Title	Innovation becoming trajectories: Leveraging lateral and vertical moves for collaborative diffusion of 21st century learning practices
Author(s)	David Hung, Yancy Toh, Azilawati Jamaludin and Hyo-Jeong So
Source	*Asia Pacific Journal of Education, 37*(4), 582-600
Published by	Taylor & Francis (Routledge)

Citation: Hung, D., Toh, Y., Azilawati Jamaludin, & So, H.-J. (2017). Innovation becoming trajectories: Leveraging lateral and vertical moves for collaborative diffusion of 21st century learning practices. *Asia Pacific Journal of Education, 37*(4), 582-600. http://dx.doi.org/10.1080/02188791.2017.1388213

Innovation Becoming Trajectories: Leveraging Lateral and Vertical Moves for Collaborative Diffusion of 21st Century Learning Practices

Abstract. This paper argues for innovation diffusion as a *becoming* process in the context of lateral and vertical moves. The context of these innovations involves technology-mediated innovations and their diffusion trajectories in the Singapore education system. Embedded in a centralised-decentralised dialectics, this paper traces particular innovations from their nascent beginnings to their present state of play. We found that the cases we observed had lateral (or decentralised) moves and subsequently supported by vertical (or centralised) ones. Characterising these innovation diffusions was challenging as we found them to move across models according to different granularities and levels of analysis. Instead, we have chosen to characterise these diffusion patterns as *innovation becoming*. We attempt to distil some substantive generalisations from three case studies presented and how decisions can be made for future innovation diffusions. We recognise that the trajectory for innovation diffusion is inextricably linked to the identity projected by the particular innovation and the leadership supporting it.

Keywords: innovation diffusion; scaling; translation; centralised-decentralisation; innovation becoming

Introduction

The Singapore education system has become increasingly decentralised since the nation's independence in 1965. Schools now enjoy significant degrees of pedagogical autonomy as compared to the past where many aspects of education were tightly prescribed. However, the prevalent emphasis on national high-stakes examination as a

measure of school performance and the relatively successful efficiency-driven model of teacher-centred transmission remain as impediments to the enactment of student-centred learning and instruction in classrooms. As such, since 1997, with the advent of the "Thinking Schools, Learning Nation" (TSLN) initiative, the Ministry of Education (MOE) has been encouraging schools to adopt pedagogical innovations, and this is supported by policies that encourage the integration of inquiry-based learning, critical thinking, and creativity into teaching practices.

With the far-reaching narrative of TSLN as a perennial backdrop, the seeding of technology-mediated learning innovations in Singapore began as a national initiative to move towards 21st century learning since a decade back. Much of the success of this movement relates to the capacity of school leaders and teachers to enact innovations, interpret resources and align the intent of the innovation to system, school and personal goals, beliefs and orientations to prevent 'lethal mutations'. The aim of this paper is to discuss the tenuous journey undergirding the pedagogical innovations championed by schools or actors with system leverages – that is, those who champion innovations with a positional authority within the Ministry of Education (MOE). The conundrum is that ground-up decentralised trajectories appear to be more sustainable within the innovation locale from the onset as they nurture the capacity of passionate ground-level champions to enact the innovations. While western-centric literature seems to have a predilection for decentralisation, centralised top-down imperatives do have merits in terms of accelerating the implementation pace of innovations and consolidating systemic insights. Unwittingly, schools may appear to support top-down roll-outs more than decentralised efforts. However, when school leaders can make proper assessments of the array of innovations and make critical decisions to appropriate the ones more relevant to the respective school, innovations have a greater sustainability propensity.

As such, we recognise that successful innovation diffusions have both lateral (decentralised) and vertical (centralised) moves, capitalizing on the affordances of the structures in the educational system.

Lateral moves refer to the heterarchical movements or interactions amongst grassroot entities on the ground. For example, researchers, industry players, community actors are considered grassroot entities without differential position in power and a lateral movement comprises a shift of diffusion role from smaller networks such as researchers to bigger networks such as industry players. Vertical moves refer to the hierarchical movements or interactions with entities that have proximal connections to our school system. Vertical progression happens when the role of diffusion is undertaken by an entity that is closer to the ground to another entity that is nearer to the central core of the education system. If a school-led innovation becomes a system-led endeavour, it will be considered a vertical move upwards.

The case studies we describe in this paper have yet to enjoy systemic outreach. While the system advocates 'top down support for bottom up initiatives' (Hung et al., 2016), the implementation is much more fraught with difficulties as conceptually recognised, notwithstanding the fact that there are coruscating centralised supports provided. Hence, the central contribution of this paper is to articulate the dialectical nature of lateral and vertical moves in the system and consider how they can perhaps contribute towards the sustainability of innovations to benefit as many schools in Singapore as possible.

Literature Review

Centralised-Decentralisation

Schools in Singapore have over the years been accorded increasing levels of autonomy to enact pedagogical innovations. However, centralisation still plays a pivotal role as the Ministry of Education (MOE) needs to ensure schools remain rooted to the national thrusts of development and that the education ends are met (Ng, 2010). Such "centering" of forces to maintain system coherence and "de-centering" of forces to allow local decisions (Chua, 2014) in a tightly coupled system is what Ng (2008) terms as "centralised-decentralisation". The centralised-decentralisation forces can also be understood from the practice of tight-loose-tight framework where our education system adheres largely to a tightly prescribed curriculum but enjoys local autonomy on pedagogical approaches and converging again on assessment aspects in the form of centralised, national high-stakes examinations for mainstream schools (Toh et al., 2016). This centralised-decentralisation phenomenon is also observed in the recent education reform initiatives of the East Asian countries such as Japan and Korea. These countries have been recognised by their high academic performance in the international comparison study. Their centralised education systems have been gradually loosening their control over the years, granting more autonomy in curriculum, assessment and instruction to schools and teachers (Zhao, 2015).

With the exception of specialised independent schools, most schools in Singapore have to follow the prescribed curriculum designed by MOE. This is in contrast with systems such as Canada where all the 11 jurisdictions have their own curriculum (Newton & da Costa, 2016). Tight accountability mechanisms also exist in other education systems, albeit with different granularities. For example, in England,

schools have the mandated freedom to come up with their own assessment system based on a set of national core standards. However, the repercussions of under-performance are considerably more austere as these schools would be subjected to regular re-inspections by regulating bodies and run the risk of restructuring and job displacement, thus muting schools' risk appetite for innovations. This results in a possible shift of emphasis towards meeting the demands of accountability regime (Greany & Waterhouse, 2016). Similarly, Korea's accountability system in education has been traditionally characterised by high-stakes examinations and tight adherence to the national curriculum standards. The recent initiatives of education reform, however, reflect the gradual shift of accountability from the central government to the local government and schools. In 2015, the Korean government made extensive revisions to the national education curriculum in order to grant more flexibility and autonomy in curriculum planning, enactment, and assessment at the school level (OECD, 2016). The free semester (free learning semester or free-exam semester) is one of the key examples of such a decentralised move in accountability. Under the major movement toward "happy education", the free semester program provides students during the first year of secondary school with an exam-free semester where they can develop competencies in the areas of their interest and freely explore various career options. The underlying goal of this initiative is to promote students' socio-emotional well-being, coupled with the aim of shifting pedagogy toward student-cantered teaching and assessment methods. Despite such an innovative move, the level of regulation in the overall education system in Korea remains high, as seen in the enforced nation-wide implementation of several recent initiatives – the most notable being the use of digital textbooks across schools in Korea.

