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The Simple, the Complicated, and the Complex: Educational Reform Through the Lens of Complexity Theory

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THE SIMPLE, THE COMPLICATED, AND THE COMPLEX: EDUCATIONAL REFORM THROUGH THE LENS OF COMPLEXITY THEORY

Working Paper No. 96

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SUMMARY

This paper explores the nature of complexity theory and its applications for educational reform. It briefly explains the history of complexity theory and identifies the key concepts of complex adaptive systems, and then moves on to define the differences between simple, complicated, and complex approaches to educational reform. Special attention is given to work currently underway in the fields of healthcare, emergency management and ecology that draws on complexity theory to build more resilient and robust response systems capable of adapting to changing needs and of identifying key pressure points in the system. Finally, this paper presents several examples of educational reform programmes undertaken worldwide that have implemented complexity theory principles to achieve positive results. It also recommends involving multiple stakeholders across the different levels of governance structure, increasing lateral knowledge-sharing between schools and districts, and transforming policy interventions to bring greater flexibility to the reform process. This move toward feedback-driven adaptive reform allows for better targeting of programmes to specific contexts and may prove a key way forward for educational policymakers.

RÉSUME

Ce document examine la nature de la théorie de la complexité et ses utilisations dans le cadre de réforme éducative. Il explique brièvement l'histoire de la théorie de la complexité et identifie les concepts clés des systèmes complexes adaptifs, puis il distingue les différences entre les approches simples, compliquées et complexes. Une attention spéciale est accordée au travail poursuivi dans les domaines de la santé, de la gestion des urgences, et de l'écologie qui s'appuient sur la théorie de la complexité pour construire des systèmes de réponse plus forts et résistants, capables de s'adapter aux besoins changeant et d' identifier les principaux points critiques. Enfin, plusieurs exemples concrets de succès internationaux basés sur la théorie de la complexité et issus de programmes de réformes éducatives sont présentés. Des recommandations sont formulées concernant la nécessité d'une implication de multiples parties prenantes sur plusieurs niveaux de structure de gouvernance, la nécessité de partage des connaissance latérales entre les écoles et municipalités, et la transformation d'interventions politiques afin d'apporter une plus grande souplesse au processus de réforme.

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"For every complex problem there is an answer that is clear, simple and wrong."

H.L.Mencken

INTRODUCTION

In many OECD nations, the centre is held responsible for the steering of the educational system but often finds itself confronted with a diffuse field of demanding and increasingly data savvy stakeholders, and fewer and fewer direct levers of control available to it, as power has, in many contexts, been devolved to the local level. The complex nature of educational governance, involving myriad layers and actors, can be an overwhelming problem with no clear entry point for policy makers. Traditional approaches, which often focus on questions of top-down versus bottom-up initiatives or levels of decentralisation, are too narrow to effectively address the rapidly evolving and sprawling ecosystems that are modern educational systems.

If educational governance is recast as the building of effective networks of strong independent schools collaborating continuously, and sharing knowledge both horizontally and vertically, there is no contradiction between the ideas of devolved power and effective national networks. It may not be that the devolution of power is increasing complexity in the system at all. In fact, increased curricular diversity, broader professional support, and the shared purpose this approach enables create a stronger and more reactive holistic system, provided its component parts are open, safe and manageable spaces for collaboration and feedback (Van den Akker, 2005). This requires strong leadership at all levels, and a new lens that focuses on the complex interactions of the actors within educational systems and subsystems, creating a broader view of educational systems as a holistic organisms.

This paper will advocate a shift in approach from the common centre versus periphery model in governance and, more specifically, reform, toward a broader vision encompassing greater humility amongst actors and a conscious effort to listen and include others at all levels and of all opinions in order to achieve win-win scenarios across the system and seize a mutual higher ground (Fullan, 2009). This will require stakeholders to broaden their vision to recognise the importance of cross-sector systems and issues, which, for education, include the domains of politics, finance and health among others, areas that can have powerful effects on systemic development. It will also require an approach that allows key issues to be identified within complex systems, perhaps borrowing from the approaches of other disciplines seeking to simplify complex systems, so that the sprawling nature of educational systems does not overwhelm attempts at reform and lead to systemic paralysis and confusion or to the temptation of oversimplification and laser-focused reforms. In short, viewing governance issues in isolation and seeking reductionist approaches targeting specific policy areas or pedagogical changes is unlikely to yield positive, sustainable change on a large scale. To be effective in a complex realm requires a fuller understanding of complexity itself.

This brief will begin by defining what is meant by complexity. The term itself is fraught with myriad interpretations and little academic consensus regarding exactly what is meant in a governance and reform context (Morrison, 2010). This current state of affairs makes it necessary to define a complex approach as distinct from other ways of conceptualising interrelated systems. The question of the difference between simple, complicated and complex problems will be explored, followed by a deeper look at the nature and behaviours of complex systems themselves. The focus of the piece then shifts to an approach currently

used in other fields – most notably, ecology – to managing complexity and reducing the information overload which complex systems often present (Johnson, 2008). This approach revolves around the modelling of complex interactions into visual diagrams, which allow for nodes of great influence to appear and for a winnowing of extraneous data through iterative, multi-level feedback. Modelling and visualising complex systems offers a tantalising tool to grasp the enormity of complex systems and bring them back into the realm of the manageable (Williams et al., 2002; Berlow, 2010). The final phase of the paper explores how these ideas have been operationalised in some contexts and makes some recommendations for future policy makers wishing to employ this approach.

What makes complex problems unique?

Glouberman and Zimmerman (2002) provide an excellent illustration of the differences between simple, complicated and complex problems (see Table 1). In a simple system, a formula can be followed and repeated with relatively little expertise and be expected to produce roughly uniform results, whereas in complicated systems, following a tried and true formula is insufficient. Higher order expertise is often required and a variety of fields may need to be drawn upon in order to produce a successful result. Once that result is achieved, however, it is in most cases replicable. An example of a complicated problem is the sending of a rocket to the moon. There are numerous inputs needed to achieve the end goal, but once it is done, it can be successfully repeated with subsequent launches requiring far less analysis and expertise than was the case during the initial phase since all further rockets, presumably, start from the same initial state and follow the same processes to achieve their goal. In short, a complicated problem, once solved, remains solved.

Table 1. Simple, complicated, and complex problems

Following a recipe	Sending a rocket to the moon	Raising a child
Recipes are essential.	Formulae are critical.	Formulae have limited application.
Recipes are easily replicated.	Sending one rocket increases assurance that the next will be ok.	Raising one child gives experience, but no assurance of success with another.
Expertise is helpful but not required.	High levels of expertise in multiple fields needed.	Expertise can contribute but is neither necessary nor sufficient for success.
Produce standardised product.	Rockets are similar in critical ways.	Each child is unique and must be approached individually.
Best recipes give good results every time.	There is a high degree of certainty in the outcome once the original issues are solved.	Uncertainty of outcome remains.

Source: Adapted from Glouberman, S., and Zimmerman, B. (2002)

The Cynefin Framework (Snowden, 1999) places these concepts into a visual context that can be applied across any number of fields (see Figure 2). In simple contexts, cause equals effect. This is the realm of the known. Situations can be clearly defined and appropriate responses identified. The policy maker's role is to delegate, use best practices, and communicate the standard operating procedures to be followed clearly and directly.

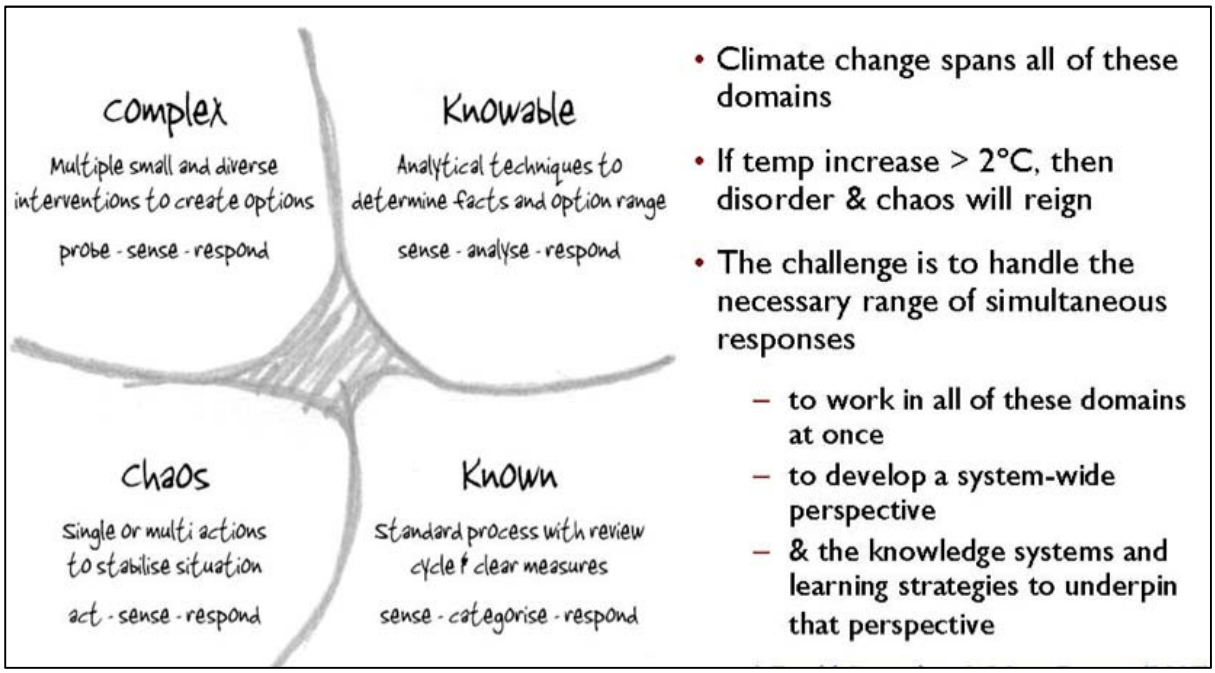
Complicated contexts are the realm of expertise and data analysis – the known unknowns. Cause and effect are not self-evident but can be teased out through analysis. The policy maker's role here is to

