Teachers and Curriculum

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Teachers and Curriculum is an online peer-reviewed publication supported by Wilf Malcolm Institute of Educational Research (WMIER), Faculty of Education, The University of Waikato, Hamilton, New Zealand. It is directed towards a professional audience and focuses on contemporary issues and research relating to curriculum pedagogy and assessment.

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Teachers and Curriculum welcomes

- innovative practice papers with a maximum of 3,500 words, plus an abstract or professional summary of 150 words, and up to five keywords;
- research informed papers with a maximum of 3,500 words, plus an abstract or professional summary of 150 words, and up to five keywords;
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- book or resource reviews with a maximum of 1000 words.

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- reports on research in the areas of curriculum, pedagogy and assessment;
- provides examples of innovative curriculum, pedagogy and assessment practice; and

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Acknowledgement of Reviewers

Thank you to the reviewers for their contribution to the process and quality of this issue. Many thanks to those who also helped with a review but the paper did not make it to this issue.

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THE SIGMOID CURVE AS A METAPHOR FOR GROWTH AND CHANGE

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Abstract

This paper introduces sigmoid or s-curve as a metaphor for describing the dynamics of change. We first encountered the s-curve as a description of a possible growth trajectory whereby populations become established, begin to flourish and the numbers increase rapidly until they reach some limit. At this point, the growth rate slows rapidly then stops and the size of the population is either maintained, something happens to stimulate a further upsurge in growth, or there is a dramatic decline. This basic biological metaphor has been picked up by social science researchers, particularly those who are interested in the complex dynamics of change and adaptation over time. The s-curve metaphor is now applied beyond population growth to describe change dynamics in social systems. We have noted this situation of rapid change followed by stability, further growth or subsequent decline in a number of projects we have worked on. The contributors to this special section discuss examples of this change pattern across a range of contexts.

Keywords

Sigmoid curve; change dynamics; complexity

Introduction

This paper introduces a set of commentaries that explore the dynamics of change over time in different education settings. All of them, in one way or another, draw on the sigmoid curve as a metaphor for growth and change. The origins of the metaphors we use to explain phenomena are not often held up to scrutiny. In this short paper, we do so for two reasons. Our first aim is to illustrate the importance of being aware of how we use metaphors in our meaning making. The very same metaphor can take on quite different meanings, and imply different courses of action, when underpinned by different theoretical frameworks. Our second and primary aim, across the collection of papers as a whole, is to dig more deeply into the dynamics of change that may be happening when all appears to be quiet on the surface of things—i.e. the times depicted by the more 'level' parts of the s-curve.

Both of us originally encountered graphs in the shape of a sigmoid curve as a *biological* metaphor. When the size of a population is graphed against time, the s-curve describes a possible growth trajectory. Populations can become established, begin to flourish, and then increase in numbers with ever-greater rapidity until they reach some environmental limit. At this point, the growth rate slows rapidly then stops as the size of the population stabilises. In classic ecological terms the carrying capacity of the environment has been reached. The shape of the graph then resembles a mathematically calculated sigmoid curve.

No doubt, this is a familiar story, particularly for those who studied biology in high school. The use of the s-curve in biology was developed in the early nineteenth century, around the time that Darwin was developing his theory of evolution, informed in part by the work of Malthus on human population