For Singapore, OECD (2011) highlighted the nation's unique coherence where the three key bodies of education, namely the MOE, National Institute of Education (NIE) and schools, share responsibility and accountability in a unified manner. The important policies undergirding the dencentralisation movement include the "Teach Less, Learn More" (TLLM) and Masterplans for ICT in Education initiatives. Under TLLM, content reduction of school curriculum was implemented in favour of providing white space for schools to tinker with forward-looking innovations to bring about changes that are pertinent to the imperatives of 21st century learning. Under the Masterplans for ICT in Education initiative, some schools became ICT-enriched schools that explored the use of cutting-edge technology for pedagogical change. These schools are also encouraged to propagate their innovations to a wider community. We have documented the diffusion trajectory of these ICT-enriched schools in Singapore and have characterised them according to planned deep and planned wide models with variants along the continuum (see Hung et al., 2016). This paper attempts to delve into this dialectics/balance of both centralised and decentralised efforts in the scaling-diffusion process. To understand the dialectics, we are framing the innovation trajectory of three exemplars as a *becoming* process to reflect its dynamic nature, interweaving and leveraging both vertical and lateral moves along the diffusion path.

Innovation trajectories of becoming

Becoming

The notion of "*becoming*" has its roots in Vygotsky's developmental theory where individual change is enabled through "transformation of socially shared and fully contextualised activities into internalised processes" (Stetsenko, 2009, p.8). As a corollary, both individual and collective practices are mutually-constituting, contributing

to the process of *ideological becoming* forged through the crystallisation of artefacts including concepts, norms, rules, rituals and procedures which embodied past, present and future enactments. These artefacts, as posited by Stetsenko (2009), are "*tools of our own becoming*" (p. 11) created as part of the activist process for collaborative social transformation. The process encapsulates the endeavours of teaching, learning and transformation into everyday practices. Such view on the inter-agentic shaping of *becoming* is also articulated by Heidegger (1998) who disavows education as "merely pouring knowledge into the unprepared soul" (p. 167) but instead advocates a reflexive stance for other possibilities and ways of being.

Building on Heidegger's philosophy, Dall'Alba (2009) outlines the four ambiguities of *becoming* as educators learn the professional ways of being. They are namely: continuity with change, possibilities with constraints, openness with resistance and individuals with others. "Continuity with change" respects temporality which, according to Dall'Alba opens up a range of possible development trajectories while directing one away from others. The central question underpinning this ambiguity is who we are (*becoming*) through the enfolding process, tapping on resources or embodied experiences accrued from the past and bringing it into the present and the future in order to become professional ways of being. The "continuity with change' will open "possibilities with constraints" where routine, regularities, historicity and social structures will serve as moderating parameters of new practices. "Openness with resistance" refers to ways in which customary ways and preconceptions or power differentials may enervate the drive to sustain nascent changes. "Individuals with others" delves into how the reciprocal interactions and mutual engagements between self and others shape the process of *becoming*. This is akin to Rogoff's (2003) articulation of "transformation of participation" where one's sense-making endeavours are holistically

intertwined with the interpersonal, personal and cultural–institutional aspects that one is situated in.

Innovation becoming

Appropriating the notion of "*becoming*", the trajectories of innovation development have long been recognised as underpinned by multi-actor processes and the institutional context in which knowledge generation, dissemination and use takes place (Hall et al., 2004). Perspectives from evolutionary economic on innovation (Nelson and Winter, 1982) further suggest that historicity is an integral element of the recognition of an innovation's trajectory of *becoming*. *Becoming*, in the Deleuze and Guattari's (1987) sense, is a non-teleological, continuous process through which any entity may make connections to other things that matter. A *becoming* is "neither one nor two, nor the relation of the two; it is the in-between" (Deleuze & Guattari, 1987, p. 293).

In an innovation trajectory of *becoming*, actors or users of the innovation, their roles and configurations evolve over time and play out in an unfolding trajectory, in response to various economic, social and policy triggers in the wider ecological environment. Such an evolution arises partially because actors involved in innovation continuously learn how to do things better and continuously adapt how they do things because the context they operate in is also constantly changing and they need to respond to this. Recognising the myriad of 'connection' possibilities, innovation path dependency and the unpredictable nature of the shaping environment intersect to produce a limitless range of innovation trajectories (Reddy, Hall, & Sulaiman, 2012, p. 479). In addition, as innovations and their varying entailments are brought into use, different skills, resources and expertise are required at different times in the unfolding trajectory. The analytical insight that comes from exploring innovation trajectories is that it starts to reveal how

organisations involved in innovation implementation marshal expertise and resources to meet the challenges of an unpredictable context and how they tackle complex social phenomena, such as epistemology, that are themselves embedded in its own dynamic context.

Further to this, while the focus of innovation development has primarily been on the actors, environment, and related social context, the analysis does not yet do justice to the agency of the innovation; that is to say, it does not reckon with the way in which the innovation is itself *becoming*, and not just a passive, inert entity. To this end, the emphasis on *innovation becoming* as an end in itself harmonises with recent explications of 21st century orientations that likewise value action and process over result and product. Particular to curricular innovations, within an experiential, social space of school environments, as actors form configurations of innovation use, they are operating at both levels of personal as well as collective enactments of the innovation. These levels, however, are not merely an aggregation, in that the social effects of the innovation at the collective level cannot merely be described as individual volitions at the personal level. Rather, interaction at these two levels may more aptly be characterized as dialectical, and an emergence of multiplicity of relations embedded in and performed by shifting connections and interactions. Such relations are in the sense that O'Riley (2003) describes as "dynamic, heterogeneous, and nondichotomous; … they propagate, displace, join, circle back, fold ... de- and reterritorialize space" (p. 27). Thus, the actor-innovation-environment assemblage is akin to an open set of unstable relations, which are in relation to *other* relations, some of them more constraining or limiting than others.

Against this backdrop, this paper orients towards a more analytical focus on the *becoming* trajectory of innovations. Specifically, we trace the *becoming* trajectory of three school-based innovations and seek to unpack the salient tenets of champion

actor/leadership functions that underpin the spread and evolution of each innovation. We discuss in detail the dialectics of innovation (vertical and lateral) *becoming* as *diffusion mechanisms* and its potential for offering a productive framework for studying innovation 'scale' and diffusion in schools. The paper will also explicate the four ambiguities of being (continuity with change, possibilities with constraints, openness with constraints and individuals with others) as *becoming* processes underpinning the three innovations.

Research Context

The three school-based innovations is part of an encompassing study on the meta-study of projects awarded under a MOE-supported funding programme to surface and spread ground-up ICT-based pedagogical innovations that are aligned with the thrusts of 21st century competencies. The three projects chosen for discussion in this paper have enduring and distinctive developmental trajectories that go beyond the locale of champion school due to whole-school technological integration and outreach efforts. Additionally, these schools have created networked communities that centre on pedagogical improvements for in-class and out-of-class learning contexts.