assemble the requisite minds and encourage differing opinions while avoiding paralysis of analysis. Once cause and effect are understood, interventions can be undertaken to tackle the problem, and, if the required expertise were present during the discussion phase, as in the case of the rocket launch above, the solution should work and be replicable.

The complex is the realm of the unknown unknowns. It is a space of constant flux and unpredictability. There are no right answers, only emergent behaviours, a concept discussed in detail later in this paper. The policy maker's role in this space is to create safe spaces for patterns to emerge, which is best done by increasing levels of interaction and communication within the system to its largest manageable level. Expertise is useful but not sufficient to solve complex problems – great patience and a sharp eye for new behavioural patterns are the only way forward.

Chaos is an area of tremendous turbulence with no clear cause and effect relationships, which makes searching for them fruitless. It is the realm of the unknowable; as a policy maker, one's only reliable approach is to attempt, through direct command and control mechanisms, to encourage disparate points of view and try to drag the problem back into the realm of the complex (Snowden and Boone, 2007).

Figure 1. The Cynefin knowledge framework



Source: Snowden, D. J., and Boone, M. E. (2007), http://hbr.org/2007/11/a-leaders-framework-for-decision-making/.

Educational initiatives, and in fact the social sciences more broadly, often attempt to dwell in the realm of the complicated when in fact they are operating in the realm of the complex (Duit, et al., 2010). Experts devise a policy targeting a single or relatively small set of problems and launch it, believing (or at least hoping), that the solution they are advocating is whole, complete, widely replicable and easily actionable. All that is then left is to wait for the results and see if the metaphorical rocket reaches the moon. Iterative feedback is often limited in this approach, and flexibility is not often a high priority in the initiative's design. What this misses is that complex problems cannot be adequately captured via such linear approaches (Morrison, 2010; Duit et al. 2010). As Johnson puts it,

> *Currently, many methods of investigating the educational outcomes of individual schools ... are based on linear algorithms that simplify and break down systems into isolated, component parts. The premise of such linear models is that inputs into the system will result in predictable outcomes. While appropriately predictive of some static, closed systems, these models fail to adequately predict the behavior of or capture the essence and emergent properties of complex systems involving three or more interacting components* (2008, p. 5-6).

Applying Glouberman and Zimmernman's (2002) work on health care systems to the realm of education, one might argue that, unlike rockets, the actors in an educational system do not come from the same initial state nor do they necessarily resemble each other. What works for one child, teacher, district or system is not guaranteed to work for another. Indeed, what works for one element of one system may not work for other elements even within the same system. This makes the problem of educational governance complex rather than complicated since solutions are not necessarily replicable and transferable. Educational governance and reform requires an entirely different approach that allows for several factors: changing initial conditions, the emergence of non-mechanistic phenomena (A will not always lead to B and on to C as it would in the development of a rocket), flexibility, and, most difficultly, it must allow for the fact that reductionism will not work – there will be no single right answer, no single particle or approach that holds the key to successful implementation. Flexibility and feedback are necessary to manage successfully in a complex system, but doing so requires a fundamental reframing of the way we look at common problems in governance and reform. Policies must move from one-size fits all solutions to iterative processes derived from constant feedback between all stakeholders.

Importantly, this is not limited to education, and looking beyond the standard confines of education and absorbing the lessons found in other sectors will be crucial to reshaping governance structures as they grow in complexity. A study done of the Canadian health care system further illustrates the different lens needed for this approach and illuminates a new way to view questions of reform in education:

> *The complicated question "What are the structures we need to make the health care system sustainable?" becomes the complex question "How do we build on current structures and relationships to stabilise and enhance Medicare?" The question "Can we afford increasing care and treatment for an aging population?" is best understood as "How can we provide care and treatment that makes everyone feel that the system will be there should their family need it?" The question "What do we have to give up to support the most effective and advanced technology (or drugs)?" would better be asked as "How can we help health care institutions and professionals enhance the quality of services and innovation in technology and drugs?" and, finally, "How much should Canadians pay for their health care?" might become "How can Medicare contribute even more to the Canadian identity?"* (Glouberman and Zimmerman, 2002, p. vii)

Whereas the first question in each set seeks a definitive answer to a complicated question, the second is open-ended and encourages a wider view that is not driving at a single solution but rather at an integrative approach that would incorporate already existing knowledge and structures with those emerging and with those present in other, interrelated disciplines. In this example, the complex questions seek to place health care within a larger system of Canadian identity, and, importantly, they take the viewpoint of individual (or institutional) actors' effect on the wider system rather than the reverse – an important distinction.

In translating this approach to an educational context, we might take the complicated question of "What governance structures do we need to create to improve education?" and rephrase it as "How can we enhance and utilise the structures, resources and processes already present to improve the equity and effectiveness of education?" "Can we afford educational reform?" becomes "How can education reform be designed to spur our economy and send positive ripple effects through our whole society?" "How can we improve student performance on high stakes testing?" is transformed to "What are we learning from current assessments and how could they tell us more?"

These are not only theoretical questions to be considered during the planning phases of a reform but vital parts of policy development itself that should begin long before an initiative is announced and continue throughout the life of the project. The barriers between design and implementation should be collapsed to create a single iterative process, driven by feedback to core decision makers from the local level actors, with the goal creating cycles of interaction between decision makers and those charged with implementation, who are most often the actors responsible for turning general ideas into practical strategies. All stakeholders, at all levels, should listen to and interact with each other to continuously refine and improve the reform (Stoker and John, 2009; James, 2006). The traditional model of policy making, in which design precedes and is distinct from implementation, should be replaced by one of experimentation, an approach explored more thoroughly later in this paper, in which end-of-programme summative assessments are supplemented by continuous formative assessments (Magro and Wilson, 2013) in what can be characterised as "an oscillating multi-level interaction" (Heilmann, 2008, p. 12). Questions regarding reform should be reframed from simply "Did it work?" to broader questions that blend research with implementation. Unintended consequences and their impact should be studied as they occur and mechanisms of causality that may emerge throughout the reform should be actively searched out and studied (Eppel et al., 2011) with feedback being taken on board by decision makers throughout the process.[1]

Employing this approach, in which the implementation and design phases are melded into a single looping iterative process, would, however, mean accepting three key and perhaps politically difficult factors as a reform is begun:

1. The first attempts might be bumpy since the reform is not fully formed. There are many unknowns, and the structures for collaborative feedback and guidance may yet need time to mature.

2. Experiential lessons have not yet been disseminated broadly across contexts, so results will vary, which is not necessarily indicative of programmatic efficacy at the outset.

3. Successful implementation will require a strong focus and commitment on the long-term change of the whole system. The actors will need to talk and work their way through the bumps in the road and build the communicative structures to smooth contextual differences and share experiences learned. This cannot be built into the reform from the outset but must grow with the programme as it expands and takes hold (Eppel, et al., 2011).

Framing the approach to reform in this manner changes the lens to a more inclusive one that is process-driven rather than outcome-driven. The reform becomes an organic, changing process rather than a preordained solution formulated in the realm of the complicated and reliant upon all the actors within it to succeed. Before delving more deeply into what is meant by all of this and what it might look like in practice, we will first step back and try to define the basic characteristics and behaviours of complex systems themselves.

What is complexity theory?

"I consider it impossible to know the parts without knowing the whole, or to know the whole without knowing the parts."

