
Title	Leadership across schools to diffuse an education innovation: Applying complexity leadership theory with ecological leadership
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**Leadership across schools to diffuse an education innovation: applying complexity
leadership theory with ecological leadership**

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Abstract

Purpose: This paper examined leadership practices which supported the diffusion of an innovation in a cluster of schools in Singapore, through the lenses of complexity leadership theory (CLT) and ecological leadership.

Methodology: The approach is a qualitative case study, with the unit of analysis bounded by the innovation and a cluster of schools involved in the diffusion effort. The case study involved investigations mainly at four ecological levels: the ministry (macro), the cluster (exo), school/subject department (meso) and teacher (micro), involving nine observations of the cluster's community of teachers in 2019, and interviews or focused group discussions with 33 participants, including ministry officers, school leaders, key personnel and teachers.

Findings and Implications: The findings illustrate the diffusion of an innovation through the interactional dynamics of administrative, adaptive, and enabling leadership, how these three CLT roles were performed by formal and informal leaders, deliberately or emergent, and across ecological levels. These leadership roles enabled learning and adaptations across and within ecologies. The study also reinforced the importance of the moral and emotional aspects of leadership in providing teachers with the motivation and support to cope with changes. The affordances, challenges, and limitations in applying CLT are elaborated.

Keywords: adaptive leadership; administrative leadership; complexity leadership theory; ecological leadership; enabling leadership; innovation diffusion

Leadership across schools to diffuse an education innovation: applying complexity leadership theory with ecological leadership

This study aimed to examine leadership practices which supported the diffusion of a mathematics innovation, Archimedes, across six primary schools (grades 1-6) in one school cluster in Singapore. The main research question was “How did leaders plan for and support the diffusion of an educational innovation across and within schools?”

Two related leadership lenses were combined to make sense of the complexities involved: complexity leadership theory (CLT) (Uhl-Bien, Marion, & McKelvey, 2007) and an ecological perspective of leadership (Wielkiewicz & Stelzner, 2005). CLT views leadership as emerging from interactions amongst interdependent agents, generating adaptive outcomes for organisations (Uhl-Bien et al., 2007). Similarly, an ecological perspective of leadership views leadership as a process emerging from the interactions of diverse individuals across and within communities, resulting in an adaptive organisation which is open to changes (Wielkiewicz & Stelzner, 2005). CLT serves as the main analytical lens with ecological leadership as a supporting lens.

A secondary objective of this paper is to share the researchers’ experience applying CLT, which has been applied in a range of organisation settings including aerospace, healthcare, financial services and the public sector (Arena & Uhl-Bien, 2016; Murphy, Rhodes, Meek, & Denyer, 2017). Morrison (2010) proposed that complexity theory is worth exploring in the study of educational leadership. A decade after Morrison’s paper was published, no empirical study applying CLT in an education setting has been found. However, there have been a handful of studies applying a complexity perspective to examine leadership in schools (Kershner & McQuillan, 2016; Toh, 2016). This paper documents the researchers’ experience in using CLT, together with an ecological perspective of leadership,

to analyse leadership practices which supported the diffusion of an innovation across six schools within a cluster.

Literature Review

This section reviews the literature on innovation diffusion and the role of leadership, which incorporates an ecological perspective. It suggests one limitation of an ecological perspective, which may be addressed by CLT. This is followed by a review of CLT, indicating commonalities CLT shares with an ecological perspective, and how CLT value adds in its proposal of three leadership roles. The section ends with an integration of the literature on innovation diffusion, ecological leadership and CLT.

The Diffusion of Innovations

An innovation is defined broadly as an “idea, practice, or object that is perceived as new” by people who consider its adoption (Rogers, 2003, p. 12). Diffusion of an innovation is the process in which “an innovation is communicated through certain channels over time among the members of a social system” (Rogers, 2003, p. 5). Rogers (1983) emphasised that “diffusion is a very social process” (in Rogers, 2003, p.19) and is influenced by the social structure, the “patterned arrangements of the units in a system (p. 24).”

A review of diffusion literature in an education setting suggests that moderating factors for the successful diffusion of education innovations include an effective web of social eco-systems that constitute patterns of relationships between people, levels of the systems, resources that are interlinked, and contextual interpretations of the innovation (Toh, Jamaludin, Hung, & Chua, 2014). Crucially, the diffusion of educational innovations is dependent on the teacher, on teacher capability, willingness to experiment, and the support rendered from different levels of the system to increase teacher professionalism (Hargreaves & Shirley, 2009).

The Role of Leadership in Diffusing Innovations

Although the diffusion of educational innovation is dependent on the teacher to a large extent, classical change models (Ellsworth, 2000) indicate that the innovation needs to be supported at all levels of leadership. However, there is little detail on the interactional dynamics of leadership, on how leadership by stakeholders at various ecological levels interact to support the innovation.

Recent studies on efforts to diffuse innovations for education change view leadership as a critical enabler, enacted in multi-voiced, collaborative work processes and social interactions (de Jong, Lockhorst, de Kleijn, Noordegraaf, & van Tartwijk, 2020; Vennebo, 2016). In examining leadership for the diffusion of innovation in professionalised settings, Currie and Spyridonidis (2019) illustrated how leadership is shared amongst managers, doctors and nurses, affirming the interdependence of hierarchical management and professional influence. They encouraged others to examine how leadership is enacted in diffusing innovations in other professionalised settings, a challenge this study has taken on.

Although the researchers have not been able to find any empirical study of education innovation diffusion from a complexity perspective, Huang (2011) proposed approaching innovation scaling-up using a complexity paradigm, which views the process as a complex adaptive process that is non-linear and diffusion as an emergence. In this paradigm, teachers as heterogeneous agents interact with their peers in social networks and make adoption decisions, which may include adaptations of the innovation for their local contexts (Huang, 2011). Huang's (2011) suggestion to study educational innovations using a complexity paradigm is what this study attempted to do, with the use of CLT.