growth. Malthus was the first economist to propose a systematic theory of population. He outlined his views in his famous book, *Essay on the Principle of Population* (1798), for which he collected empirical data to support his thesis. The s-curve is a staple of school biology textbooks, which often still focus on the classical ecological theory of the late nineteenth and early twentieth century. The metaphor takes on apocryphal dimensions when used to warn against the fable of unlimited growth, as implied by the juxtaposition of two graphs in Figure 1. Seemingly, exponential growth cannot continue indefinitely and we'd better be ready for what comes next.
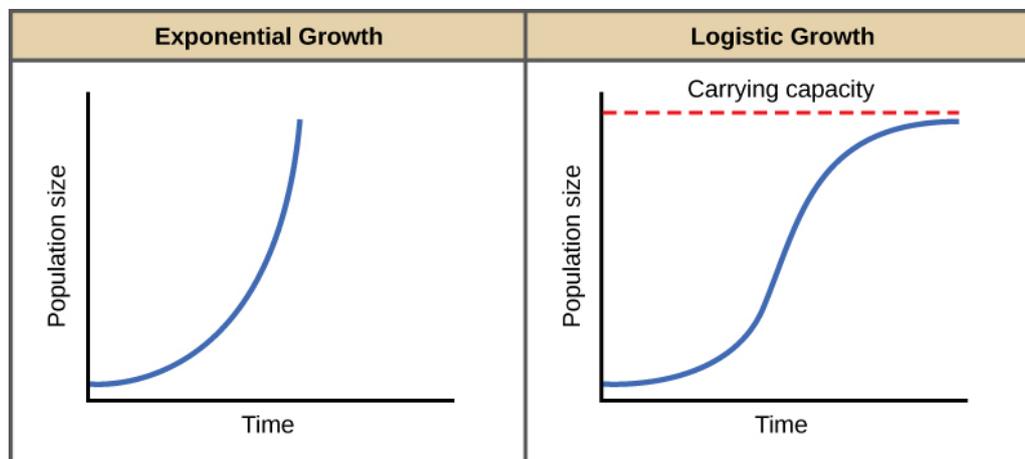
Figure 1:   Exponential and logistical population growth. Retrieved from: goo.gl/HBW7QW. Open source

The timing of ideas is important. This classical use of the s-curve in biology precedes the mid-twentieth century development of complexity theories. Ideas about the complexity of systems have increasingly come to dominate *explanations* of biological phenomena. The *description*, as an overall pattern, looks the same but the phenomenon is understood in quite different terms. Complexity concepts have transformed ecological theory, genetics, and cell biology, to name just three fields of biological inquiry (see Hipkins, 2009, for a critique of the theoretical faming of genetics in school biology). The idea that an apparently unchanging population is 'in equilibrium' with its environment is now seen as an inaccurate description of the actual dynamics in play. In complexity terms, seemingly stable systems are being actively maintained in far-from-equilibrium states. Rapid and unexpected change could begin at any time, prompted on some occasions by apparently minor changes, as encapsulated in the metaphor of the 'butterfly effect'. Emergence is one term used to describe this phenomenon.

From a complexity perspective, a biological population near or at the carrying capacity for the environment maintains its numbers via a series of feedback loops, in a far-from-equilibrium state that nevertheless looks stable on the surface of things. This might seem like splitting straws (the description of the pattern remains the same) but dynamics are important if we want to predict—and be ready for—what might happen next. As biologists know all too well, seemingly stable populations sometimes crash very quickly in response to what seemed like small changes in the environment. Increasingly, complexity theory is also changing the ways we think about social phenomena (see for example Eppel, Matheson, & Walton, 2011). In the following sections of the paper, we discuss implications of this theoretical framing for the use of the s-curve metaphor in education.

The sigmoid curve in the social sciences

In the mid-twentieth century, researchers of technological innovation and change were among the first to adopt the s-curve as an explanatory metaphor in the social sciences. The s-curve can be used to describe and explain the pattern of introduction, rapid development, and ultimate maturity of new technological innovations. A pattern of overlapping s-curves has been used to demonstrate how opportunities to develop new technologies emerge then take off as designs are refined and new products open up new possibilities. A related use, perhaps better known in education, describes and

explains the pace of uptake of new technologies. From slow beginnings and 'early adoption', new technologies begin to diffuse across social settings. At a certain point, exponential growth occurs until the market is saturated, at which point the pace of uptake slows and stops.

These contexts of use are essentially different faces of the same coin, albeit with a different emphasis in each case. Figure 2 illustrates this. Overlapping s-curves are used to describe changes in the way technology is employed in advertising. New technologies begin slowly, develop rapidly and consolidate. At the same time, only early adopters initially use the technology, then more people do so, and ultimately use becomes prevalent. The place where an s-curve and its successor overlap is seen as a critical space of opportunity. Those who anticipate the 'next' big thing gain a commercial edge on the market. Importantly they do not wait for comprehensive consolidation of the technology itself and/or extensive diffusion and uptake. Instead, they begin their research and development before the pace of change triggered by the previous innovation begins to slow down and level out.
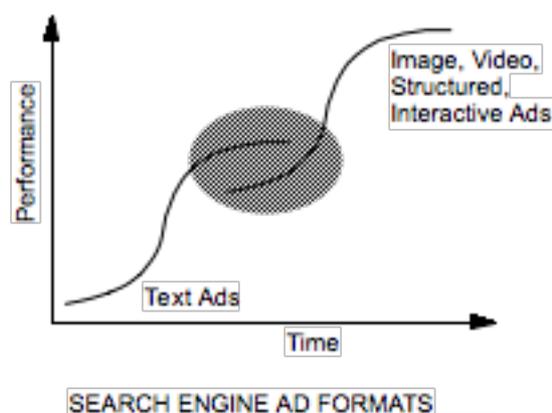