Pascal (as cited in Morin, 1999, p. 115)

Modern complexity theory has its roots in the work on general systems theory done by Ludwig von Bertalanffy during the late 1940s and 50s as well as in Weiner's work on cybernetics in roughly the same period. General systems theory posited that while general laws of thermodynamics applied to traditional closed systems, open systems such as living organisms or systems of actors with individual motives and behaviours were not necessarily subject to these same properties. The field of cybernetics contributed the concept of positive and negative feedback as a governing mechanism for open systems, which in turn led groups of actors to self-organise and allow new patterns of behaviour to emerge. These concepts – self-organisation, emergence and feedback – are at the heart of modern complexity theory. Their decidedly non-mechanistic approaches and resistance to reductionism make a worldview based on these principals starkly different from the traditional scientific approach taken to systems management that had preceded this work. Later scholars such as Beer, Churchman, Byrne, Beinhocker, and Forrester extended these concepts into the sphere of systems management in fields as diverse as finance, health care, ecology and numerous social sciences while others, such as Prigogine and Mandelbrot, took a more mathematic approach to understanding systemic behaviour leading to developments in fractal geometry and eventually chaos theory. By the 1980s, researchers at the Santa Fe Institute attempted to unify some of these core concepts into a model known as a complex adaptive system. While this model shares commonality with elements of all the preceding theories, the nature of complex adaptive systems is in many ways an entity unto itself and still an evolving construct (Alhadeff-Jones, 2008).[2]

Sabelli (2006) cites a useful definition by Kaput et al. (2005) to identify some core components of a complex system:

- The interconnected components' behaviour is not explained by the properties of the components, but rather emerges from the interaction of the components.
- The system is non-linear and relies on feedback to mould and shape its evolution.
- The system operates on multiple time-scales and levels simultaneously.

Put simply, complexity theory posits that systems begin as collections of individual actors who organise themselves and create relationships. These relationships form in response to positive or negative feedback – though a degree of randomness is inarguably involved as well. New structures and behaviours then emerge as the actors act and react to each other. As Haffeld puts it, "Value is created as a result of individual interactions, and often the emergent result is more than, or qualitatively different from, the sum of individual actions" (2012, p. 453).

Feedback loops serve as the driver for this evolution of the system. Positive feedback moves individual actors or groups of actors closer to a goal perceived to be important while negative feedback serves to suppress change and drive the system towards equilibrium. Feedback can take any form, from the trivial and difficult to perceive to the obvious form of outside intervention, but, no matter the origin, these feedback loops tend to grow larger and more influential, their effects spreading to more and more actors within the system, both laterally and vertically, and they are vital to successful reform implementation in a complexity-based approach (Mason, 2008; Morrison, 2006).

Key to all of this – and problematic for policy makers trying to steer from the centre – is the fact that there is often no guiding central hand in the evolution of the system. What the centre can do is create a fertile environment that embraces the emergent nature of complex systems and work to create processes that maximise the flow of feedback between and across levels in a safe and manageable space. This will allow for self-organisation in which structures will emerge born from the collaboration of all stakeholders (Morrison, 2010). Where to direct policy efforts and how to remain open to feedback without becoming overwhelmed by it does, however, remain problematic. An OECD working paper on multiple school accountability, which seeks to involve a broader array and larger number of stakeholders in the accountability process of schools, reports: "Initial reports are mixed: there is great appreciation for the process and a broader range of stakeholder voices. However, ministries report a reluctance to rely too heavily on information generated by multiple accountability mechanisms due to doubts about its reliability and the risk of information overload" (Hooge et al., 2012, p. 13). The same paper, however, does note that research into taking what it terms a "participative democracy" approach, that is, incorporating parents, teachers, employers and community groups in the decision making process, "seems to show a positive impact on schooling and/or greater effectiveness or efficiency in education" (Hooge et al., 2012, p. 7). What is needed, it seems, is a way to better manage the flow of information and identify the important from the extraneous. Ecology and other sciences that may offer new approaches to this question will be further explored later in this piece.

Tipping points and cascading effects

Beyond self-organisation, complex systems share a few other common and powerful characteristics – namely the presence of tipping points, often small events or thresholds crossed, which cause tremendous change across the system via cascading effects. These tipping points are often difficult to anticipate, but policy makers' aim should not be to prevent these thresholds and cascade effects but rather to recognise that they are going to happen, limit the unintended consequences of these rapid shifts, and perhaps harness them to affect desired change. The approach is not unlike that taken with regard to earthquakes: they will happen, they will be sudden, and the effects will be somewhere between mild and devastating. Trying to stop them is futile, so all that can be done is careful planning of the structure of daily life to ensure the best possible outcomes when they inevitably occur. Flexibility, both literally in the buildings themselves, and figuratively in the design of rapid response teams, is seen as a key element of a successful approach to earthquake preparedness. In a paper on public policy, Daniel Nohrstedt found that the common traits of Sweden's high-performing emergency management networks were "stable inter-personal relationships, clarification of the terms of collaboration, shared problem perceptions, and coordination of joint decision making" (2013, p. 1). All of these traits emerge out of feedback and interaction and are difficult, if not impossible, to centrally plan. Codified responses, applied broadly, are not as effective, at least in this context, as a few clearly stated goals from the centre and a free hand at the local level to build feedback mechanisms that allow individual networks to reach these goals in the manner that best suits them. The Dutch educational system functions in this manner, with most policy developed in local contexts according to broad goals set forth by the centre, and they have enjoyed substantial success in improving poorly performing schools in their system (Maasen et al. 2011; Van Twist et al., 2013).

With regard to educational systems, the hope is that through developing a more interactive, flexible, collaborative system with an eye toward complexity theory, sufficient pressure can be applied across the system prior to a trigger event such that it moves in a favourable direction – much like the felling of a tree that has grown too near a house – when trigger points are reached. Further, much like a falling tree can knock down several others and create a cascade of destruction throughout a forest, so too can relatively small proximate events irrevocably change whole systems. This cascade effect can certainly be devastating but managed correctly, as in the case of emergency management systems above, deleterious effects can be mitigated and it can also be a powerful force magnifier for positive change across a system. This holds out the tantalising possibility that it may not be necessary to launch sweeping reforms tackling whole

educational systems if the right levers of governance can be identified and triggered. The cascading properties of complex systems, coupled with their ability to create reactions far larger than initial events would likely warrant, can be a powerful part of a policy maker's toolkit. It is admittedly akin to steering a tiger by its tail, but by successfully aligning the stakeholders in the system through a constant feedback process, a more resilient and flexible system can be created that might allow it to be done.

A note of caution: it is important to avoid viewing small tipping points or trigger events as causal – a tempting approach that reverts to complicated rather than complex thinking. The impulse to fix only the perceived problem that is most clearly defined and closest in temporal space, for instance, structurally weak buildings in the emergency context or low PISA scores in an educational one, should be resisted. Many other factors should be included in the reform process to fully prepare for the unexpected but certain to occur events that are the nature of complex systems. It must also be recognised that the triggering event is likely to be only the endpoint of an inexorable inertial march of the entire system toward a new paradigm. As such, attacking any one actor or process is unlikely to reverse the course of the larger system.

A hypothetical example from education might be an investigation of a failing school which discovers that there are too few textbooks in a class. An A-to-B linkage is drawn that the students are not learning due to this, so more books are provided and a concomitant rise in scores on assessments is anticipated. Unfortunately, that rise never comes, indicating that providing more books does not seem to be a guarantee of improvement. It may have been one of the key factors that needed to be addressed to improve outcomes, but it was clearly not enough by itself. Other equally powerful forces are impeding progress and they must be found and integrated into the reform. The takeaway here is that addressing singular issues – resources, for instance – misses larger issues that may, and often do, have significant impacts. Fullan states, "One cardinal rule in systems reform is never, ever, endorse one factor at a time as key. For example, to note that Finland has no national testing and is at the top does not mean that the absence of testing is always a good thing. Successful system reform usually means that a small number (up to half dozen) of powerful factors are interacting to produce substantial impact. It is the interaction effect that accounts for the results" (Fullan, 2009, p. 108).

School and community culture, economic factors, parental achievement, health issues, local and national politics, and any number of other diverse inputs play a role and can only be captured and made a part of the system's development by bringing all actors into the process. "A complexity approach acknowledges that all levels of focus, whether this is the individual, class, school, national or international associations, reveal humans and human endeavour as complex, and that focusing on one level will not reduce the multi-dimensionality, non-linearity, interconnectedness, or unpredictability encountered" (Kuhn, 2008, p. 183). In short, launching an initiative targeted at only a single, identifiable problem is akin to throwing a pebble into the ocean. In order to create more than a ripple, the intricate web of different intersecting systems must be better understood and modeled so that pressure may be applied to the system at as many key points, and by as many actors across as many levels, as possible to nudge systems toward desired outcomes. A shift in emphasis is needed away from the analysis of individuals and outcomes to an analysis of processes and a shift in institutional culture toward greater systemic engagement amongst all actors and levels.