An ecological perspective of leadership in educational change. A Singapore study examined the diffusion of educational innovations from one school context to another, and

coined the concept of “ecological leadership” (Toh et al., 2014), building on the concept of an ecological environment conceived by Bronfenbrenner (1979) as a set of nested structures. In the Oxford English dictionary (<https://www.lexico.com/definition/ecosystem>), an ecosystem is a biological community of interacting organisms and their physical environment, referring to a complex network or interconnected system. According to Bronfenbrenner (1979), the immediate setting which influences the developing person is the microsystem. Then there is a larger setting, which the developing person participates in, the mesosystem, and another setting, the exosystem, in which events occur that affect what happens in the person’s immediate environment. The macrosystem refers to overarching generalised patterns of social institutions and ideologies common to a particular culture. Finally, in 1986, Bronfenbrenner (1986) proposed a chronosystem which examines changes over time in the environment in which the person is living. Toh and colleagues (2014) adapted Bronfenbrenner’s concept to map the nested context of educational ecological systems which they proposed shape the diffusion of innovations across schools:

- a) Micro level: teachers at the classroom level
- b) Meso level: school attributes such as school and department cultures and structures
- c) Exo level: peripheral members of the school system, which in this study includes the cluster of schools
- d) Macro level: national policies by the ministry and global trends
- e) Chronosystem: ingrained culture which influences the interactions of the different levels across time

Building on this concept, Hung and colleagues (2016) observed that since schools are situated within an ecological system with different subsystems, multiple levels of leaders need to navigate and exploit the interacting levels of the ecological system to forge

alignments, leverage collective social capital and resources, and mitigate systemic tensions (Hung et al., 2016).

Although the term “ecological leadership” was coined, there are echoes of an ecological-oriented leadership in the literature. Rincón-Gallardo and Fullan (2016) observe the importance of a mix of senior leaders and other leaders across layers of a system to enhance the effectiveness and cohesiveness of system networks. Similarly, Earl and Katz (2007) mentioned the need for multi-level leadership in networked learning communities, while Hadfield (2007) noted the need for different layers of network leadership at the school-to-school level, within-school level, and the project group level. Ecological leadership is also consistent with an ecological perspective in examining the diffusion of innovations for educational change, which requires interactions across multiple levels of the education ecology (Chapman, 2019). Adopting an ecological lens, Brown, Husbands and Woods (2019) illustrated how political leadership at the district and school levels worked with professional leadership at the teacher level to transform education for all schools in a district, reflecting the interdependence of hierarchical management and professional influence found by Currie and Spyridonidis (2019) in the healthcare setting.

In an article on an ecological perspective of leadership theory, research, and practice, Wielkiewicz and Stelzner (2005) recognised that organisations are open social systems which are influenced by their environments through feedback loops. Leadership is viewed as an “emergent process” (p. 330), emerging from the interactions and actions of diverse individuals within a “web of interdependent social and biological systems” (p. 332), resulting in an adaptive organisation. Wielkiewicz and Stelzner (2005) emphasise the need to balance the tension between industrial and ecological processes, between the former’s centralisation of organisation decisions by positional leaders and the latter’s participative decision processes involving multiple agents. The industrial-ecological balance is similar to the

proposal by Hung and associates (Hung, Lee, Jamaludin, Toh, & Wu, 2019a) for a calibration of “top-down and bottom-up approaches and structures” to support and sustain the diffusion of innovations (p. 287).

One limitation of an ecological perspective of leadership is a lack of clarity about how to use this perspective to guide analysis of the emergent process of leadership. If leadership is not performed solely by individuals but emerges from the interactive “spaces” between agents, or between individuals and contexts (Lichtenstein & Plowman, 2009), how does one analyse such leadership and what is the nature of such leadership? CLT helps to address this limitation.

Complexity Leadership Theory

As observed by Morrison (2010) and Rosenhead and colleagues (Rosenhead, Franco, Grint, & Friedland, 2019), there is no single, agreed upon complexity theory; instead, there are complexity theories. A search for the use of complexity theory in empirical studies in an education setting, as opposed to conceptual or review papers (Mason, 2016; Price, 2014; Schneider & Somers, 2006; Tourish, 2019), yielded very few studies (Kershner & McQuillan, 2016; Toh, 2016).

The researchers chose CLT as the overarching analytical lens as it appears to be the most fully developed framework which links complexity theory and the construct of leadership. The theory is also currently the most influential in terms of citations (Rosenhead et al., 2019). CLT was first introduced by Uhl-Bien, Marion, and McKelevey (2007). Complexity leadership is driven by the goal to enable the organisation’s adaptive responses to challenges and complex problems, to generate adaptive outcomes, disseminate and integrate innovations into organisation (Uhl-Bien et al., 2007).

In CLT, organisations are complex adaptive systems (CAS). Like an ecological perspective of organisations, CAS are open systems, consisting of interacting, interdependent agents bonded by shared needs. Similar to an ecological perspective of leadership, CLT sees leadership as “a complex interactive dynamic” from which adaptive outcomes, defined as learning, innovation and adaptability, emerge (Uhl-Bien et al., 2007, p. 314).

Thus, CLT and an ecological perspective of leadership (Wielkiewicz & Stelzner, 2005) share the following commonalities: organisations as complex, adaptive, open, and interdependent; leadership as dynamically emerging from interactions, with the aim to foster the organisation’s adaptability. What CLT further provided was three “entangled” leadership roles for consideration: administrative leadership, enabling leadership, and adaptive leadership, reflecting “a dynamic relationship between the bureaucratic, administrative functions of the organisation and the emergent, informal dynamics of CAS” (Uhl-Bien et al., 2007, p. 298).

- a) Administrative leadership is grounded in bureaucratic notions of hierarchy, alignment, and control. It is generally performed by individuals in positions of authority, and involves strategic functions such as setting a vision, and the control of formal systems and structures (Hazy & Uhl-Bien, 2020).
- b) Enabling leadership refers to leadership which fosters enabling conditions to support creative problem solving, adaptability, and learning, conditions involving trust and safety which connect individuals or encourage them to take risk. It manages the tension between administrative leadership and the emergent adaptive leadership by creating conditions to foster adaptive leadership and managing the innovation-to-organisation interface. The innovation-to-organisation interface refers to effort to disseminate innovative products organisation wide through the formal managerial system (Uhl-Bien et al., 2007). Enabling leadership works to mitigate top-down

administrative leadership from stifling bottom-up creative ideas, while assisting innovative ideas or products to be integrated into the formal managerial system and structures.

- c) Adaptive leadership refers to adaptive, creative, and learning actions which emerge from CAS interactions as CAS adjust to tensions, imposed by the external environment, or injected by administrative or enabling leaders. This tension could include the introduction of an innovation.

Enabling and adaptive leadership can be found at all levels of a CAS, while administrative leadership is usually performed by persons/institutions in positions of authority.

Integrating the Literature on Diffusion of Innovation, Ecological Leadership and CLT

In analysing theories of educational leadership and management, Bush (2003) noted that the multiplicity of leadership theories suggests no single theory is sufficient to guide practice, and the need to develop what Bolman and Deal refer to as conceptual pluralism. Similarly, Hallinger, Gumus and Bellibas (2020) and de Jong (2020) observed a trend towards an integration of models.