Data were drawn from interviews with school personnel, vendors and (teacher) champions of the innovations. For the purpose of this study's inquiry, we used a purposive sampling method when selecting our interviewees across the three projects. Maximum variation sampling was considered when selecting the schools amongst the three networks. As far as possible, we tried to gather data from schools of different profiles and outcomes of implementation. Key actors of the three projects were selected, taking into account their different roles in order to gain a holistic perspective of policy formulation regarding pedagogical innovations, partnership and apprenticeship model; as well as ground sentiments on innovation implementation. These data were further

triangulated with observations of professional development sessions to understand the nature of professional discourse emerging from the various communities, thus distilling insights regarding the extent of participatory dialogues and innovation ownership, as well as observations of fieldtrips and classroom enactments to understand how teachers had translated pedagogical principles into lessons and how they had negotiated their identities and co-constructed knowledge with students. Artefacts arising from the innovations as well as analysis of documents such as closing reports and publications related to the projects were also analysed (see Table 1). Pseudonyms are used for the three innovations. Consistent to the *becoming* trajectory principle at hand, the meta-study traces the developmental processes of these three cases over time.

The first project, *Cross-contextual Inquiry-based Science Learning (CIBSL)* leverages 1:1 mobile technology to enable learning across both formal and informal learning contexts. The use of mobile technology serves to create synergistic learning moments in the daily lives of primary three and four students (aged 9-10 years). Currently, the innovation which started in 2008 had since spread to another 10 schools. It entails the re-design of science curriculum within and across participating schools, change in instruction to student-centred inquiry learning processes, as well as new design capacity for mobilised learning activities to be conducted both in and out of the classroom contexts.

The second innovation, *Knowledge Building Across Domains (KBAD)* began in 2010 and had since spread across different disciplinary domains to (currently) 21 schools. The innovation centres on the co-construction of ideas based on authentic problems and multiple perspectives to advance knowledge for deep understanding. Ideas and discourses are developed for both face-to-face and in class use as well as via an online platform with strong learning analytics embedded for understanding the

interaction and critical thinking patterns of teachers and students. The innovation thus requires teachers to be attuned not only to idea-centric pedagogy but also to facilitating online and offline discussions as well as interpreting the rich data afforded by the online medium.

The third project, *Digital Trails Across Domains (DTAD)*, was introduced in 2011 as a curricular innovation to "harness elements of real-world data collection, inquiry-based learning, collaborative learning and active knowledge construction" (Toh et al., 2014, p. 842) during learning journeys. Due to the mutability and flexibility of innovation enactment as core or peripheral aspect of classroom learning, the innovation has spread to more than 200 schools at both cross-zonal and cross-cluster levels and across different disciplinary domains (Hung et al., 2016).

Table 1 shows how the objectives of the three innovations are mapped to Singapore's 21st century competencies, as underscored by the MOE (2016); and, the data sources we have drawn reference from for the analysis of the three innovations.

Innovation	**Objectives**	**21st Century Competencies**	**Data Collection**
Cross-contextual Inquiry-based Science Learning (CIBSL)	Using mobile technology for integrated and synergistic effects of inquiry-based learning in both formal and informal settings, which is distributed across different learning processes - emergent or planned as well as across different spaces - in or out of	Self-management; Critical and Inventive thinking; Self-directed learner.	Interview data with school leaders, middle managers and experimental teachers from nodal school and 5 other CIBSL schools from the same zone that experienced varying degrees of success in innovation implementation. We also interviewed the university researchers involved in the project. Observational data of professional learning sessions conducted within the nodal school and networked learning communities across all CIBSL schools. Observational data of lessons enacted by experimental teachers in the nodal school.

	class (Toh et al, 2013).		
Knowledge Building Across Domains (KBAD)	Using technology with embedded learning analytics to capture and 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 in order to collectively improve ideas and achieve knowledge advancement.	Relationship management; responsible decision making; Communication, Collaboration and Information skills; Critical and Inventive thinking; Active contributor.	Interview data with school leaders, middle managers and experimental teachers from selected KBAD schools. The selected schools include four CORE KBAD schools that have a sustained KB programme as well as one school that faced multiple challenges in continuing the innovation. We also interviewed the educational specialist from MOE championing the project. Observational data of professional learning sessions conducted within core KBAD schools and networked learning communities across all KBAD schools. Observational data of lesson enacted by adept experimental teacher in one of the KBAD schools.
Digital Trails Across Domains (DTAD)	Using mobile technology and leveraging resources outside the classroom to enrich learning. Social resources such as participation from the community to enable students to engage in innovative authentic learning experiences within designed learning spaces were crucial (Hung et al, 2016).	Social awareness; Communication, Collaboration and Information skills.	Interview data with school leaders, middle managers, experimental teachers, students and commercial vendor. Data were drawn from the nodal school and three other consortium schools that have scaled DTAD in their respective schools. Observational data of professional learning sessions conducted across consortium schools. Observational data of fieldtrips conducted by the nodal school and three consortium schools mentioned above. We also followed through the observation of the National Learning Trails Competition, from its inception to completion.

Table 1. Mapping innovation characteristics to 21st century competencies.

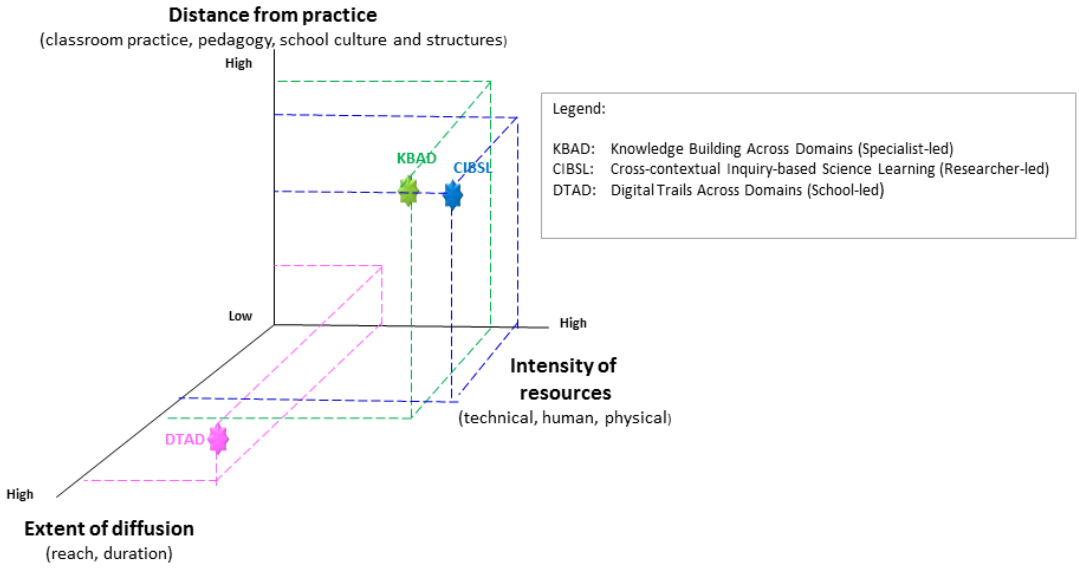

Figure 1. Comparison of the 3 innovations

The three innovations differ in terms of the distance from the prevailing practices in schools; intensity of resources required and reach of diffusion (see Figure 1). The prevailing practices refer to the performative pedagogies that are deeply instrumental and rarely "deviated from a logic of curriculum coverage, knowledge transmission and reproduction (assessment)" (Hogan et al., 2013, p. 58). The projects represent attempts to expand teachers' pedagogical repertoire to integrate 21st century competencies through the use of technology. In particular, the three innovations exhibit orientations towards inquiry-based learning. However, KBAD is considered the most radical amongst the three as it requires teachers and students to be imbued with the skills of facilitating dialogic interactions; co-constructing knowledge online and offline; and interpreting and capitalising on the learning analytics embedded in the innovation to improve learning outcomes. On the other hand, CIBSL is considered the most resource intensive as it requires the use of 1:1 computing devices for frequent in-class and out-