Lock-in

A final concept, which runs counter to conventional market-based views of systemic development in which an invisible hand guides production and process towards ever more efficient outcomes, is the concept of lock-in. As described by Mason (2008), lock-in is the state when a new behavioural pattern or paradigm has been adopted system-wide and becomes entrenched even if it is probably not the most efficient model. Mason cites the VHS tape and the QWERTY keyboard as simple examples of this phenomenon. Both of these items were widely known to be sub-optimal but became industry standards

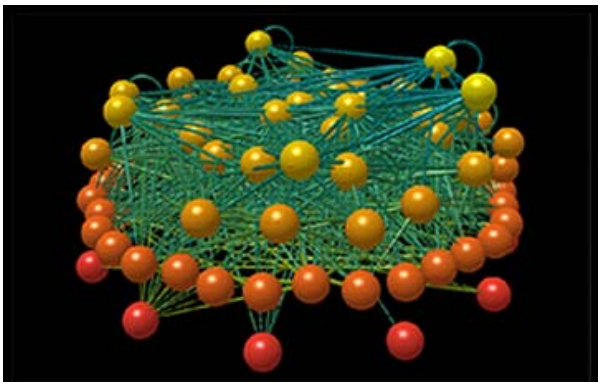
nonetheless. The QWERTY keyboard, specifically designed to be inefficient to solve the problem of early mechanical typewriters' keys jamming when typists worked too quickly, gained near universal adoption and remains the standard today despite the move away from mechanical typing devices that suffer from this problem. New, more ergonomically appropriate keyboard designs have been created, but a snowball effect of more and more actors in the system using the keyboard over the years has led to deeply entrenched systemic resistance to change, or lock-in, that is only likely to be changed by a wholly new technological approach that makes traditional keyboards obsolete – the touch screens and voice recognition of today's mobile devices may be a first step in this direction. Thus, technological breakthroughs (in an educational context this could be online learning, for example) can break systemic lock-in, but waiting for them to come along wastes valuable time and resources. It is far more efficient for policy makers to be cognizant of virtuous and vicious cycles being formed and attempt to address them before lock-in occurs by addressing a wide range of actors. Parents, students, administrators, teachers, government and the media all have a role to play in either creating a virtuous cycle (e.g. setting a school system on the road to improvement) or furthering a vicious spiral (e.g. enrolment dropping and motivation ebbing as a school drifts further and further from success.) Obtaining the recognition of systemic inefficiency and suggestions for a new process through open feedback channels with every involved stakeholder can spread a sense of ownership across the system and increase the chance of either preventing the onset of a vicious cycle or breaking out of one already present due to the lock-in effect of ineffective practices.[3]

Making complexity manageable: Lessons from ecology

The idea of addressing and working with all stakeholders to address all issues can be overwhelming, but, as has been hinted at in previous paragraphs, it may not be necessary to address every aspect of the system to affect change. As has been shown, complex systems are non-linear and prone to cascading effects that not only spread change throughout a system but often increase in scope as they go. Harnessing their power to promulgate change and create self-sustaining waves from small triggers may be a practical way forward for policy design, and ecological science is providing certain clues to approaching the vastness of complex systems in a more manageable way.

Ecologist Eric Berlow (2010) proposed another approach to affecting change within a complex system in a brief TED Talk given in Oxford, England. While doing research on the interaction of aquatic species in which he and his team sought to understand the impact of one species on another, Berlow began to use visual modelling of the various animals to better understand the composite picture. His models contained simple nodes connected on a wireframe much like the models of molecules found in nearly any child's classroom (see Figure 2).

Figure 2. Food web from Little Rock Lake



Source: http://research.microsoft.com/en-us/um/cambridge/groups/science

What they found was that by focusing solely on the interaction of any two species, in a direct linkage of cause and effect with all other inputs ignored, far too much pertinent information was lost in the black box. Paralleling the earlier example of textbooks in schools where only a single node was identified and treated, success remained elusive. What was needed, the team realised, was a way to focus in on the specific node of interest and then explore its sphere of influence rather than only the node itself or the entirety of the ecosystem. When doing this they found that,

> *Empirical evidence suggests that such strong effects rarely propagate through food webs more than three links away from the initial perturbation…Here, we show that species within large communities from a variety of aquatic and terrestrial ecosystems are on average two links apart, with >95% of species typically within three links of each other. Species are drawn even closer as network complexity and, more unexpectedly, species richness increases*. (Williams et al., 2002, p. 12913)

This work revealed that influence on any given node (or species in this case,) rarely extends beyond two or three degrees of separation from any other node. If this phenomenon were to translate to educational governance, one can imagine that whole system change need not necessarily require broad-brush application of reform. Targeted applications on the right nodes could create a ripple effect throughout the system leading to positive and, to at least some degree, predictable, outcomes. In essence, policy makers could create a conducive space and then create a trigger event that would ripple through the system.

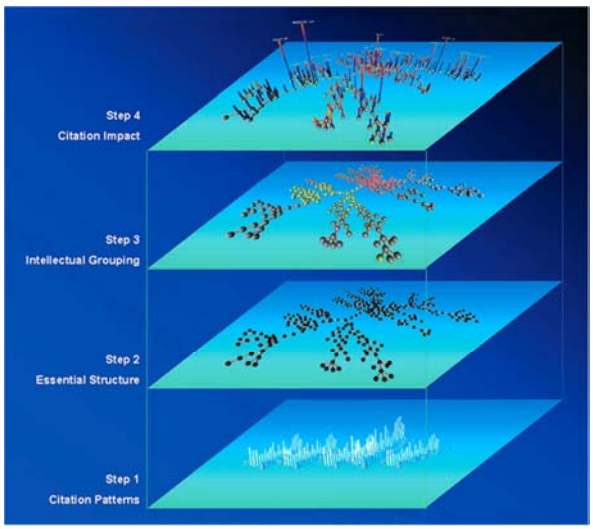
This approach is built upon an ecological model that argues that the environment is comprised of four layers of systems which interact in complex ways and can both affect and be affected by a person's development (Bronfenbrenner, 1995). Bronfenbrenner later added a fifth dimension that comprises an element of time. This theory can be extended to model the complex systems of a school district or even of an individual school. The five layers of the model are (adapted from Johnson, 2008):

- **Microsystem** – interactions at the interpersonal level.
- **Mesosystem** – The bi-directional linkages between microsystems (i.e. teacher and student, or faculty and parent)
- **Exosystem** – The larger social system in which individuals act and which exerts influence upon them (i.e. the elements of the local community.)
- **Macrosystem** – The underlying cultural blueprint in which the system exists (i.e. regional or national level interests.)
- **Chronosystem** – Both short and long term time scales, which affect individual and systemic actions (i.e. the disconnect between the political and educational programme cycles for instance).

An illustration of this approach being applied, admittedly to a complicated rather than complex problem, has already been tried with regard to knowledge structures by Chen and Paul who have taken traditional author co-citation (ACA) modelling, and extended it into a visualisation tool, called Pathfinder, which models connections and interrelations between scientific authors and topics in 3D space. Though not a direct example of complexity modelling, it is illustrative of what could be a useful way to visualise and better target governance interventions. The programme "provides an effective way to extract the most essential relationships from a given set of proximity data and simplifies a network by retaining only the strongest paths" (2001, p. 66). It simplifies the network via a four-step process (see Figure 3) that makes

key nodes and nexus points pop out. Whether these are causal or not would have to be determined through separate research.[4]

Figure 3. 3D Modelling of ACA database



Source: Chen, C., and Paul, R. J. (2001), www.pages.drexel.edu/~cc345/papers/ieeecomputer2001.pdf.

If this technique could be applied to governance, tracing all actors, policies, interventions, and external inputs to the system (health, political, financial, etc.) and modelling their interrelations, it could help to reduce possible distractions and make clear critical areas, actors and processes where the greatest change can be affected with the smallest reform. This would then allow the nature of complex systems themselves to help propagate desired change system wide by relatively small interventions directed at these key nexus points.

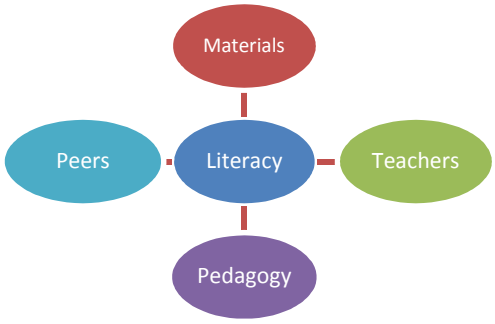
Admittedly, finding and modelling all the underlying data for who the actors are and what the issues might be in governance is not as simple as crawling through a database of citations, but iterative and inclusive feedback amongst all stakeholders can help tap into already extant institutional knowledge and begin the process of identifying the working from the broken, the important from the extraneous, and the efficient from the wasteful. At the same time, such feedback will also bring the actors closer together and in better alignment so that the reform wave proceeds in the manner in which it is intended and structures are flexible and responsive enough to react to the unexpected. As such, processes and structures that facilitate and increase feedback should be created at all levels and between levels. This may initially create a cacophony of opinion, but in the longer run, clarity and operable approaches focusing on the right nodes to address to create systemic reform may emerge.