As explained, CLT and an ecological perspective of leadership share many commonalities. Integrating the two would enable a better understanding of the interactional dynamics of leadership amongst different actors, and how these are mapped against the ecological levels in an education system. Applying CLT and an ecological perspective to examine how leadership practices interact at different levels to support the diffusion of an innovation may help us move closer towards more sustainable implementation of educational reforms, which has long been the holy grail in a field known to be very resistant to change (Dimmock & Goh, 2011; Hartley, 2009). Table 1 illustrates key characteristics of CLT, ecological leadership and innovation diffusion.

Table 1: Integrated Table of Diffusion, Ecological Leadership, and CLT

Innovation diffusion	Ecological leadership	CLT
<u>Non-linear process:</u> Innovation diffusion is a non-linear process among agents of a social system (Ellsworth, 2000) Diffusion process: communications, relationships, social system, resources, contextual interpretations	<u>Webs of social eco-systems</u> Innovation diffusion is a complex, non-linear process which requires interactions by agents across different levels of social ecologies (Hung et al., 2019a) Communications and interactions at different ecological levels. Collective social capital and resources	<u>Dynamic interactions and emergence</u> Focus is on enabling conditions to facilitate the emergence of adaptive outcomes, including innovation, learning and adaptability. Innovation includes the adoption of new products and embedding these into the formal organisation system (Uhl-Bien et al., 2007). Adaptive responses by interdependent agents who are bonded by shared needs and complex problems.
<u>Leadership at different levels</u> The literature acknowledges the importance of administrative support and the need for formal and informal leadership at all levels (Ellsworth, 2000) though the focus appears to be on hierarchical leadership.	<u>Ecological-oriented leadership</u> Leadership as the key driver for change within an ecological system; an ecological-oriented leadership which includes systems thinking, leveraging collective resources and addressing tensions across multiple levels, contextualisation of innovations, and development of capacities (Hung, Lee, Jamaludin, Toh, & Wu, 2019b) Multi-levels of leadership include political leadership at the system level and hierarchical leadership within schools.	<u>Leadership as dynamic interactions and entangled</u> Three entangled leadership roles which reflect the dynamic relationship between the bureaucratic functions of an organisation and the emergent, informal dynamics of CAS (Uhl-Bien et al., 2007)

As suggested in Table 1, the literature on innovation diffusion, while recognising the importance of leadership, does not provide details on the interactions between formal and informal leadership or their specific leadership roles. In examining leadership for an innovation, ecological leadership provides the lens to consider leadership interactions across multiple ecological levels while CLT proposes three interacting leadership roles which may be performed by stakeholders at the different ecological levels. Together, ecological leadership and CLT can provide insights on who may provide leadership and what kind of leadership may be required to diffuse an innovation which is initiated at a higher hierarchical level for implementation at the micro classroom level.

Brief Context

It has been established in the literature that context is key in understanding leadership practices (Hallinger, 2016). From an ecological perspective, the chrono or historical layer is also important (Hung et al., 2019a). This section briefly describes the context of the cluster community, the six schools involved, and the innovation.

In Singapore, schools are organised in clusters of 12 to 13 schools, involving a mix of primary schools (grades 1-6), secondary schools (grades 7-10), and junior colleges. The Ministry of Education (MOE) assigns schools to these clusters and the assignment occasionally changes. A cluster superintendent is assigned to oversee each cluster, and the superintendent is also the reporting officer of the principals in his/her cluster.

In 2019, there were six primary schools in the cluster studied, with five of the six opting to join the cluster community. The sixth school who chose to join the cluster community in 2019 was previously with the cluster in 2018 but had been reassigned to a new cluster in 2019. All six schools were government or government-aided mission schools. Government-aided schools in Singapore were historically schools set up by various

community organisations to cater to the educational needs of their respective communities. Both school types charge standardised fees, follow the national core curriculum, and their grade six pupils participate in the same national examination.

Archimedes was an innovation first introduced by MOE in 2012 and was disseminated only to schools with weak mathematics results in the primary six national examination. The innovation included a package of eight guiding principles, a detailed lesson plan template, intensive training on the innovation based on specific mathematics topics, and on mentoring for school chosen mentors, spread over a year, and a mandatory mentor-mentee structure with a stipulated number of guided lesson planning and observations. The superintendent concerned promoted the adoption of Archimedes in his cluster even amongst schools which were not in MOE's official list of Archimedes schools. The cluster adapted the innovation to include the guiding principles, the lesson plan template, and an open classroom structure in which schools took turns to plan and conduct a lesson, followed by a debrief session.

Each of the six participating schools was at a different stage in the adoption of Archimedes when the researchers began the investigation. Refer to Table 2 for a brief description of each school's profile.

Table 2: Description of school profiles in relation to the innovation

School	Brief profile in relation to Archimedes	Other relevant details
School A A government-aided Catholic school for boys c. 1100 pupils c. 100 teachers	2018: School joined the cluster community	School is not an official Archimedes school

School	Brief profile in relation to Archimedes	Other relevant details
School B (Lead school) A government school c. 1300 pupils c. 105 teachers	2016: superintendent linked the school to MOE to be trained in the use of the innovation 2017: School B conducted a workshop on Archimedes for schools C and E, together with CMM from school C 2018: conceptualised & implemented the open classroom structure	School is not an official Archimedes school In 2019, the cluster community was led by the vice-principal, the Mathematics HOD (the lead KP) and a teacher (the lead teacher)
School C A government school c.1000 pupils c. 106 teachers	2017: The school co-opted to join the cluster community from 2017. Training by MOE on Archimedes	An official Archimedes school A senior teacher in the school is also the cluster mathematics mentor (CMM).
School D A govt-aided mission school for girls c. 1200 pupils c. 93 teachers	2018 – Vice-principal was brought in by superintendent to develop the teachers’ assessment literacy 2019 – School left the cluster but asked to join the cluster community	School is not an official Archimedes school VP recommended to the principal who was newly posted to school D in 2019 for the school to join the community
School E A government school c. 1000 pupils c. 94 teachers	2017: Training by MOE on Archimedes 2018: joined the cluster community	An official Archimedes school School declined to participate in the school level study.
School F A govt-aided Catholic school for girls c. 1000 pupils c. 81 teachers	2019: school newly joined the cluster and agreed to join the community	School is not an official Archimedes school School declined to join the school level study.

Methodology

This study sought to examine leadership practice in a cluster's effort to diffuse a mathematics innovation, Archimedes, across and within six schools. The main research question was "How did leaders plan for and support the diffusion of an educational innovation across and within schools?"