of-class usage, especially in its earlier years of implementation – an indication of the routinized use of mobile technology as part of teachers' daily pedagogical repertoire and students' learning strategy. In terms of diffusion, DTAD has enjoyed the widest reach of more than 200 schools. All three projects have, at certain point of their innovation trajectory, received funds from the MOE to embark and continue the spread of their innovations.

Diffusion and Becoming Mechanisms Underpinning the Innovations

Case Portrait 1: Cross-contextual Inquiry-based Science Learning (CIBSL)

The genesis of CIBSL began in 2008 under a school-university partnership which saw two resident university researchers situating themselves in an ICT-enriched school, working intensively with an experimental teacher to re-design the science curriculum and influencing pedagogical enactments both in and out of the classroom contexts. The researchers aimed to infuse inquiry-based learning across different learning spaces via the use of 1:1 mobile technologies. In this instantiation, researchers symbolise the exo-level (partners from the community) actors who are *lateral* re-contextualisers of pedagogic discourse. The longitudinal intervention study grew from strength to strength. In year 2011, the school formed a taskforce to improve the co-designed primary Year three and four curricula to specifically integrate more activities for differentiated learning. By 2014, the differentiated curriculum was scaled up across both primary three and four levels. The innovation was also spread to another 10 schools by 2016. The nodal school acted as a focal point and absorbed the implicit cost of device maintenance and technological development for a suite of mobile applications to be used across participating schools. The nodal school also corralled a series of dialogues

with school leaders, middle managers, teachers and technical assistants of schools participating in the project.

There was an apparent shift of innovation ownership since 2013 as researchers faded into the background and the two experimental teachers who were developed from within the school exhibited readiness to lead the inter-school networked learning communities (nLCs). The spread of the innovation to two clusters of consortiums schools was facilitated by both system and community players. The former was epitomised by the involvement of the Cluster Superintendent who selected five schools in the North Zone to partake in the innovation. The latter was epitomised by the diffusion mechanism of Clan Association that convened its five affiliated schools together to embark on the innovation. The last school that joined the nLC was not an affiliated clan school but came on board due to leadership transfer. The former vice-principal of the nodal school became the principal of another school and expressed interest for her school to participate in the nLC. Industry players such as a renowned IT company and overseas consultants from other universities also provided expertise in terms of developing an integrated suite of mobile applications for the students. The innovation *becoming* trajectory can be categorised into these three main phases: shift of ownership in technology deployment, followed by curriculum design and more recently in professional development (Toh, Lee & Ting, 2016). Both *lateral* and *vertical* moves contributed to the diffusion of the innovation.

Continuity of change was evident in this innovation. The school made a strategic decision to focus on 1:1 technologies in year 2005. The change of leadership in 2008 did not disrupt this vision, thus enabling the school to enjoy continued progression in this niche area by opening a range of possibilities and at the same time; streamlining resources for their 1:1 learning endeavours. Pedagogical consensus was forged through

iterative feedback on the teaching and learning framework. However, the school faced *possibilities with constraints* too, which were most exemplified through the debate of how the use of mobile technology as a new routine may jeopardise syllabus coverage and how a constructivist approach may compromise scientific literacy, which the then-head of department (HOD) thought should be best taught through traditional methods and assessments. Technological infrastructure also posed a tenacious challenge which was later resolved by working with vendors. Teachers had also undergone the process of *openness with resistance* where the innovation challenged their assumptions and caused initial displacement in terms of their identity during enactments. They had to relinquish their power and make pedagogical judgements on when and what would constitute the best way to validate answers to students' queries. The current HOD recounted the struggles:

> … Before I get myself into this project, I was also very half hearted, honestly speaking, because all these while I have been teaching upper primary students. The teaching emphasis is very result and examination-oriented….But results have shown that the students have improved after embarking on this project…… not only in terms of responding to higher-order thinking questions in examinations but in terms of expressing their ideas in class as well. In the past, the students just rely on the teachers to give them the answers. Now they pose great questions that the teachers have difficulty in responding. I tell my teachers it is alright not to know the answers to these spontaneous questions as we are not walking encyclopaedia. We can start a discussion around the question and find out the answer together.

The new pedagogical direction necessitated co-learning with parents too. Teachers had to master the art of managing parental expectations in-situ, especially with regard to content delivery. As some of the activities involved parental engagement, the ex-HOD was concerned that the design of out-of-class activities may inadvertently exacerbate the issue of equity where students with challenging family circumstances may not be able to participate fully. The differentiated curriculum which was devised at a later stage afforded teachers more flexibility in deciding a best-fit for the class without compromising the spirit of CIBSL.

The tipping point that led to sustained change occurred when the proof-of-concept was achieved across all enactment classes with different contextual conditions. Such changes occurred as a result of intensive interactions and rapport building with peers, students, researchers and educational technological officers, as manifested in an open classroom culture where all can observe, affirm and respectfully provide suggestions for refinement. Such inter-agentic dialogues and trust between *individual and others* shifted the mental models and pedagogical discourses of actors involved, attesting to the postulation that "individual learning is socially conditioned so that tacit cognitive commonalities emerge within intensely communicating groups (Witt, 1998, p. 68). As the innovation spreads to other schools, the curriculum went through another round of re-design which saw a significant downplay of the informal learning context. Classroom context and national instructional model of 5E (Engagement, Exploration, Explanation, Elaboration, Evaluation) took precedence, suggesting the presence of both macro and micro-level forces at play.

Case Portrait 2: Knowledge Building Across Domains (KBAD)

Knowledge building hinges upon the notion of deep constructivism where students can improve one another's ideas through collective inquiry process to reify the conceptual artefacts that emerged from the on-going discussions. The KBAD innovation is championed by a specialist in the Educational Technology Division (ETD) from the MOE with embedded professional capital accrued during her days as a school teacher and as a PhD student mentored by academics well-versed in knowledge building. As KB is a process-pedagogy that requires nuanced facilitation skills and deep technological-pedagogical-content knowledge, the champion is aware that it cannot be supplanted into Singapore classrooms without any re-contextualisation. Due to the champion's deep understanding of Singapore classroom practices and the mental models of local teachers, she is able to facilitate changes over time through intensive and meaningful PLCs. By forging "structural congruence", the champion and teachers worked within the parameters of the existing context in Singapore schools while making attempts to introduce new theory, pedagogy and environment to seed favourable conditions for nurturing a mature KB community. This symbolises a *vertical* move propelled by a player with systemic leverages.