Modelling school systems using ecological approaches is advocated by Johnson as a "useful alternative to the linear models that often form the basis of educational research and policy" (2008, p. 1). She argues that traditional approaches "too often fail to consider the complexity of interactions that result in student achievement" (Johnson, 2008, p. 1). Coupling this recognition with Berlow's work on finding access points and levers of control in a complex ecological system, leads to the possibility that not only can natural systems be modelled in this manner, but also governance systems like those found in education and other social sciences (Johnson, 2008; Duit, et al., 2010).

Modelling complexity in educational governance: A thought experiment

Returning to the earlier example of a school with poor literacy scores that has identified a lack of textbooks as the core reason for this outcome, we see a very linear cause-effect model that might be represented visually by two nodes connected by a single line: (poor literacy scores <-> lack of text books). This tight focus on a single problem area loses a tremendous amount of causal information in the web of the black box. If the same problem is reframed to try to ascertain the broader sphere of influence, a simple model that looks more like Figure 4 might be a starting point.

Figure 4. A simple model of an educational system



It shows that literacy is directly impacted by factors such as teachers, materials, peers, and pedagogy, but it does not, however, tell us how much each of those factors matter, what factors are in turn acting on those nodes, or what may be missing entirely from the picture. It rapidly becomes clear that this model is far too limited, the categories too broad. A more realistic model might include everything from politics, to cultural identity and history, to economic factors, and locally contextualised opportunities. However, when the problem is viewed in this manner, it can seem an overwhelming picture with no clear entry point.

When trying to embrace the entirety of a complex system, it quickly becomes clear how the network of impacts can expand and lead to a perceived choice between addressing a singular issue, like providing more books, or the equally detrimental approach of launching an array of initiatives that tax systemic resources and lead to fatigue among the human elements of the system – be they teachers, administrators, policy makers, parents or the students themselves. Launching too many initiatives can lead to a muddled approach that creates significant barriers to successful implementation such as:

- Lack of clarity amongst stakeholders
- Conflict between short and long term visions
- Inability to build capacity necessary to affect such wide ranging reforms
- General resistance to change and “innovation fatigue” throughout the system
- General lack of communication between governance agents as the systems have not evolved to meet the reforms and the reforms themselves may require conflicting practices. This can often lead to poor communication and an exacerbation of the above points (OECD, 2009).

Box 1. Guiding principles from Australia's *Learning to Learn project*

Initiated in 1999, *Learning to Learn* was implemented in 77 schools and preschools in South Australia. It was designed to respond to concerns that prior attempts had led only to incremental improvement rather than the desired transformational change of a systemic culture. The principles below are illustrative of a whole system lens applied to reform.

- Transformation rather than incremental improvement is needed;
- A catalyst or leader is required to trigger the development of partnerships between stakeholders as a basis for achieving a change;
- Complex problems need complex solutions and can come from the local level;
- A sense of vocation constitutes a motivational resource for teachers in the context of education;
- Learning comes through trust and acceptance of risk;
- Reflection on deeply held worldviews and a questioning of identity, not just administrative change, is needed for sustainable benefit;
- Change and uncertainty are ubiquitous and form the backdrop for transformation;
- Sustainable change comes only through responsibility taken at a local level, not through imposition.

Further, the programme avoided:

- Excessive formalism and quantification;
- Seeing planning as a useful activity in itself;
- An institutional view of "human resources", focusing rather on people and reinforcing professionalism;
- Seeing leadership as about authority, focusing instead on quality relationships;
- Centralist control typical of bureaucratic and managerial thinking.

Source: Goldspink, C. (2007). doi: 10.1177/1741143207068219, adapted from Foster (2001).

What is really needed is a reframing of the question from what affects literacy (or any other issue being targeted) to a question of what has the *most direct effect* and *greatest impact* on literacy in that particular context. All of the nodes cannot be treated as equally important. As all of these factors clearly have some impact on outcomes and none is solely responsible, the key lies in determining *how much* a particular node matters and to what extent it can affect other nodes further out in the web. Once identified, due to the cascading, self-organising nature of complex systems, nodes not affected by the initial programme should also see improvement, it is hoped, through the knock-on ripple effect that is characteristic of complex systems. The key question remaining then is how to target the right nodes; the answer, complexity theory tells us, lies in opening wide multi-level feedback channels to tap into the institutional knowledge already present in the system. The following sections will show some real world examples of where this approach has been tried. Finding key nodes: Regional examples

Tapping into institutional knowledge in Ontario

In discussing the reforms launched in Ontario in 2003, Michael Fullan writes:

> *The Ontario strategy is based on three overriding sustaining elements: respect for staff and for professional knowledge, comprehensiveness, and coherence and alignment through partnership between the government and the field (schools and districts). Ontario identified a small number of ambitious goals (literacy, numeracy and high school graduation), established a dedicated capacity building infrastructure of leadership, and works to negotiate targets and use data to mark progress and intervene early where problems are occurring. While there is much still to be done the strategies are 'working' in that progress has been steady (with some plateaus) in the 6 years that it has been underway* (2009, p. 108).

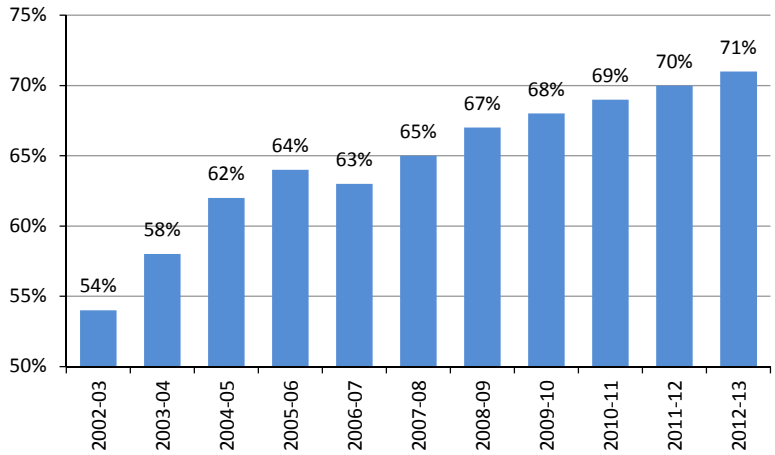
This approach echoes many of the complexity principles previously outlined. In practice, Ontario went about identifying the key nodes by eliciting feedback from all stakeholders, at all levels, through a variety of forums and panels. Ministers and deputy ministers met regularly with provincial officers, teachers and principals, and outreach programmes were launched to parents and community groups to outline the key goals of the programme and processes by which they would be achieved. A collaborative body called the Student Success Commission was created which included representatives from the four major teacher organisations, as well as principals and supervisory officers from both the provincial and Ministerial levels. This commission was tasked with providing its endorsement of policy changes so that all the concerned stakeholders could speak with a single voice and prevent disputes at the local level (Levin, Glaze and Fullan, 2006).

Quoting a source from their research for a 2010 McKinsey Report, Mourshed et al. write:

> *Ontario did not centrally script and cascade new teaching and learning practices to all classrooms. Instead, it focused on cultivating school-led innovation and improvement. As one Ontario system leader described, "We minimised the amount of directing or mandating we did. Instead, we needed methods to get school professionals' ideas so we could build on them. We regularly brought people together to share their practices and exchange ideas. We did almost no mandating of specific strategies – we got them to develop their own plans. We didn't micromanage schools or districts in this process. We empowered them"* (p. 50).

The actors were allowed, through intentionally created feedback mechanisms, to design their own reform process, and the results, as can be seen in Figure 5, have been impressive.

Figure 5. Percentage of Grade 3 and 6 students in Ontario achieving provincial standards in literacy and numeracy, 2002-13



Source: Government of Ontario (2013), www.edu.gov.on.ca/eng/about/ConsultationStrategyNONBoard.ppt

A key node identified through the feedback process was that of capacity building and professional development. In response, the government of Ontario made a huge commitment to change and did the following:

- Hired thousands of new teachers.
- Expanded tutoring to key underperforming groups.
- Reduced class sizes and dispatched specialist teachers.
- Prioritised preparation and professional development time – including the addition of two more professional development days to the school year.
- Created a new Secretariat designed to bring together outstanding educators from across the province and to help develop leadership teams for literacy and numeracy for every board and every elementary school.
- Formed partnerships with colleges and universities to offer dual credit programme and with employers and community groups to create "high skills majors," a package of courses designed to lead directly to employment and further learning.
- Created user-friendly databases of achievement results to increase capacity at all levels and to increase internal and external accountability (Levin, Glaze, and Fullan, 2006).