The study adopted a qualitative case study, which enables an in-depth understanding of a situation when the focus is "in the process rather than outcomes, in context rather than specific variable, in discovery rather than confirmation" (Merriam, 1998, p. 19). Yin (2003) also proposed the case study method to study a contemporary and complex social phenomenon in which the relevant behaviours cannot be manipulated. The specific approach is an instrumental case study (Stake, 1995) in that the case was purposively selected to provide insights into how leadership for an innovation could be enacted by stakeholders at different ecological levels, and how these leadership actions interacted. The unit of analysis is bounded by the innovation, Archimedes, and a cluster of six schools involved in its diffusion over a period of one year, with support provided by MOE.

Data collection

The case study involved investigations mainly at four ecological levels which were more closely linked to the diffusion process: the ministry (macro), the cluster (exo), school/subject department (meso), and teacher (micro). At the cluster level where six primary schools participated in a cluster community, researchers observed seven of eight open classroom sessions (lesson observation followed by post-lesson debrief discussion) and two review sessions in 2019. At the school level, four schools agreed to participate in the study, which involved researchers interviewing the school leaders, key personnel (KP) such

as the head of the mathematics department, senior teachers (ST) and teachers who participated in the cluster community from 2018 to 2019. Table 3 summarises the participants involved in the six primary schools. Schools A -D participated in the school-level study, while schools E-F agreed to their teachers being observed in the cluster community.

Table 3: Participants involved in the study

	School A	School B (lead school)	School C	School D	School E	School F
School Leaders	1 P, 1 VP P: principal VP: vice-principal	1 P, 1 VP	1 P, 2 VP	1 VP	1 P	1 P
Key Personnel (KP) and senior teachers (ST)	1 ST (2018), 2 KP	1 KP (lead KP) 1 teacher leader assigned to work with the KP (lead teacher)	1 KP 1 ST (also the cluster math mentor)	1 KP	1 KP, 1 ST	2 KP
Teachers	Tr 1 (2018), Tr 2, Tr 3	Tr 1, Tr 2, Tr 3, Tr 4, Tr 5, Tr 6	Tr1 (2018), Tr 2, Tr 3 (2018), Tr 4	Tr 1, Tr 2	Tr 1, Tr 2, Tr 3	Tr 1, Tr 2

At the macro level, three officials from MOE, including a Master Teacher (MTT) and two curriculum officers, were also interviewed to solicit a better understanding of the thinking and history behind the innovation and the roles played by the MTT in the cluster community.

Figure 1 illustrates the CAS investigated, with the cluster community as the exo-level system linking the various CAS from the macro ministry level to the meso school and micro teacher levels.

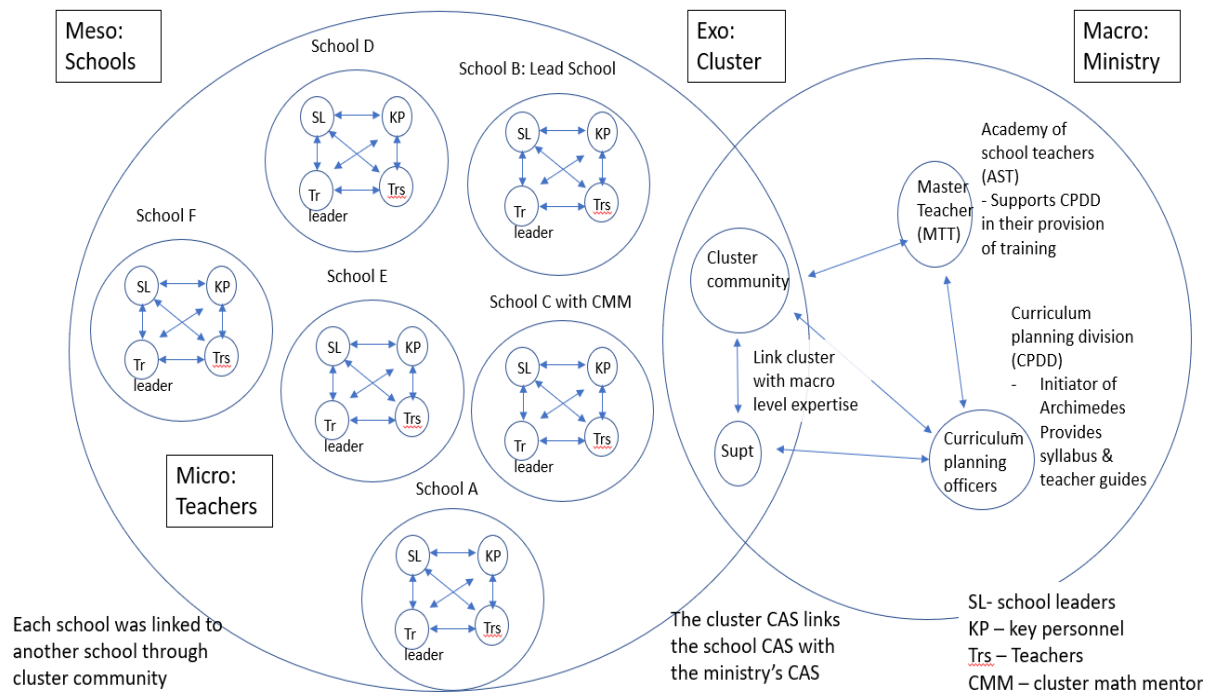


Figure 1: The Interacting Complex Adaptive Systems (CAS) in the Study

Three researchers were involved in the observations, interviews, focused group discussions (FGD), and data analysis. Detailed field notes were taken at the cluster community sessions by at least two researchers. All interviews and FGDs were audiotaped and transcribed, with three exceptions when the interviewees preferred not to be audiotaped. Field notes were taken by two researchers for those interviews to capture the content as verbatim as possible. All the interviews and FGDs were transcribed in-house by one of two researchers, which enabled them to have intimate knowledge of the data.

Data Analysis

Field notes and transcriptions of interviews and FGDs were analysed independently by the three researchers. The researchers adopted a grounded approach and did detailed line-by-

line analysis (Charmaz, 2006) to surface leadership practices enacted by various parties. There was deliberately no predetermined list of codes because the researchers did not want to constrain the complexities involved. However, the ecological perspective served as a preliminary theory (Yin, 2003), sensitising researchers to look out for who enacted the observed leadership practices and in which ecological setting, for example at the Ministry level by Ministry officers, at the cluster level by the superintendent, Master Teacher or lead school, or at the school level by school leaders, middle managers and teachers. The three entangled CLT leadership roles, administrative, enabling, and adaptive leadership, served as the main lens to analyse the leadership actions that were observed. The use of two leadership perspectives supports Yin's argument that a case study should examine evidence from different perspectives (Yin, 2003).