The specialist's roles include creating a visible point-at-able model where others can see and take reference from; injecting cultural dissonance to challenge teachers to think about new problems of practice; curating the resources from teachers (student artefacts, lesson notes and teachers' reflection notes) to orchestrate for momentum to take place during discussions on how to move students' inquiries forward; anchoring teachers within a frame of reflexivity that is digestible and aligned with the principles of KB; helping teachers understand the affordances of Knowledge Forum and proposing strategies that would promote meta-cognitive thinking as well as developing school-based core expertise at each innovative site so that the innovation can be sustained. She

also proactively encourages selected school leaders to adopt sustainability strategies, creates networking opportunities for teachers and spreads KB across schools through teachers' own sharing and leverages on MOE's existing structures for across school networks to be formed gradually. In addition, she also shares emergent developments and findings with school leaders every six months.

The innovations started with two schools in 2010 and had since spread to 21 schools by 2017. Concomitantly, as diffusion occurs, there is a need to rethink about the sustainability of the growth of community members. The specialist had trained up a cadre of school champions who would be able to lead not only in their schools, but also in the cross-school networked learning communities (nLCs) too. It appeared that the specialist had progressed from being a pedagogical champion to being a community champion of KB building up a network of second layer champions, thus imbuing schools with capacity to make *lateral* moves to diffuse the innovation. In fact, recent development shows signs that schools are beginning to spread the innovation to other new participating schools, and these new KB teachers will be mentored by the transformed teachers instead of the specialist. In terms of socio-technological infrastructure, the specialist will act as a conduit to link local school practitioners to overseas developers and consultants to learn how to harness the new features of the enhanced platform. The *continuity of change* is thus evident, as seen from the longevity of the innovations and transformation of teachers' capacity over the years. Said the principal from one of the core KBAD schools:

> [The core KB teachers] who are already quite competent, have taken a bigger role, to invite teachers to look into their KB lessons and also to go into classes. So that the teachers can see for themselves how it works…..I'm trying to get more teachers on board, strengthen the team. I mean I've got the lead KB

> teacher, [but] one day she might become a master teacher (who will be re-deployed to MOE Headquarters)…..so we have to ensure succession planning and sustainability of keeping [KBAD] going.

Notwithstanding the favourable developments of the innovation in general, there are also *possibilities with constraints* that confound the variegated contexts of schools enacting the innovation. One of the school leaders expressed the concern that KB which is demanding in terms of cognitive processing and literacy skills may not be pitched at a right level for their challenging cohort of students. In another instantiation, the change of preference for performative pedagogies, brought forth by a change in school leadership, resulted in a school being sclerotic about innovations. Teachers' *openness* can thus be met *with resistance* from school leaders, or sometimes even peers. One champion teacher recounted her arduous road to "convert" other teachers to come on board. She circumvented the problem by aligning the innovation thrusts to the overarching imperative of equipping students with 21st century competencies. The KBAD lead teacher recounted:

> Initially [that teacher] kept delaying coming on board, and I couldn't form enough members. And finally one day I just went to her and I said: 'Can you imagine if you taught those children and they walked out of your hands, graduating but not learning more, not learning deeper, just learning enough to survive and scrape through… they don't have skills of being a collaborative learner, or resourceful self-directed learner adept in finding solutions? [KBAD] offers that platform for change…Are students going to be happy, always going for something like results, academics? What about enjoying working with people?' And that got her. Finally, she said okay, I do it just for you. And I said

> no, if you do it for me, I'd rather you get out of my PLT (Professional Learning Team). And that's where she came full on board. And she really took off.

Under intensive apprenticeship from exo-level actors, participating teachers had witnessed the transformation in students' engagement level and their ability to frame problems after the introduction of KB in lessons. Students had "matured cognitively". Teachers themselves were more predisposed towards exercising critical thinking in their teaching approaches, foregrounding students' ideas and becoming less prescriptive in their outlook. Another KBAD lead teacher reflected:

> In the past I've been using frontal teaching basically from the start to the end. In between I may have activities definitely, like oral presentation, we have role play all these, definitely we still have it. As of now I still have all this in between my knowledge building lessons too. But the focus is quite different. In the past, activities are just activities…..I will just design any activities related to the content knowledge that we have……Now, Students' entries form the foundation, the most important part of it. But no matter what… whatever questions they are going to ask will still fall within our lesson plan. It's just how we put it together and how we think through the process.

As the epistemic agency shifts towards the students, they now have a greater role in shaping the classroom discourse.

Case Portrait 3: Digital Trail Across Domains (DTAD)

Since its inception by an ICT-enriched school in 2011, *DTAD's* reach has been extended to more than 200 schools in Singapore. Following a successful and pervasive implantation of the innovation within the nodal school, the school continues to devote

time to help other like-minded schools in their journey towards digital age learning. The principal of the nodal school had participated in policy formulation at MOE before she was posted to the nodal school and appeared to be imbued with a systemic view about capacity building at the multiple levels of the school ecology. Notwithstanding the intensive resource deployment, the school was able to meet accountability structures, yet at the same time attending to accelerated diffusion based on teachers' core competencies and volition. Thus, whilst the school consolidated diffusion efforts within a nested, selective group of inclined teachers, it was also attuned to the needs of individual teachers on the ground. The selective group of teachers comprises a tier of ICT champions who were oriented towards specialized training that was meant to "stretch" the school's ICT expertise and to seed the school's innovations to other interested schools; either from the same school cluster or beyond (ref removed for review). Within the formal structure of school cluster, the nodal school provided consortium leadership to help the 10 schools that were under the same cluster to advance the innovation while concurrently also spreading the innovation to other schools in the system through other means such as the learning trail design competitions and bootcamps which drew wide participation from across Singapore schools. Representatives from the MOE and Institutes of Higher Learning were roped in as judges of the competition. In 2014, the school organised an inaugural National Learning Trail conference which explored the use of learning trails for 21st century learning. The school also shared learning trail design toolkits and proffered a platform for schools to come together to share their practices. The current ICT HOD remarked:

> …….I think when we started off, we do have ideas of sharing, but I'm quite surprised how things evolved……When we are reaching the third and fourth year, we started to put in the structures, the strands and the program. The ability

to, I would say, share the ideas and getting other schools engaged, that actually surprised us a bit in terms of how much we did is relevant and applicable to other schools and how willing other schools are to come on board.…Our school leaders believe in the scaling part. We have received so much support from the past, now it is the time to give back. And when we say to give back, it is not just organising a yearly conference, but having many constant follow-up engagements with schools that continued to seek support and advice on ICT implementations.

In the endeavour to scale *DTAD*, the school harnessed an amalgamation of social resources. For example, they collaborated with a software development company to develop the mobile application that allowed users to design learning trails and use the application in-situ. The vendor also trained adopting schools on the use of the application. Community engagement was also featured prominently in the diffusion process. The school engaged the National Heritage Board and museums to: (i) promote heritage to the schools and encourage heritage to be infused into classroom subjects; (ii) advise teachers and students on the design tenets of a sustainable and interactive trail; as well as (iii) mentor the methodology to gather oral history data to support the design of the trails.

