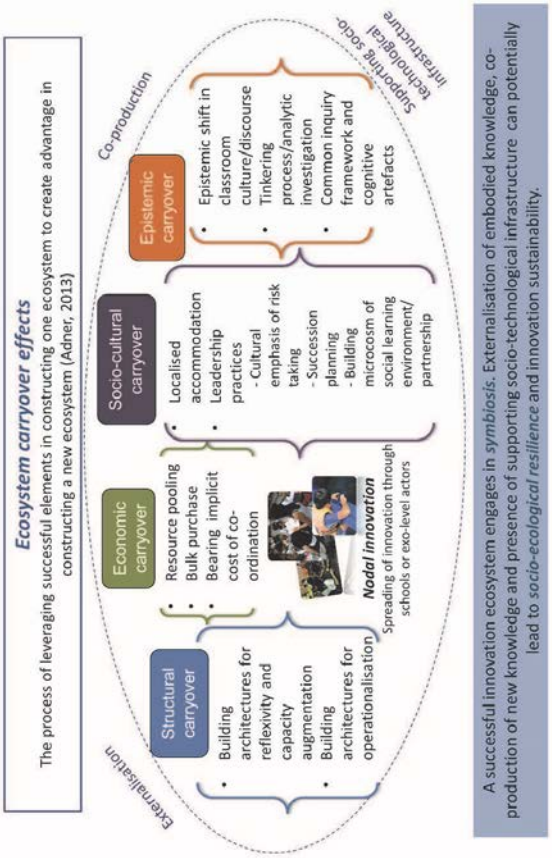
Common Inquiry Framework and Cognitive Artefacts

While teachers may come together frequently for professional learning within, and across schools, there is still a need for the members of the learning network to relate to the binding artefacts. We call these "epistemic anchors" which teachers can fall back on to enhance their teaching and students' learning.

For LxC, this was manifested in the form of co-designed lesson plans conceptualised over a two-year time frame. For KBxC, these "epistemic anchors" could be refreshed or expanded through on-going professional dialogues conducted by Christine. Student-generated artefacts on the technological platform were also anchors for teachers to plan their lessons. Similarly, for CCT, members of the network can take reference from the learning trails designed by schools which were made available to serve as anchors.

Figure 1 sums up the four ecosystem carryover effects that we have discussed. The crux is that the innovation ecosystem needs to be producing new knowledge, instead of merely recycling knowledge for the networks to grow over time. The externalisation of tacit knowledge has to be clearly present. Only then can these individual knowledge become "ecological knowledge" where many actors across the ecology could have access to this tacit knowledge and subsequently embody it (Toh *et al.*, 2014). These actors who have participated in the co-production of new knowledge will help to proliferate the innovations, in contextualised forms that are best suitable for their own local contexts. As long as the critical connections

Figure 1: Leveraging ecosystem carryover effects to build sustainable learning networks[a]



[a] Adapted from: Toh, Y., Hung, D., Chua, P., He, S., & Jamaludin, A. (2016). Pedagogical reforms within a centralised-decentralised system: A Singapore's perspective to diffuse 21st century learning innovations. *International Journal of Educational Management*, 30(7), pp. 1247-1267.

amongst the different innovation nodes are present, the learning network will be less hit by the ebbs and flows of manpower transitions.

Also, we should not underplay the importance of socio-technological infrastructure as it is through these platforms that we get to "preserve" knowledge and share it across time and space. Lastly, we recognise that an innovation ecosystem that constantly engages in symbiosis is a "living system" that is buoyant and expansive, striving to level up capacities collectively.

IMPLICATIONS FOR SCHOOL LEADERSHIP

The ecosystem carryover effects bespeak collectivism as both nodal and innovation-adopting schools need to release resources for the betterment of the members in the network. What then is the role of leadership in enabling such collectivism? We think leaders can play two important roles:

Forge alignment across layers. In our indigenous culture, the goals of greater collectives may be defined by someone with authority and may not be aligned with the needs of the schools or individuals. It is therefore of paramount importance that school leaders, who have proximal connections with the logic of national and organisational goals to forge coherence in terms of meaning-making, amid the plethora of pursuits teachers are engaged in. One important structure that school leaders could establish is to align the school-based professional learning communities with that of the networked learning communities to optimise learning. This is akin to the concept of ecological leadership expounded in chapter 3.

Harness network resources to close competency gaps. School leaders can leverage meaningful networks to mitigate competency gaps of the school. As enumerated by some principals, teachers' participation in learning-focused networks can develop their pedagogical-content knowledge in an ongoing fashion. In general, artefacts such as lesson plans alone do not travel far but knowledge could. The knowledge deepening process can be actualised via interactions, knowledge co-construction as well as strong

support and commitment from member schools to enable a common change agenda.

CONCLUSION

While bottom-up learning networks are common in other systems, such networks are not prevalent in our system yet. These networks should be encouraged as they can provide innocuous contexts for innovation tinkering. Conventionally, these innovations would have achieved proof-of-concepts in pilot schools before we diffuse these innovations into other schools. With this as a backdrop, such networks provide alternative opportunities for schools to groom their promising teacher leaders who may not have attained formal appointments such as Senior Teachers (which are conferred by MOE) yet. These promising teachers can start proliferating innovations and gain experience in leading change within informal learning networks. Schools that are innovation-ready can take the lead in facilitating joint practices. For schools with nascent capacity, they can look to such networks to level up the capacity of their teachers to become change agents.

We have distilled the successful ingredients of an innovation ecosystem, focusing on the concepts of structural, economic, socio-cultural and epistemic carryovers. When these ecosystem carryover effects are present in the learning networks, we are more confident that the learning would be deeper and more sustainable, while also acknowledging the fact that individual school context does matter. However, at the network level, champions could consider integrating these four principles when facilitating professional learning. In alignment with the spirit of a "living" innovation system, we believe these principles will also become more sophisticated over time with continued research and sharing of insights by both researchers and practitioners alike.

The next chapter will discuss the specifics of designing for empowering partnership that brings stakeholders together to achieve scale and sustainability of school-based innovations. This empowerment of

partnership will be another instantiation of ecological leadership where an ICT-enriched school examines its relationship with other actors, within and across the various subsystems, to make attempts to create a win-win solution for all partners along its trajectory of reform.

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