Table 4 provides examples to illustrate the analysis process: identifying the leadership practices, person(s) enacting the leadership observed, the ecological setting and mapping these against the three CLT leadership roles to check which practice corresponded to the three roles and which did not but were nonetheless still important. Leadership practices which did not correspond to the three CLT leadership roles are highlighted in the discussion section.

Table 4

Leadership practices	By whom and in what setting	CLT three roles
Initiated a cluster community and persuaded principals to involve their schools and release their teachers for this purpose	Superintendent at the cluster level	Administrative leadership by the superintendent as the person overseeing the cluster
School leaders communicated that their focus was to engage students in the learning of mathematics, and not on academic results	School leaders at the school level in their communication to middle managers and teachers	Enabling leadership by principals which encouraged teachers to explore the use of Archimedes without the pressure of producing results

Leadership practices	By whom and in what setting	CLT three roles
Teachers led in developing lessons for their peers to observe the innovation in action	Teachers in the cluster community with the support of the lead head in the cluster and the mathematics heads in their schools	Adaptive leadership by teachers in adapting Archimedes to create unique lessons designed to meet the needs of their students; Enabling leadership by the lead head and the department heads.

Analysis was done collaboratively both online and through monthly meetings to gain group consensus (Saldaña, 2016). From the analysis, four individual school case reports were generated and shared with the schools for member checking. Schools agreed with the findings.

Findings

This section presents the findings, with a focus on how applying CLT and ecological leadership as lenses supported the analysis of the data. Figure 2 summarises the key leadership practices observed, categorised by the three CLT leadership roles, and the stakeholders who performed these leadership practices at the different ecological levels.

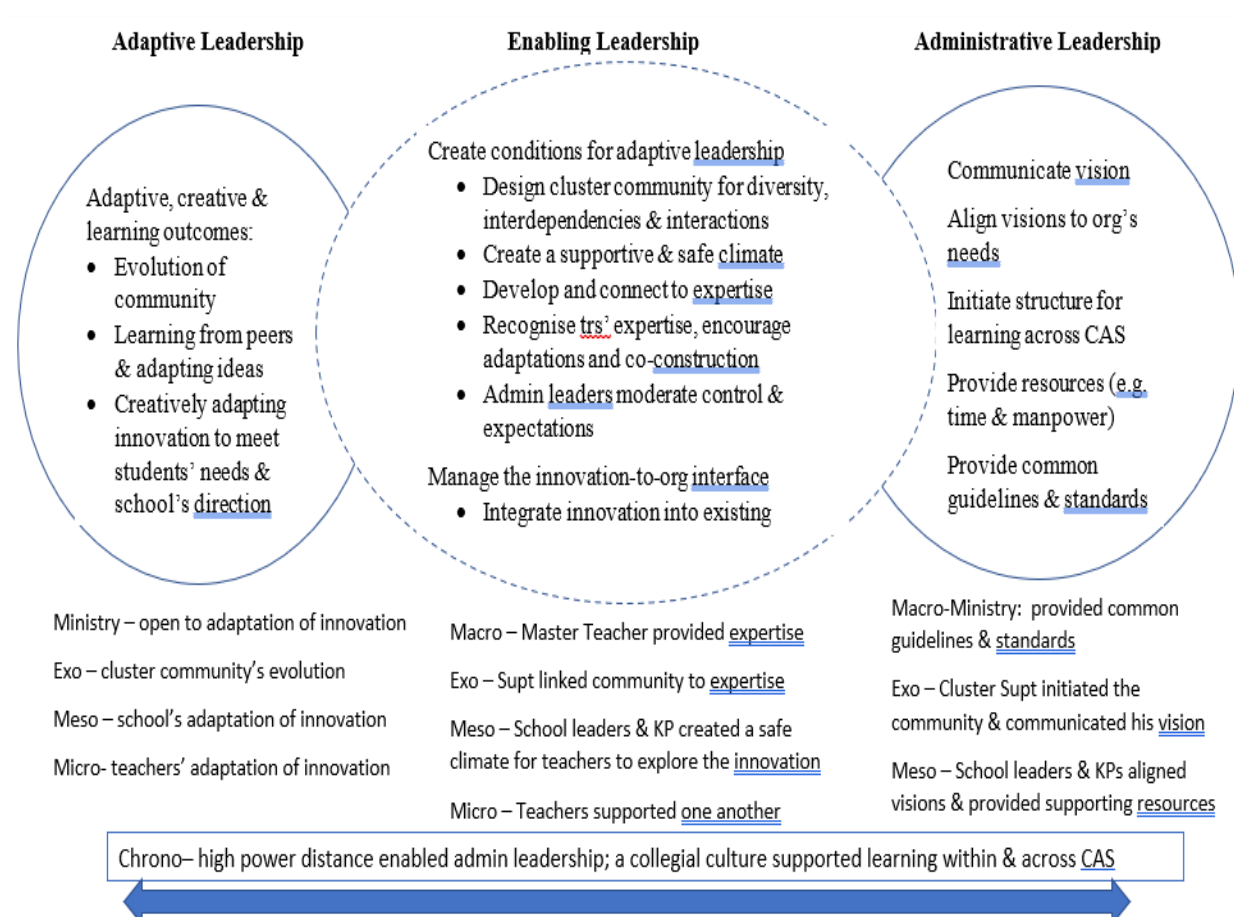


Figure 2: The entangled leadership roles and the stakeholders at different ecological levels

Administrative Leadership

Administrative leadership at the exo level was performed mainly by the cluster superintendent, who was acknowledged by both school leaders and key personnel as the person who initiated the cluster community, recommended the focus on Archimedes, and appointed a lead school (school B) to oversee the community. The cluster community “start[ed] from cluster; that means start[ed] from the superintendent” (school B, principal). The superintendent was very clear that one key vision of the community was to develop the teachers, through learning from one another and learning in a natural setting (Sep review session). School B’s principal shared that “we were appointed to change let’s say two or three people right, okay, from the cluster so that they can go back and shared what they have learnt.”

In addition, in his higher position on MOE's hierarchy, the superintendent had to come in to mediate amongst school leaders who had equivalent authority, to get them to agree on a common day and time for the community to meet. As the principal of school B explained, "Superintendent is the one who chaired the meeting [of principals] and – and make everybody fix a date. Principal to principal, it's very difficult lah, to go and fix a date." As observed by the vice-principal of school A, "when cluster takes ownership and there is a lot of ...support, it jumpstarts our processes". As the administrative leader in charge of the cluster, the superintendent clearly had a lot of influence, supported by a high power distance culture in Singapore (Hofstede, 2003) in which there is generally a respect for authority.