In comparison to the two innovations mentioned above, *DTAD* adopted an ecological approach from the onset and made more *lateral moves* to harness social resources from the ground.

Possible reasons that propelled the innovation's accelerated diffusion pathway are: (i) the great flexibility it affords in terms of curriculum integration; and (ii) win-win proposition amongst all partners. The innovation can be implemented as a core or peripheral activity across a wide range of disciplines. Due to this attribute of mutability,

the innovation undertook a different ecologically- encompassing diffusion path - diametrically different from the phased apprenticeship model as demonstrated in case studies 1 and 2. In terms of sustainability, the nodal school is open to the possibility for vertical progression -- to transfer innovation ownership to the system to proliferate the innovation further.

The *continuity of change* can be seen from the rapid growth of the community and the iterative enhancements to the application after gathering feedback from the ground. As an example, indoor trails were incorporated based on teachers' request and made feasible via vendor's research into Augmented Reality (AR) technology, thus circumventing technological constraints coalescing around the use of Global Positioning System (GPS). However, there were advanced features that the vendor had incorporated but were underutilised due to inadequate knowledge of practitioners, indicating the *possibilities with constraints*. Notwithstanding the mitigation of technological issues, there were also infrastructural issues that need to be resolved. Some new adopting schools did not have enough devices and would need to borrow them from the nodal school or vendor. In some adopting schools, the content syllabus dictated and restricted the design of the trails. This compromised the authenticity of the trails which would in reality span boundaries beyond the prescribed curriculum of various disciplines.

Whilst most experimental teachers embraced the use of digital trails, getting buy-in from their peers proved to be challenging for some adopting schools. The *openness* was met *with resistance*, the most prevalent being the pragmatic concern of how the innovation can add value to high-stakes national examination. One experimental teacher lamented on how their peers could be "fixated on numbers" about learning gains, indicating the challenge of catalysing lateral movement on the ground without top-down pressure. The interactions between parents were also ineluctably

filled with tensions where the desire to integrate their views and not to be swayed too much by their interference had to be skilfully managed.

Comparison of the Innovation Trajectories

Figure 2 is a visual metaphor of the innovation trajectories of the three innovations. *CLIBSL* originated from university researchers' epistemic apprenticeship. The design and enactment capacity were subsequently transferred to the teacher champions of the nodal school who propagated the innovation further to other schools. Involvement of central players was rudimentary, except when selecting zonal schools to participate in the project. *KBAD* spread as a result of the intensive brokering of a learning specialist with system leverages but was originally started by a researcher from the university. A new layer of school-led champions was nurtured by the specialist over the years. For *DTAD*, the nodal school played a pivotal role in harnessing ecological resources to spread the innovation. Depending on the goals of the innovation, the three cases spread to differing degrees and not all innovations are intended to be scaled to the "system". However, for widest reach, multiple players are needed. An ecology is needed to sustain a community of teachers with researchers and industry players involved.

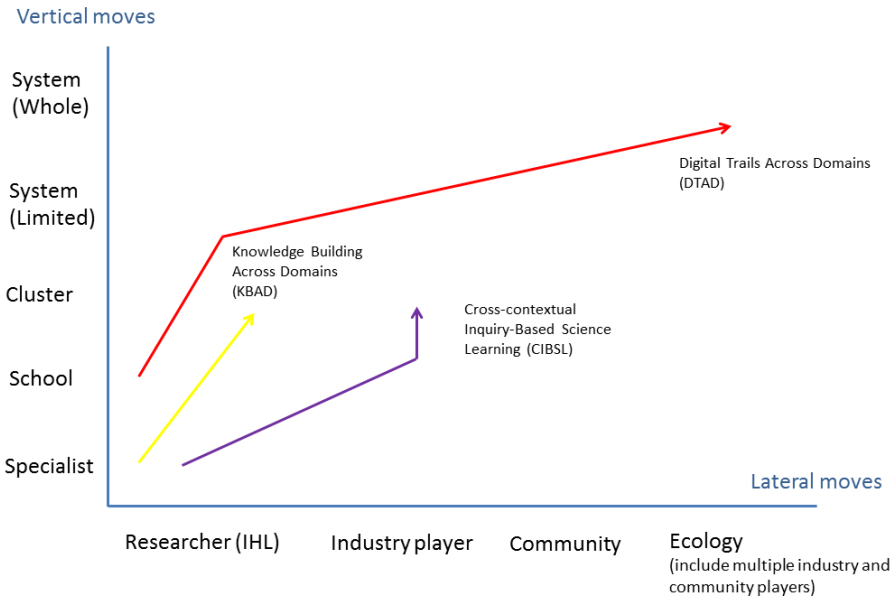

Figure 2. The lateral and vertical moves of the three learning innovations over time.

In practical way in terms of implementation, the three cases could be described along the following tenets (see Table 2):

Leadership functions	Comparisons		
	Case 1 Cross-contextual Inquiry Based Science Learning (CIBSL)	Case 2 Knowledge Building Across Domains (KBAD)	Case 3 Digital Trails Across Domains (DTAD)
Curriculum	Distributed expertise among teachers as well as school leadership for school-wide implementation.	Evidence of distributed expertise between teachers and champions in terms of resource creation. However, champions play a more prominent role in terms of providing overarching pedagogical framework.	Contextual-initiation and innovation integration design driven by core ICT team champions.
Administration	Centralised selection of and support for teachers to ensure high innovation fidelity.	Provision of structural scaffolds and robust selection of schools for innovation fidelity.	Distributed, focusing on multimodality, mobility, innovation mutability and

			teachers' recontextualisation agency.
Trust / Dialogic	Strong dialogic leadership pertaining to system/ school/ classroom levels.	Strong dialogic leadership, but pertaining more to classroom level between teachers and champions (e.g., from ETOs) and increasingly with HODs too.	Strong dialogic leadership, concerted effort to achieve teachers' trust and buy-in seeded by on-the-ground embodied leadership.
Data-informed/ evidence based	Engaged researchers and consultant to analyse data for learning gains. Teachers are also trained in action research to ensure research integrity.	Within-School PLC is driven by co-analysis of student artefacts and strong evidence of learning outcomes.	Iterative, design thinking approach driven by needs analysis, surveys, feedback, constant curricular conversations.
Managing tensions	Dialectical tensions between fidelity and scaling.	Dialectical tensions between fidelity and scaling.	Mitigate tensions by intentionally designing for innovation mutability from the onset to achieve scale.
Lateral relationships	Involving actors across different layers to be involved in inter-school PLCs.	Emerging evidence of champions building lateral relationships through inter-school PLCs.	Reaches out to partners such as industry commercial vendors, other schools, and parents on a mutuality basis.
Vertical relationships	Educational Technology Officers from the MOE are attached to the project(s) from the onset. They facilitate communications and plans from MOE to the schools – leaders and teachers.	MOE's specialist champions the KB innovation and works with HQ for succession planning intents, growing the teachers' capacities to function at the NLC.	Educational Technology Officers (ETO) are distributed according to subject domains to assist teachers in the trails and to make sense of the evidence of learning collected.
Ecological impact	Diffusion process can be slow but with deep change.	Diffusion process can be slow but with deep change and systemic support is centrally co-ordinated.	Wide ecological outreach planned from the onset; however pedagogical depth

			may be compromised by the rapid rate of diffusion.