Taken together, these actions served to create an interconnected network of educators, providing rich feedback loops between and across sectors and levels, in the hopes of addressing the programmatic goals not by introducing a single new curriculum or programme tightly focused solely on literacy and numeracy skills, but by aligning all levels of the system and providing what the actors had identified as lacking – professional development – with improved literacy and numeracy results as a second-order knock-on effect. This process was designed to allow the system to find its own best practices in an organic approach

that was neither top-down nor bottom-up (Fullan and Levin, 2009). The process, akin to letting water find its own way across a barren land, turns on its head the usual reform cycle in which a new policy is rolled out and implemented only to be perceived by stakeholders as "correct" practice before there is any such data to that effect. It encourages policy experimentation to separate what is working from what is not as the process unfolds via the direct input of those who are actually implementing it, and it eschews a "fire and forget" approach that is reliant upon one-off high-stakes testing and pre-determined metrics. Targets should absolutely exist and be clearly articulated to all stakeholders, but, at the same time, it must be recognised that complex systems evolve and change constantly, and a successful approach to reforming them must be able to do the same.

Complex approaches to reform in the United States

New York's District 2, responsible for the education of 22 000 students from a wide variety of ethnic and socio-economic backgrounds across Manhattan and studied by Elmore and Burney (1997), employed an approach to systemic reform that focused on collaboration and highlighted isolation as the enemy of systemic change. In the case of District 2, this took the form of regular visits from district administrative staff with teachers and principals in both formal and informal settings. Within grade and cross-grade level, conferences were held for the sharing of ideas, and teachers were encouraged to visit other classrooms and even other schools including, in some cases, extended periods away from their home schools to work on instructional practice. Teams of principals and teachers worked together on curricular issues, and principals travelled between schools to compare practices and often worked in pairs on difficult issues. The process was broadened out to other districts in New York to deepen the knowledge base available for effective reform: "The underlying idea behind all of these forms of interaction is that shared expertise is more likely to produce change than individuals working in isolation" (Elmore and Burney, 1997, p. 9).

After enacting these reforms the district moved from 10th in reading and 4th in math out of 32 districts in New York, to 2nd in both reading and math in under ten years. It is impossible to prove direct causation between these reforms and the improved outcomes, but it is certainly difficult to argue that the system as a whole was not moving in the desired direction. It is possible that the exact mechanics may not or cannot be understood due to complex systems' inherent resistance to reductionism. If that is the case, then the only successful approach may be the application of strong leadership and long-term open thinking that creates a space for safe dialogue between all stakeholders at all levels and incorporates feedback, thus allowing the system to capture some of the undefined inputs and influences and find its own way to success. Further, this approach provides an opportunity to get the best interests of the actors within the system in alignment with the desired outcomes of the system, as they are an integral part of its development, which is the most likely way to affect substantial and sustainable whole-system change.

Moving to Los Angeles, the LAAMP programme (Los Angeles Annenberg Metropolitan Project) created 28 "school families"' (high schools and their lower-level feeder schools), encompassing over 200 000 students. Schools self-organised and voluntarily formed work teams comprising representatives from all member schools within a family. These teams were then tasked with creating appropriate governance structures, developing site-specific learning plans, using data to inform practice and identifying and targeting students and programmes in greatest need in their particular contexts. The school families worked hard to narrow down and make very specific their learning plans with most of them choosing to target literacy. They, like Ontario, and New York, also decided to invest heavily in professional development – in particular, in programmes related to the key node they had identified, literacy (Fullan, 2000). This approach operationalised the search for key nodes as per the Berlow model previously referenced, by utilising a combination of data and local knowledge to get all members of the family working collaboratively and deploying resources where they were most needed and would create positive ripple effects.

The programme ran from 1994 to 2000 at a total cost of 53 million dollars. At the end of the programme, a commission, known as the LACE (Los Angeles Compact for Evaluation) Commission, evaluated the programme's effect and found it to be mixed. Herman and Baker (2003) analysed the commission's report and found that, while no substantial change was found in the state test scores (California's Stanford 9 Test) for the students, a measure the researchers themselves acknowledge as possibly being too blunt an instrument to capture programmatic effects, there were many changes they categorised as successes. Schools and school families became more accepting of accountability and more focused on performance, with teachers and administrators gaining a far greater facility with the use of assessment data. The new collaborative support networks were viewed as invaluable to newer and less experienced teachers, which was a particularly important outcome since a significant number were hired due to a mandated reduction in class sizes. Parents also became more involved in the schools as well as in their own child's work with demonstrably positive effects.

Unfortunately, by the end of the programme, classroom practices did not seem heavily effected, but the researchers do point out that the relatively brief six-year window of the programme, coupled with the tremendous upheaval going on in California's public sector of the time, could very well have impeded the development of crucial structures, setting a slower pace for the whole programme than was hoped for. They note that it took substantial time to get the "family" structures into place (these were self-organising rather than mandated groupings,) and that, towards the end of the programme, once the structures had been fully developed, LAAMP initiatives were beginning to permeate at the school level. Indeed, an upward trend in scores was noted when the programmatic effects were broken down into two-year intervals (Herman and Baker 2003) indicating that perhaps the window for this programme was simply too short for its full impact to be felt.

Complexity in Hong Kong

One of the best examples of the successful implementation of whole system reform can be found in Hong Kong. Jensen et al. (2012) studied the intensive analysis undertaken by the Educational Commission of Hong Kong. This involved government officials, academics, school teachers and administrators in a 20-month long process with the participation of over 10 000 people at 34 different seminars and forums. This tidal wave of feedback was solicited to obtain an in-depth understanding of the current challenges and the context in which they were occurring. As in Ontario, continuous and iterative feedback was viewed as a key component of the reform. Indeed, mechanisms for dialogue created during this process still continue, with weekly meetings of working groups representing stakeholders at various levels, the Education Bureau, and the Hong Kong Examination and Assessment Authority.

The lesson learned from this feedback was that learning was too exam-driven and lacked room for creativity and exploration. Teaching had become a one-way passive process; whereas what was wanted was a change in outcomes to life-long learners with strong critical thinking and communication skills that would allow them to be competitive in a knowledge-based economy. Two key nodes were identified as critical to achieving this educational paradigm shift:

1. Improving teaching:

    a. Namely a move away from rote learning and passive knowledge transmission and toward active student engagement.

    b. A pedagogical shift that broadened education to include moral and civic education, more project based learning and IT usage, and cross-curricular, school-based approaches with increased focus on learning outside of the classroom setting.

c. The individual teacher and classroom became the primary unit of analysis and implementation.

2. A reduction in high-stakes summative testing in favour of more formative approaches:

   a. Less focus on standardised textbooks and pure knowledge acquisition.

Resources were distributed using a constant feedback and evaluation system to flexibly deploy them as needed rather than as a one size fits all roll-out to achieve these goals (Jensen et al., 2012).

In practice, Hong Kong made changes at all levels of the system, laying them out clearly and exhaustively before implementation with detailed timelines given to all stakeholders. 42 measures were created to support teachers, schools and administrators with each measure being explicitly described and clearly explained as part of a single comprehensive overhaul. All stakeholders were made aware of what would take place and when, and, most importantly, they were told why a given approach was being taken.

From early childhood education – where entry requirements for teachers were raised, more and better training was given, the age of entry for students was lowered, and a single regulatory body was created to aid in facilitation of these changes – to higher education and beyond, where high-stakes testing was abolished in favour of low-stakes competency exams and an expansion of formative assessments with a wider range of mechanisms, the reforms were put in place as part of a single, whole-system approach from the youngest child to the oldest learner. University admission criteria were broadened to include all-around performance rather than remaining tightly focused on exam outcomes, and alternative avenues for continued post-secondary education were created. The reforms were not always popular with the general public, but strong leaders from multiple sectors – namely politics, business, and academia – stood together and put forward a coherent vision of where Hong Kong was and where it needed to go. As a result, the educational culture of Hong Kong today has changed, and teachers and parents alike acknowledge that learning takes place in many contexts, inside the classroom and out, and encourage this broader acquisition of knowledge (Jensen et al., 2012).

Implementation of the programme began in 2000 and is scheduled to conclude in 2016. As of this writing (2013), Hong Kong school authorities have stuck rigorously to the plans developed during the initial consultation and development phases. This long-term view is often absent from reform approaches and is thought to be a key element of a complexity approach because it allows time for rich feedback to accrue and for the system to evolve in response. Further, it can reduce "reform fatigue" amongst actors and lead to greater stability and understanding within the system. Reconciling the needs of the short, medium and long-term stakeholders is a constant balancing act and can be a significant barrier to the success of any reform.

Box 2. Did it work?

In 2001, Hong Kong ranked 17th out of 35 countries in the Programme of International Reading Literacy (PIRLS) test. By 2006, it had risen to 2nd place and trailed the leading country by a single point.

Hong Kong also excels in recent PISA tests: in 2009 Hong Kong placed 3rd in Math and Science and 4th in Reading; and in 2012 Hong Kong placed 3rd in Math and 2nd in Science and Reading.