On the other hand, the superintendent did not use his higher authority to dictate that all the primary schools in his cluster had to participate in the Archimedes community. Over the two years the community was in existence, at least four schools declined to participate in the community. In addition, school leaders as administrative leaders of their schools made the decision for their schools to participate in the cluster community with different reasoning, visions, and focus, in alignment to their school's needs. For example, school A's reasoning for joining the cluster community in 2018 was to develop their relatively young key personnel and because they had just appointed a School Staff Developer and were ready to "go deeper into the professional development of our teachers" (School A, vice-principal). That school leaders were administrative leaders who made their own decisions whether to promote Archimedes was illustrated most clearly in school D's context, in which the school decided to join the cluster community one year after the community had started, and after the school had left the cluster. As the vice-principal explained:

So I went through one year with them [the community] and I saw how other schools have benefited. And the second year, that's where I suggested that my school came on board. ... I spoke to the new principal...and she supported [my suggestion].

Furthermore, while the superintendent played a role in reminding school leaders of the need to support the teacher participants, school leaders had to endorse the protection of time for the teachers to attend the community. Some school leaders also tried to offload the teachers involved by reducing the teachers' duties in other work:

So our timetable on Wednesdays are blocked up from 1130 so they cannot touch us for relief or anything. So that helps in a sense because the teachers can go [for the cluster community] without missing the classes (School A, KP)

... whenever we go for this cluster community, we are missing [staff] contact time and all these other things. They [the school leaders] do allow us to do so, so I must really be [laughed] thankful for that (School C, KP)

There were indications of the Ministry indirectly playing an administrative leadership role in providing common structures and guidelines, mainly through artefacts and the leadership provided by the lead KP. There was evidence from both the lesson observation debrief sessions and the interviews that the lead KP used MOE's Teaching and Learning Guide (TLG) for Mathematics as a guide for lesson planning and the teachers' discussion of the lessons:

Okay, actually for TLG right okay, because it's provided by CPDD [the curriculum division in MOE]. ... the lesson sequence is already there. So we want to fall back on certain common resources. Yeah. So that at least when - when we have our conversation, the teachers are not so lost. And because these are all drafted by CPDD, at least we can roughly follow the guide. ... so TLG is only a common platform for us to, to talk about for the lesson itself (School B, lead KP, second interview)

The Master Teacher observed that mathematics teachers in Singapore share a "common context" in terms of following the same syllabus, curriculum, framework and the TLG; these

common standards helped teachers to adopt Archimedes as it was compatible with what they were already familiar with.

Enabling Leadership

Unlike administrative leadership which was provided by people in positions of authority, like the cluster superintendent, enabling leadership was also enacted by teachers.

Design and Implementation of the Community. Enabling leadership manifested mainly in the design of the cluster community as a safe platform for interactions, dialogue and learning amongst the teachers, incorporating diversity and interdependencies. The community was conceptualised and facilitated by the lead school leaders and KP. As the principal of the lead school B explained,

So instead of just I [the teacher] come in and we share ideas, and then that's it, we wanted them to – to have this structure so that they're used to this kind of commenting, discussion with each other.

Schools were interdependent in that they took turns to host the meetings, with their teachers taking turns to prepare and conduct lessons for the cluster members to observe and discuss. The lesson planning involved the teacher-conductor, the lead KP, lead teacher, the cluster mathematics mentor, and minimally one key personnel from the teacher's school. As a community participant, each teacher had the opportunity in 2019 to visit six schools to observe eight teachers and diverse classes.

The lead KP enabled interactions by creating a safe climate for open discussion of the lesson during the lesson debrief. As she explained: "So that is I think the very first thing that when we start off right, definitely cannot be too threatening. Too threatening, nobody wants to be the one who is observed". She reminded participants that the lesson planning was a joint effort, not just the teacher's individual effort. She shared that she "tried our best to anchor on

the lesson itself. We don't talk about the teachers' style... we try to direct them to the lesson rather than the person" (second interview). She was careful to acknowledge problems faced by the teacher, while demonstrating openness to critique of the lesson design and implementation.

The teachers contributed to the safe and constructive culture that was palpable during the lesson debrief discussion. They started with positive comments and positioned their critique as suggestions on what they might have done in the teacher's position, without putting the teachers down, acknowledging the difficulties faced, and providing the rationale for their comments:

Consider using the visualiser but don't use division signs. Later when they do the worksheet, you can see that they are just doing procedure; no meaning. Maybe if I were to do it, I'll ask for suggestions – ask them to do it with you on their own tablets. Then maybe can go to the board and show them with the magnetic stuff. Actual and written are different (27 March debrief session, School E, KP 1)

Here KP 1 (School E) reminded all that conceptual understanding and being able to perform the mathematics procedure was different and offered her suggestion as to what she might have done if she were in the teacher's shoes. In another example, teacher 1 (School F) used the pronoun "we" in reminding all of the need to be "careful of the way we associate words with [mathematical] signs" (20 Feb session), signalling this is an issue faced by all teachers, and not just the teacher conductor.

The teacher conductors interviewed agreed that the debrief sessions were constructive and they benefited from their peers' input, despite the stress of designing and conducting the lessons in front of others. Teacher 4 in School C shared at his interview how he felt about the feedback given after his lesson:

for the post-ob debrief, I thought it was, you know, quite very frank, and it was, you know, very enriching I mean to hear the ... the feedback given..., there were some truths in what they said, so there were also some feedback which, you know, I felt that those areas could have been improved. ... I remember the day after that, you know, they - they made some recommendations, ... And I - I went back to like, you know, tighten up some of the loose ends.

Connecting People and Expertise. Performing a boundary spanning role (Uhl-Bien et al., 2007), besides connecting the teacher participants across the schools, the superintendent connected the lead school and teachers to experts in MOE who were familiar with Archimedes, which enabled the lead KP and the lead teacher to facilitate the lesson planning and lesson debrief sessions. The principal of school C provided her Senior Teacher, who was also the cluster mathematics mentor (CMM in Figure 1) to support the community and persuaded the Master Teacher who was supporting her school to also support the cluster.