Table 2. Tenets underpinning the diffusion process of the three innovations.

Discussion

The three innovations have enjoyed robust growth but have yet to exert system-wide influences. The process of diffusion, as illustrated by the case studies, is a dynamic re-configuring process where social influence, pervading culture, innovation type, structural reinforcement and capacity building can heavily influence the direction and extent of propagation. It is noteworthy that within our tightly coupled system, there are attempts to incorporate ground-level insights of innovation implementation back into the central system. For example, MOE officers who have observed and contributed during the inter- and intra-school PLCs distilled design principles from these niche innovations. These principles are then incorporated into the nation-wide learning communities, such as the mobile learning community which MOE has been facilitating. Figure 3 below shows the enablers underpinning the vertical and lateral moves of the three innovations.

The red arrows symbolise the enablers for scaling out while the blue arrows symbolise the reasons for moves toward the point of origin. The dotted arrows represent projected reasons for moves that have yet to occur. The catalysing reasons for the uptake of innovations include the emergence of internal capacity, as demonstrated by disruptive innovations *CIBSL* and *KBAD*. On the other hand, *DTAD*, enjoyed an ecological outreach after successful implementation within the nodal school, signifying a move from school-deep to school-wide implementation. The nodal school also

demonstrated consortium leadership when the ICT HOD orchestrated the integration of the innovation for other consortium schools in terms of device loaning or conference sharing, which represents an ecological outreach move from school-wide back to school-deep implementation. There is also tactical outsourcing as the ICT HOD worked with community exo-level actors such as industry players to develop software and organisations such as the National Heritage Board to contextualise the use of digital trails for history learning journeys, underscoring the importance of collaborating with community exo-level champions in the area of technological development.

As seen from the dynamic nature of innovation diffusion underpinning the three different innovations, the epistemic, cultural and social identities that are encapsulated in these movements evolve over time - a feature redolent of a *becoming* process. These identities are mediated through apprenticeship, social affiliations, socio-technological infrastructure and systemic brokering by regime, industry and school players.

As we observed and characterised the innovation diffusion efforts, we recognised the need to put on a historical lens and frame the innovation diffusion journey of the respective innovations as a *trajectory-becoming* process. We posit that the lateral moves accorded by any particular innovation would have increasing vertical moves when its identity (or recognition by the system) develops. In order to seed these *identity-becoming* trajectories, the development of relationships with the social others as well as the schools' aspirations play a crucial role. For example, in case studies 1 and 3, there is self-referential identity as the nodal schools took on the identity of ICT-enriched schools that fulfil the moral purpose of tinkering with cutting-edge technology to prepare future-ready learners for itself and other schools.

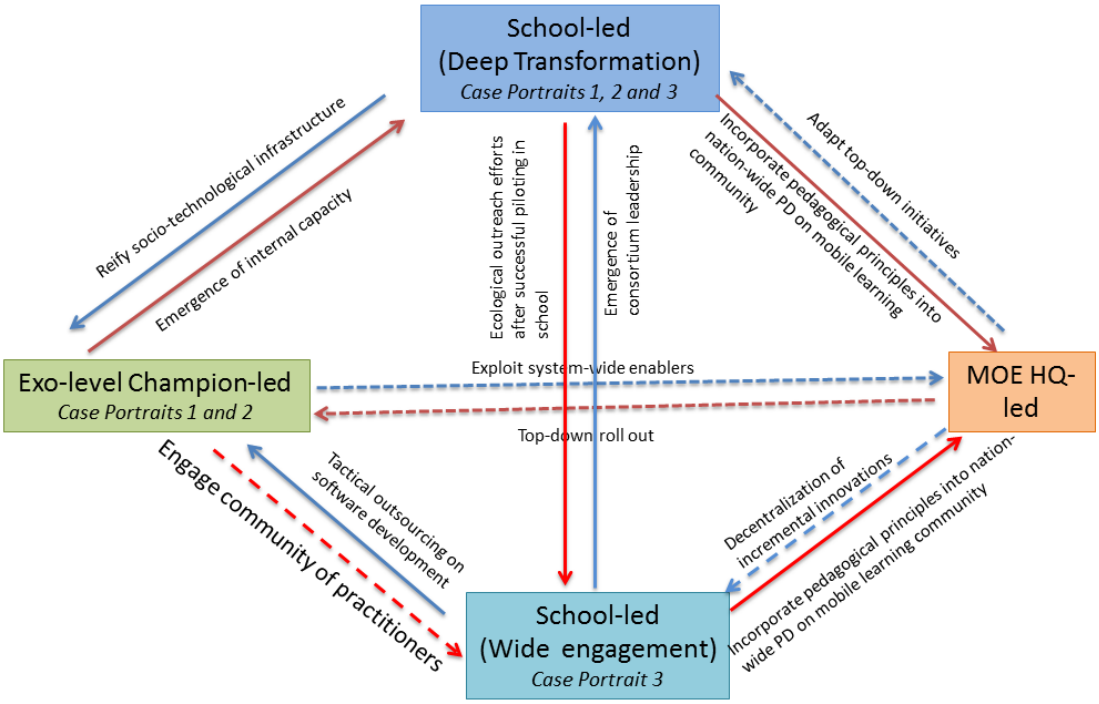

Figure 3. Enablers underpinning the trajectory of the three innovations.

To enhance the interplay of both vertical and lateral moves (see Figure 2), there is a need to: (i) make visible the proof-of-concept so that vertical moves can be facilitated; and (ii) gain traction as far as policy support is concerned. However, there is no prescribed code for deciding lateral or vertical moves if we view innovation trajectories as emergent and contextualised. We need to consider instead the goals of the school in appropriating a particular innovation; the radicalness of the innovation with respect to the readiness of the school and the resourcefulness of the school leaders in managing tensions. As surmised from the three case studies, the multi-faceted tensions of implementing inquiry-based innovations for 21st century learning include: forging episodic versus sustained transformation; incorporating accountability while building trust; emphasising fidelity versus mutability in innovation implementation; ensuring content mastery versus 21st century competencies; and, embracing openness while confronted by resistance. From the system's perspective regarding diffusion, there is

perhaps a need to examine the system's goals and gaps, assess the capacity it has on the ground to enact these innovations with fidelity as well as discern the identity formed on the ground as an assessment of its rootedness and hence a proxy of its sustainability.

Using fractals as an analogy, the centralised-decentralised dialectics exist at the different levels of analysis for the three innovations with orientations toward building 21st century competencies. At the (micro) classroom level, centralised top-down decisions are made. An example being teacher implementing a particular curricular unit, and yet at the same time students are given latitude to direct the discourse of lesson. At the (meso) organisational level, school leaders may decide to embark on the innovations as levers of pedagogical change, but allow the innovation to enfold organically within the school. At the (macro) cluster level, school superintendent may have selected prospective schools to participate in the project, but left it to the prerogative of the school leaders to decide whether they would like to come on board.