Further lessons from Asia

Jensen et al.'s (2012) study of the success stories of Asian school systems in Singapore, Korea, Hong Kong, and Shanghai, four of the world's top five performing school systems in terms of PISA results, found several network based approaches consistently present. Notably:

- Mentoring extended well beyond the induction phase of teacher training. Constant feedback loops were developed between schools, teachers, and other stakeholders to continuously provide feedback focused on teacher performance and student learning. Further, peer groups were formed of teachers allowing them to observe and share with each other beneficial techniques and approaches and providing a safety net of sorts for teachers at all points of their careers. In fact, mentoring others was not just a component of the job, but a requirement for promotion and a clear part of the teacher's job description. The very best teachers were thus not promoted out of classrooms and into administration, but rather promoted into more classrooms, or to the district level, to spread knowledge horizontally and create a cascade effect strengthening institutional memory. This was not done without trade-offs. Class sizes were allowed to rise, and teacher's teaching hours were greatly reduced in comparison to most Western systems, but the overall system became far stronger as is evidenced by the meteoric rise of all four systems in terms of student learning outcomes.

- Principals and administrators were not exempt from this process and were also involved in networked mentoring. In Singapore, an executive education program was created that allowed for training in other sectors and industries – tacitly acknowledging the inter-related and complex nature of educational governance.

- Research was made a key component of teaching. In Shanghai, published, peer-reviewed work was made a requirement for promotion. Research groups were formed by teachers of the same subject within and, at times, across schools, and they conducted school-level research work, with at least one published work expected every two semesters. They were required to meet formally at least five times a year and conduct at least six observations of other group members' classrooms during the project period. This research-based community provided yet another forum for discussion, feedback and interaction that energised teachers, encouraged innovation, and provided a link between theory and practice. These school-level groups were also echoed at the district and municipal government level. Schools were networked together to share resources on research and co-ordinate training methods based on their findings. In Huang Pu district, the network consisted of 13 schools, and it was found that the higher performing schools helped raise the level of their lower performing colleagues. This kind of group development was even extended to lesson planning where year-long plans are developed in planning groups which then meet five times a year to review goals and tweak the process to take on board new findings and identify key questions (Jensen et al., 2012).

Knock-on effects

Taking a more inclusive view of the educational system as an evolving organism requires leaders to step back and observe all systemic effects rather than focusing purely on the initiatives in play and the hoped-for outcomes. Broader cultural shifts as well as secondary and tertiary changes may take place, and, if the ground has been properly prepared and the feedback loops are in place to guide systemic evolution, beneficial knock-on effects can occur. Involving virtually all stakeholders in a complex approach not only helps to isolate core nodes to address, but can also help to ensure greater trust and broader buy-in at all levels in the hopes of making the reforms sustainable over the longer term (Loorbach, 2010; Maasen et al., 2011). As the Hong Kong example has shown, longer term approaches can pay large dividends.

The type of vertical and horizontal networking present in a complex approach also appears to have a further benefit, a second- or third-tier effect in the modelling sense with regard to the issue of school inequity. Education is what is called a "merit good" in economic terms, and the benefits of these types of goods accrue to the whole community rather than just to the individual being educated. As such, as Goldspink (2007, p. 31) puts it, "Economic theory suggests (and practice bears out) that markets will under-allocate resources for such services. This under-allocation will accrue inequitably in the community". Chapman and Fullan state that collaborative feedback approaches can help to counter this under allocation and ensure a more equitable distribution of resources with regard to merit goods (in this case, education.) They note:

> *The evidence is that collaboration between differently performing schools can help to reduce the polarisation of the education system, to the particular benefit of students who are on the edges of the system and performing relatively poorly. It does this by both transferring existing knowledge and, more importantly, generating context-specific 'new' knowledge, thus contributing to capacity building across the education service* (2007, p. 207).

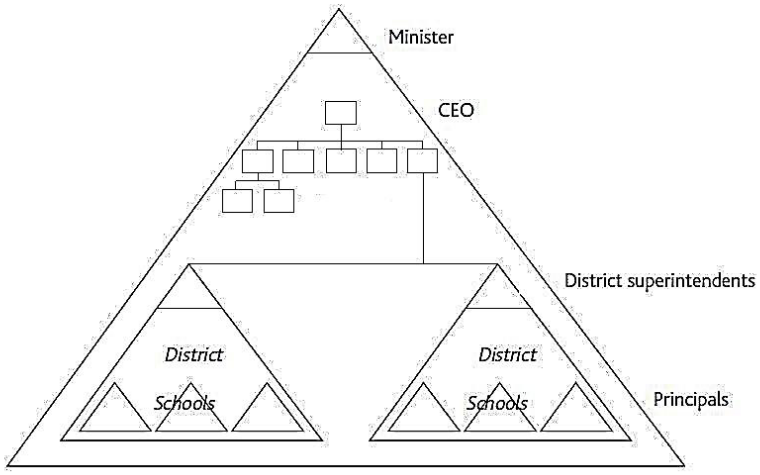
So, the difficult issue of schools "at the edges of the system" can perhaps be addressed not only through direct targeting of programmes earmarked for their improvement but also as a knock-on effect of greater feedback and sharing across the whole system. This is an example of how change can be propagated across all the nodes of the system through a complexity approach rather than solely through direct, targeted interventions.

Chapman and Fullan (2007) also determine that this approach can help address the common "too-tight" versus "too-loose" conundrum faced in many governmental reforms. Many governments struggle to find a balance between central controls with possibly strict accountability measures and wholly devolved systems with no central control. For example, recent work in Norway indicated that, while allowing a very loose, localised implementation of their recent Assessment for Learning reform created a very rich dataset with a wide variety of approaches, it rapidly became too loose to effectively evaluate programmatic efficacy and get all stakeholders in alignment regarding the actual goals the programme was hoping to achieve. Researchers found that there was too little communication of baseline expectations and specific targets; as a result, the project became difficult to govern and assess. Had more feedback mechanisms been built into the programme, stakeholders may have been brought more easily into alignment, and the gains made from localised creativity with regard to new approaches to assessment may have been more effectively spread (Hopfenbeck et al., 2013). A feedback-based complexity approach may have made it easier to find the dynamic balance through embracing networked learning communities that will organically provide checks and balances against the system becoming overly restrictive or too diffuse.

Restructuring governance

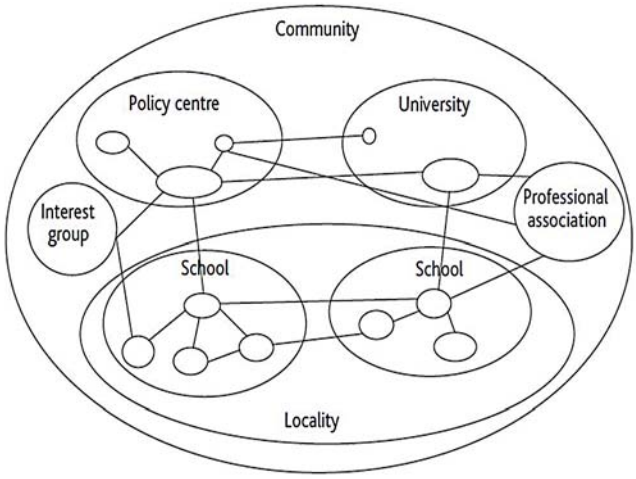
Synthesising all that has been discussed thus far would mean moving from a conventional governance model like that pictured in Figure 6, in which there is little interaction horizontally and vertical channels are restricted and flow only through certain key personnel, to a more open, interactive structure akin to the one pictured in Figure 7.

Figure 6. Traditional model of governance



Source: Goldspink, C. (2007). doi: 10.1177/1741143207068219.

Figure 7. Education as a loosely coupled system



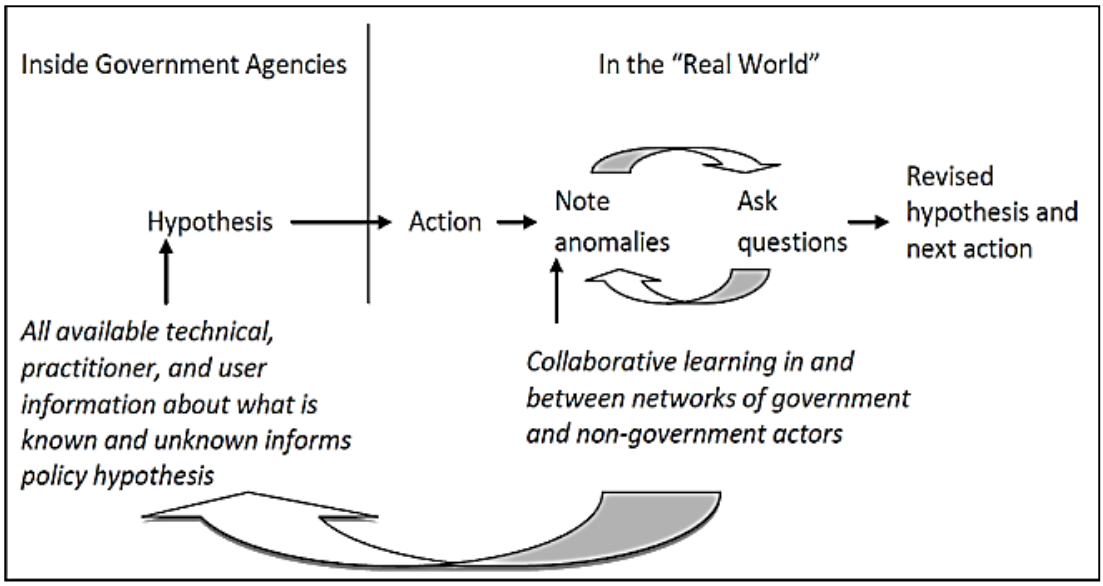
Source: Goldspink, C. (2007). doi: 10.1177/1741143207068219.