Managing the Administrative-Adaptive Interface. Another aspect of enabling leadership is to manage the entanglement between the bureaucratic (administrative leadership) and emergent (adaptive leadership) functions of the organisation, or the administrative-adaptive interface (Uhl-Bien et al., 2007). For a society which has consistently valued academic results, one interesting finding was school leaders' messaging that they were not expecting immediate improvements in the mathematics results, and that results were not the reason why the school leaders were promoting Archimedes. The vice-principal in school C shared that "we make it clear it's not evaluative or judgmental so the teachers will know that they are given trust. Have moved away from this numbers game". That this messaging was consistent from school leaders to middle managers, received and believed by the teachers, was confirmed during the teachers' interviews:

Teacher 4 (School C): I think to be fair, she [the Mathematics HOD]- she didn't really ask for results lah. Yeah, as in - like, you know, like

Researcher: That's a support?

Teacher 4: Yeah...So - so there's like, there's no like, you know, like, "how come there's no results?" and things like that. Yeah... she's [the principal] very supportive and she - she - for - for her, she has always emphasised that, you know, that results is - are not the end of - it's - it's not like, you know, the everything.

This messaging by school leaders came across as a deliberate attempt to moderate the control usually exerted by administrative leaders through the expectations of key performance indicators which are usually linked to academic results. This moderation of expectations by school leaders helped teachers feel that they had the space to explore the use of Archimedes to focus on improving students' engagement with mathematics:

I must really thank our school leaders ah. At least they give us a period of time. They don't force you like, "oh, the next year everything must be in place this time." Yeah, so they give us time and the - the space right, for us to grow (School B, lead KP, 1st interview)

Managing the Innovation-to-organisation interface. There was also evidence of enabling leadership in terms of managing the innovation to organisation interface by helping to integrate innovative products into the formal management system (Uhl-Bien et al., 2007). In School B, the mathematics teachers agreed as a department, with the lead KP's and school leaders' support, to replace their usual lesson plan template with the Archimedes lesson plan template for their annual lesson observations.

Adaptive Leadership

There was evidence of adaptive leadership at all ecological levels, though the leadership provided was often not deliberate or planned. At the ministry level, the messaging which came through was that although Archimedes provided a lesson plan structure, the lesson plan components could be re-arranged and customised based on students' needs: "these are just guidelines" which teachers can "amend or modify...to suit their students' needs" (Ministry officers interviewed). This messaging that Archimedes was flexible in implementation appeared to have been received by the participants across the ecological levels.

At the cluster level, there was an evolution in the community's focus. Although Archimedes was originally designed for lower progress learners, the schools and teachers in the community felt Archimedes was also useful for other student profiles. Interactions amongst the teachers led to a "consensus" (school C, teacher 4) to shift from focusing on low progress learners to using Archimedes for other student profiles. KP 3 from School A also observed how the cluster community had "improvised" its interpretation of Archimedes to cater to "the [different] school profiles".

At the school level, in response to varied student needs and teacher profiles, schools interpreted and adapted Archimedes in different ways. In School B, the principal was clear that Archimedes incorporated good teaching strategies which could be applied to all student profiles, including the higher progress learners in her school. In School C which had a lot of young teachers, the vice-principal viewed Archimedes as providing a useful structure to guide her young teachers to develop their own teaching styles. The adaptation of Archimedes, arising from specific contextual conditions, was most clearly articulated by school D:

I am doing a modified Archimedes [laughed] to suit the needs of my school. ... to drive the few things that I would like to - to focus on ...I won't say that it is full Archimedes, because

like I say we do it a bit differently. I put in the things that I think is important to address some issues that I have in School D (School D, KP).

Schools also adapted the mentor-mentee and the open classroom structures of Archimedes. School C, in response to the teachers' feedback, factored in time for the mentees to observe the mentors' lessons, in addition to the mentor observing mentee's lessons. School A adapted Archimedes' open classroom structure by removing the need for a lesson plan, to make it less stressful for their teacher conductors.

Finally, at the teacher level, the lesson planning discussions which involved the lead KP, lead teacher, cluster math mentor, the host school's KP and the teacher conductors resulted in lessons which could not have been created by any of them individually:

It's really going in depth into the lesson and then also to hear insights from, from [the lead KP], from [the lead teacher], from [CMM], ... and then how they would conduct it if we didn't have the conference, myself and the teacher, we may not have conducted it that way, we may not have seen the lesson in that way, so I think it's an additional insight and another additional way we can teach the lesson (School A, KP2)

Teachers also enacted adaptive leadership when they creatively adapted Archimedes in the way they designed lessons for their peers in the cluster community. Teacher 2 at school F integrated differentiated instruction, a pedagogical philosophy which her school subscribed to, in her lesson design. Teacher 4 at school C incorporated his routine use of technology using Nearpod into his Archimedes lesson. There was evidence these innovative strategies were noticed by the participants, suggesting that the teacher conductors exerted influence even if they had not deliberately set out to do so. KP 2 at School A acknowledged this influence, recalling "there was some classroom that used Nearpod" and how this influenced School A's decision to "infuse" technology into their own lesson. Beyond lessons conducted for the cluster

community, within their own classrooms, teachers continued to enact adaptive leadership in combining “different doses of different types of the [Archimedes lesson] components” (School C, KP).

Limitations of the Study

Limitations in using complexity theory to study educational leadership have been raised, particularly by Morrison (2005). One of Morrison’s criticisms is that complexity theory mainly enables researchers to describe what has occurred but has limited predictive power. This study suggests that the value proposition of CLT is precisely as an analytical lens or conceptual metaphor (Rosenhead et al., 2019; Tsoukas & Hatch, 2001) to help make sense of what happened, to help researchers see what might have been missed without this lens. The researchers are not proposing to use CLT to prescribe how leaders ought to behave or to predict outcomes. However, understanding how interactions by formal and informal leaders at different ecological levels can facilitate an enabling culture that encourages learning, adaptation and creativity arguably has value for leaders who aim to nurture such a culture.

Another criticism by Morrison is that complexity theory appears to absolve formal leaders of responsibility though he acknowledges that complexity theory does not promote laissez-faire leadership. Our findings suggest that formal leaders, such as the cluster superintendent and lead KP, still have important roles to play and can influence leadership dynamics and outcomes. This finding is consistent with Uhl-Bien and associates (2007) who observed that all organisations are “necessarily enmeshed with a bureaucratic superstructure of planning, organising and missions” (p. 302), suggesting that formal leaders are still critical.

Discussion

Mapping CLT to the ecological perspective of leadership enabled the researchers to see how leadership actions were interrelated, as well as how the three CLT leadership roles were performed by different stakeholders across the ecological levels, as reflected in Figure 2. In brief, figure 2 illustrates how the integration of lenses enabled a more nuanced understanding of leadership for the diffusion of an innovation across and within ecologies, including who enacted what leadership practice, at which ecological level, and how these leadership practices interacted and reinforced one another.