At the different levels of analysis, centralised-decentralisation needs to be facilitated either loosely in the manner of centralised selective funding to ensure alignment with the system's strategic thrusts and accountability of the deliverables; or more tightly in the manner of scaling up promising innovations bubbling from the ground. When there is a desire for vertical moves to propagate the innovation further, there should be mediating mechanisms made available to facilitate the expansion of innovation ownership (encompassing the tacit knowledge of conceptualisation and implementation science) to MOE. This could be done through multi-pronged approaches: (i) educational specialists from MOE who shadow the school and integrate insights into a wide array of nation-wide professional learning platforms; (ii) university researchers who document the diffusion process and inform policymakers and other interested schools on pertinent design, implementation, translational and theoretical

principles; and (iii) school champions who are seconded to MOE for the purpose of bringing their nodal innovations to scale through epistemic apprenticeship. Hence, there could be ownership alignments forged through the multiple levels of centralisation-decentralisation forces. These actors should make visible, as much as possible, the identity *becoming/projection* process so that informed decisions on vertical and lateral moves could be orchestrated across the multiple levels of the system.

Implications and Conclusion

Singapore's education system has a unique opportunity to be positioned as one which can leverage both vertical and lateral moves in order to accelerate innovation diffusion for inquiry based learning and 21st century learning competencies and dispositions. Leadership at the multiple levels of the system mitigates and makes possible the lateral and vertical moves, including that of the system and school leaders' ability to network and form community partnerships both laterally and vertically. However, it is evident from the three case studies that teacher champions (or teacher leaders) are needed to enact and sustain the required (micro) classrooms learning inquiry designs. These efforts need to be aligned to the school, cluster, and system levels of interaction. This is in congruence with OECD's (2015) observation of Singapore's on-going attempts to forge system coherence through the concerted efforts of government, university and schools. It is also akin to O'Riley's (2003) assertion that the *becoming* process entails the dynamic sense-making efforts of all actors involved.

We cognise that not all innovations are to be levelled up to the system level; and not all system level innovations have to be dogmatically and prescriptively implemented at all levels of the system. A two-way dialectical interaction of innovation movement from system to schools and vice versa is needed to achieve system symbiosis. The guidelines for deliberations can be summed up by what we termed as the

ARC principles - *Accountability, Readiness and Coordination*. In terms of *Accountability*, whilst Singapore does not subscribe to the model of deregulated curriculum similar to that of Canada; or the sharp, tight accountability mechanism akin to that of England; or the eschew of standardised assessment as practised in Finland; our autonomous space for pedagogical innovations allows like-minded schools to come together to embark on innovations, with the knowledge that they are not dabbling with unfettered experimentations and will be expected to rationalise the outcomes of their experimentations to schools, MOE and sometimes parents before deciding on the next move. In this vein, there is a need for a system pulse (see Figures 1 and 2) of how innovations are moving vertically and laterally even as schools adopt a decentralised movement of *innovation becoming*. The movement of innovations would have to be constitutionally dependent on the identity formed and projective manifestation of the innovation and the leadership that helms it (see the tenets in Table 2).

In terms of *Readiness*, the Singapore government has primed schools for innovations since 1997 with its introduction of "Thinking School, Learning Nation" initiative, which was further buttressed in 2005 with the advent of "Teach Less, Learn More" policy. Similarly, in Finland, policies are implemented with a long-term view in mind, premised on strong consensus-based foundation. Both Singapore and Finland have enjoyed sustainable leadership and renewal over the years, thus allowing educational policies to gain momentum and maintain coherence between economic and educational development. According to OECD (2014), schools in Finland are encouraged to take risks and there is strong presence of bottom-up networks of schools that stimulate and spread innovations – a deliberate national strategy that encourages collaboration instead of competition across schools. It is envisaged that such networks will help the teaching fraternity combat isolation and foster sustainable implementation.

Moreover, a low teaching load allows Finnish educators to devote more time to curriculum and assessment design, as well as experimentation to improve teaching methods. More importantly, Finnish educational policies have put "creativity and experimentation on par with teaching for academic achievement" and created an innovation culture that is built on trust, resulting in successful priming of the ground for "deep sectoral reforms" (OECD, 2014, p. 183). In Singapore, we are also witnessing more school-to-school collaborations, as outlined in our three case studies. However, such sustained ground-up networks are still few and far between at this stage, with teachers citing time constraints, saturated curriculum space and professional accountability for performative pedagogy as main impediments to innovations.

In terms of *Coordination*, the MOE has established structures that enable it to harness feedback loops for capacity building. As delineated in the (ETD) work with teachers and school leaders on the ground to distil important design principles of innovations and integrate the lessons learned into nation-wide professional development programmes conducted by ETD. Examining the policy intent, orchestration efforts are evident. The various funding programmes for school innovations are construed with a developmental stance in mind, where the system provides funding for experimentation and also further support if progress unfortunately becomes stalled. Whilst some schools may welcome just-in-time support from the central body, others may have interpreted these as restrictive or intrusive. Nonetheless, we can interpret such mandatory upward percolation of feedback by schools on innovation progress as a vehicle for MOE to maintain coherence between policy formulation and translation. Schools that are successful in implementing pedagogical innovations will be invited by MOE to showcase their stories through nation-wide professional building platforms. Additionally, through these ideation or sharing sessions, MOE officers encourage like-

minded champions to form a community to continue the various innovations. Such intensive coordination entails deliberate planning and implementation, which is made possible due to the nimble nature of small economy.

While the small size of the country and the education system in Singapore may make these innovations appear inapplicable or irrelevant to economies with larger scale of education, it has been noted that the core principles and lessons learned from the innovation trajectories of *becoming* in Singapore can be applicable to the level of states, providences or cities at different scales (OECD, 2010). In particular, the case of Singapore' *innovation becoming* demonstrates the complexity of educational innovations at the multiple ecological layers and dialectics interactions across multi-actors through the close partnership and coordination among the ministry, schools and other institutions. It provides implications to other countries struggling with the centralisation and decentralisation dilemma. For instance, in Korea, despite the decentralising force to grant more autonomy in schools through the national curriculum reform, there are various challenges that impeded the transformation of the education system. The challenges faced include contradictions between the desired autonomy and the granted autonomy to schools and teachers (Hong & Yongs, 2016), and the conflicting discourse between policy makers and researchers/specialists (So & Kang, 2014). The complexity of education innovations and diffusion process highlights the importance of coordinated efforts by multiple actors with and outside the education system, such as gaining parental support and buy-in, promoting dialogic interactions, and resource allocations acknowledging different circumstances of schools (Park, 2016).

We hope the analytical frameworks as proposed in this paper will provide thinking tools for system, cluster, school, and teacher leaders for the purposes of

innovation diffusion. Undoubtedly, the *innovation becoming* process is a nested ecology. As demonstrated earlier, the innovation trajectory will be intertwined with the broader social-cultural issues upon which the *ARC* principles will be applied to. Thus, the whole diffusion process should be perceived as a living system in its own right, where future paths will continue to shape and be shaped by constituent actors and the environment in a situated fashion.

Acknowledgement

This work was supported by the eduLab initiative under Grant NRF2014-EDU001-IHL06. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the NRF or NIE Singapore. The authors are grateful to the participating schools for collaborating with us on this research.

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