In fairness, many governments are already moving in this direction, (Loorbach, 2010) but the focus has largely been on moving the loci of power out from the centre and more towards the periphery with less attention paid to constructing looping co-operative structures that can utilise all of the knowledge contained within the system to better target the areas or nodes of greatest import to the whole ecosystem. As Loorbach puts it, "Dealing with persistent societal problems in the long term will require approaches that give special attention to learning, interaction, integration, and experimentation on the level of society instead of policy alone" (Loorbach, 2008, p.164). Devolving power to the local level and allowing them to set their own course, then, may not be enough. Greater connective tissue must be created between the disparate levels and areas of the whole system to facilitate the constant feedback that guides complex systems. Whether this is best done via "hard" approaches like mandates from the centre or the "softer" approach of systemic persuasion is an important element that cannot be overlooked but is beyond the scope of this paper.

Policy experimentation

As mentioned at the outset of this piece, an experimental approach to reform, where each reform is approached as a learning exercise and research question rather than as a fully formed answer, is an important part of a complexity approach (Eppel et al., 2011). Though the actual meaning of experimentation in this context is fairly vague, this paper advocates a definition put forth by Heilmann (2008) in which he states that experimentation is "a purposeful and coordinated activity geared to producing novel policy options that are injected into official policymaking and then replicated on a larger scale" (p. 3) This is not a random roll-out of trial and error reforms but a concerted effort to find out, at a local level and in differing contexts, what works, and more importantly, *why* it works, before scaling it up to broader applications. It occupies a middle ground between the hypothesis testing of randomised control trials and qualitative case studies, and incorporates elements of both. Design experiments, as Stoker and John term them, do explore and test hypotheses as one might expect in a randomised control trial, but rather than taking a "one and done, end of project" approach, there is a rapid evolution of research questions built upon the main hypothesis and tested iteratively with minute adjustments made to the programme as data is collected (2009). These adjustments incorporate not only statistical assessment data, but also qualitative input from stakeholders at all levels to create a collaborative, learning, design/implementation cycle like that pictured in Figure 8. This is distinct from pilot programmes, which generally operate on much shorter time scales and tend to be evaluated by one-off testing that deems them to be successes or failures – since an experimental approach expects to find both successes and failures in the reforms and be reactive to both. This method requires much more time and communication than is afforded by most pilot programmes and is a broader systemic path to change. As Eppel et al., put it, "Making use of evidence seamlessly requires applying continuously a habit of mind which asks not 'what are the facts?' but 'what is the next question?' (2009, p. 15).

Figure 8. Experimental model of policy design and implementation



Source: Eppel, E., Turner, D., and Wolf, A. (2011), http://hdl.handle.net/10063/2585.

Encouragingly, this need not involve a huge investment of resources as the institutional structures needed for this approach already exist in most contexts and the method relies on changing the process in which they interact rather than creating new structures out of whole cloth. Further, an experimental approach to reform, with iterative feedback and adjustments, can reduce the cost of reform overall by

adjusting and improving a programme as it rolls out rather than having an initiative go nationwide, with all of the concomitant expenditures in materials, trainings and publicity, only to find out in summative testing years later that it was ineffective, or worse, detrimental. This approach does require strong and adaptive leadership with an eye toward the future and long-term systemic change together with a willingness to alter current practices, admit that not all of the answers are known at the outset, and build new experimental and iterative processes based on the principles of interaction. Local knowledge must be blended with systemic goals, and new findings must be disseminated as they appear, which requires a strong centre to guide and co-ordinate reform as it rises through the system but a free hand at the local level to innovate and experiment with implementation.

As a final step, policy makers must embrace the idea that they cannot do it alone and that every stakeholder must be taken seriously and viewed as an integral and valued part of the process. Each step of the design/implementation should be viewed as a learning exercise rich in opportunities to gather information, revisit preconceived notions, build multi-level connections and modify implementation as needed. Reform should be exploratory in nature and guided by feedback. In collapsing the conventional separation of design and implementation into a single on-going process, policy makers must embrace ambiguity and be comfortable with the idea that not everything will work as intended right away. This, however, does not necessarily mean that nothing has been gained. Where a pilot programme must often succeed the first time or be abandoned, a policy experiment requires patience to allow time for lessons to be learned from each iteration and for redesigns to be implemented. It does not require a reform to be exactly right the first time but accepts the need for adjustment and improvement as the initiative develops (Stoker and John, 2009). It will be a gradual, communal process that requires strong leaders and broad consensus based on commitment to work, talk, analyse and revisit the way to success (Eppel et al., 2011).

CONCLUSION: OPERATIONALISING A COMPLEXITY APPROACH

> *If our goal is "every school a great school" then policy and practice have to focus on system improvement. This means that a school head has to be almost as concerned about the success of other schools as he or she is about his or her own school. Sustained improvement of schools is not possible unless the whole system is moving forward*." (Van den Akker, p. 46)

This paper has tried to show that a complexity approach to educational reform, borrowing elements from ecology to refine the scope of the challenges and predicated on feedback and collaboration, can utilise the intrinsic properties of a complex system to propagate system wide change as a beneficial way forward for policy makers. Key elements of operationalising this approach include:

Fostering a collaborative environment throughout the system by actively creating opportunities for interaction (Loorbach, 2010). The Student Success Commission of Ontario, the rotating teams of principals and teachers in New York, and Hong Kong's long standing weekly gatherings of concerned actors are all examples of process-oriented changes that increase feedback and self-organisation and do not require massive new investment. It is important that these structures, be they symposia, conferences, training sessions or any other form, involve as many actors on as many levels as possible and that they respect and use the knowledge already present in the system. Encouraging collaborative practices has the added advantage of moving the drivers of improvement away from the centre and closer to the front lines

of schools, which should help reforms take hold more broadly and be more self-sustaining (Mourshed, et al., 2010).

Designing ways for collaboration and interaction to be continuous. Once a year conferences or bi-annual trainings do not allow for a sufficient level of familiarity and trust to be built to allow for a free flow of ideas (Levin, 2010).

Making reforms iterative, experimental and flexible. Do not launch a finished product, but roll out an idea for consideration. As the frequency and quality of interaction increases, reforms can be adjusted to better fit local contexts or disseminate more efficacious practices (Loorbach, 2010).

Adapting a "non-deficit" approach to reform (i.e. avoiding the assumption that the current system is dysfunctional because of the individuals within it). This opens up possibilities for institution-wide learning and such learning can grow from the local area out (Goldfink (2007), p. 38).

Focusing on a few key nodes and pursuing them collaboratively. Do not attempt to address every systemic ill. Analyse and identify the most pressing issues, address them with vigour, and allow the self-organising properties of complexity to bring other aspects of the system into alignment through continuous feedback (Fullan, 2009).

Engaging and energising teachers through collaborative research and longer term peer-to-peer mentoring.

Taking on board the developments and management structures of other sectors and industries by increasing interaction with not necessarily obvious collaborative partners like healthcare providers, emergency management teams, military institutions, finance, ecology and many others. In short, acknowledge that education does not exist in a silo and that the problems of a complex system can be tackled in numerous ways regardless of the individual actors. Look outside the field for answers and be open to what might be found.

Summing it all up with the words of Michael Fullan:

> *Collective capacity is when groups get better – school cultures, district cultures and government cultures. The big collective capacity and the one that ultimately counts is when they get better conjointly – collective, collaborative capacity, if you like. Collective capacity generates the emotional commitment and the technical expertise that no amount of individual capacity working alone can come close to matching...*
>
> *The power of collective capacity is that it enables ordinary people to accomplish extraordinary things – for two reasons. One is that knowledge about effective practice becomes more widely available and accessible on a daily basis. The second reason is more powerful still – working together generates commitment. Moral purpose, when it stares you in the face through students and your peers working together to make lives and society better, is palpable, indeed virtually irresistible. The collective motivational well seems bottomless. The speed of effective change increases exponentially …* (as cited in Mourshed et al., 2010, p. 74)**.**

NOTES

1. For a deeper look at the role of research and the interaction between knowledge and governance, see Fazekas and Burns (2012).

2. For a thorough discussion of the evolution of complexity theory, see Alhadeff-Jones (2008)

3. For an excellent example of both virtuous and vicious cycles see, Van Twist, M, M. van der Steen, M. Kleiboer, J. Sscherpennise and H. Theisens (2013).

4. For an explanation of the mathematical processes behind this model, see Chen, C., and Paul, R. J. (2001).

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