The findings applied using CLT for the diffusion of an innovation in schools resonate with Currie's and Spyridonidis' (2019) findings of the diffusion of innovations in healthcare: executive managers (equivalent to cluster superintendent and school leaders) provide the direction and resources; middle-level leaders with professional backgrounds (key personnel and senior teachers in schools) act as linking pins and champions; and frontline professionals, nurses or teachers, actively adapt the innovation to local contexts. The hierarchical managerial influence in Currie and Spyridonidis (2019) can arguably be mapped against administrative leadership, while the professional influence can be mapped against enabling/adaptive leadership.

Contrary to Tourish's (2019) concern that CLT reinforced the romance of leadership in which an administrative leader with power exercised uni-directional influence over others, there was evidence in the study of followers engaging in what Tourish referred to as 'selective followship'. While school leaders subscribed to the general vision set by the superintendent for the community, it was clear that they promoted local visions which were aligned to their schools' unique needs, illustrating local leadership. This selective followship was also seen at the teacher level, where teachers clearly had the autonomy to decide the extent to which and

how they wanted to use Archimedes, autonomy important in sustaining the use of an innovation (Scheirer, 2005)

One difficulty in using CLT as an analytical lens was deciding if a leadership action by a positional leader constituted administrative or enabling leadership. On the one hand, some actions by formal leaders are possible because of the leader's positional authority. At the same time, these actions enabled conditions which supported teacher learning and problem solving. One example is school leaders' freeing up of the teacher participants' timetables every Wednesday, so that they could participate in the community. However, the difficulty in distinguishing between administrative and enabling leadership accentuates the entanglements between these two forms of leadership, an inherent characteristic of CLT.

The researchers also had some difficulty deciding if an observed practice was a deliberate enabling leadership practice or a leadership practice which emerged in response to the actions of administrative leaders. For example, the lead school's decision to design the community to involve the different schools in conducting the Archimedes lesson could be interpreted as responding to the superintendent's initiative to create a community for Archimedes, instead of a deliberate enabling leadership. However, to classify all subsequent actions as responding to the superintendent's initiative would give the erroneous impression that only the superintendent exerted leadership agency, while every other stakeholder was simply reacting as followers. The researchers' observations, interviews, and interactions with the research participants over the course of one year suggested that though there was administrative influence, stakeholders at the different ecological levels exercised agency in jointly creating conditions which generated the outcomes of learning and adaptation.

Another difficulty encountered was in capturing data which could illustrate how the "interactive exchanges" or "a dynamic of interdependent agents" gave rise to the adaptive,

creative and learning actions (Uhl-Bien et al., 2007) observed. While there was clear evidence of adaptation, creativity, and learning, it was less clear how these arose from the interactions of interdependent agents. This limitation was partly because many of these adaptations were self-reported during interview/FGDs, although some of these adaptations were directly observed by researchers in the lessons enacted. As observations of interactions were only at the cluster level, researchers were not privy to interactions at the school level, and how these gave rise to the schools' or teachers' adaptations of Archimedes.

There were some leadership actions which might be overlooked if CLT is the sole analytical lens, the most critical being instructional leadership. Instructional leadership is unique to educational settings, since it is leadership that is meant to influence classroom teaching and ultimately students' learning (Hallinger et al., 2020). There was evidence of instructional leadership in this study, performed by multiple individuals, from the Master Teacher to the classroom teacher who opened their classrooms for their peers to learn from. This form of leadership was not determined simply by one's position, as in the case of the Master Teacher, but also based on teachers' respect for one another as professionals with subject and pedagogical expertise. It is possible to position instructional leadership as enabling leadership, in that teachers can be perceived as providing professional knowledge and input, which fosters a learning environment for their peers. However, subsuming instructional leadership under enabling leadership might neglect the importance of instructional leadership.

Morrison (2010) observed that complexity theory appeared to be non-moral while he argued that school leadership is, at heart, a humanistic and moral enterprise. CLT does not appear to include the more humanistic aspects of school leadership, such as the support school leaders demonstrated simply through their presence at lesson observations and lesson debrief sessions. In explaining the school's role in leading the community, the principal of school C observed that it was their "commitment – since we're the first school – our commitment is to

roll it out to all the other schools.”. The moral purpose to engage lower progress students was also the key motivating factor for many of the teachers in adopting Archimedes.

That the emotional aspect of leadership is critical was clear in School B where there was an existing strong collegial culture in the mathematics department, which explained why the teachers supported their HOD’s decision to adopt Archimedes and their ability to work together and have fun despite the stress involved. Indeed, the emotional dimension is also present in the collegial culture in the community that enabled the constructive post-lesson debrief discussions, which might have been born out of respect for the cluster system over time and manifests itself in the chrono layer of the educational ecology. An ecological perspective of leadership incorporates the critical dimension of history and time, which engenders a culture that shapes interactions in and across the various ecological systems. Thus, combining an ecological perspective of leadership with CLT helped to surface Singapore’s collegial collectivist culture at the chrono-historical layer (Hofstede, 2003), which may also explain why the interdependencies built into the community were able to work. In addition, administrative leadership by persons in positions of authority appears to be enabled by the existence of a high power distance culture in Singapore (Hofstede, 2003).

Conclusion

While there was complexity in infusing an innovation across the six schools at the cluster level, the context was clearly not as urgent or complex as other situations in which organisations must adapt and innovate to survive. Nevertheless, CLT provided a useful metaphor to make sense of the various leadership actions, deliberate or fortuitous, by both formal and informal leaders, at different ecological levels, and how these leadership actions interacted to enable learning and adaptations of the innovation.

One major issue with CLT is that most attempts to diagrammatically represent the three entangled leadership roles either end up too complicated as in Gallagher IV's (2017) attempt to represent the emergence of amphibious warfare, or too static and seemingly a planned and deliberate process as seen in Figure 2. It is difficult to represent on paper the dynamism in real life. The team is currently exploring how social network analysis might be combined with CLT to represent the leadership dynamism emerging from social interactions.

The three entangled CLT leadership roles provide a useful framework for practitioners to make sense of the different kinds of leadership required to support innovation, learning and adaptability, how stakeholders in various positions can enact such leadership, and how such leadership practices interact and reinforce one another across ecological levels. In addition, the combined lenses of CLT and ecological leadership may help frame the design of leadership development programmes to consider training people in management teams, rather than to train individuals in silos based on their official positions. If leadership is required across ecological levels, and such leadership must synergise, it is arguably more effective to train people to work and lead as teams, across ecological levels.

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