Figure 2:   **An example of the use of the s-curve in business studies of technology.**
Retrieved from http://chiefmartec.com/post_images/search_ad_s_curve.png
(Figure redrawn by Don Cowie Draughting.)

From the world of 'things' and their development, the use of the s-curve has also spread into the description and explanation of other types of complex social phenomena. For example, just over 20 years ago, Charles Handy published a prescient discussion of the changing nature of work and the dynamics of how people respond to those changes (Handy, 1994). He called his book *The Empty Raincoat*, to signify how impersonally workers are often treated. He argued for a more constructive and proactive shaping of futures, whether by individuals or by organisations. Like the technologists before him, Handy described a need to anticipate and adapt to next changes while things still appear to be going well, rather than waiting for change to be imposed by external circumstances. He added the idea that progress could stall or even go backwards, unless attention to likely next steps is anticipated, during the time when things appear to be going well. He too deployed the s-curve metaphor to illustrate the different *timing* of response trajectories and their likelihood of success. Figure 3 illustrates this emphasis on proactive timing.
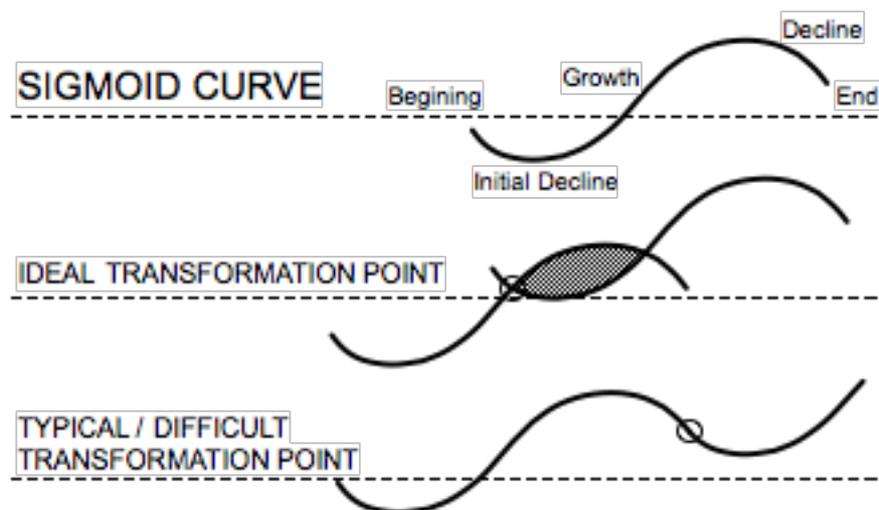
Figure 3:   **An example of the use of the s-curve metaphor to explain social dynamics**
Source: http://blogs-images.forbes.com/rebeccabagley/files/2013/01/SigmoidCurve.jpg
(Figure redrawn by Don Cowie Draughting.)

From the wider social sciences field, the s-curve metaphor has travelled into discussions about changes in education. Michael Fullan was an early populariser of the idea, using it when communicating with education leaders and policy makers. He highlighted an s-shaped change trajectory as starting with an implementation dip, followed by a growth spurt as new practices are tried. This growth spurt is then followed by a 'plateau' which can act as a period of consolidation and preparation for the next spurt. If no further change is forthcoming, or if attention is diverted by other activities, the time on the plateau can be followed by loss of the gains that had been made and a return to the previous status quo (see for example Fullan, 2004).

Importantly, Fullan (2004) moved the educational discussion beyond timing per se to draw attention to the *complexity* of ongoing educational change. From a complex systems perspective, the plateau or maturation phase is not a time of quiescent stability but rather a time when the ever-present potential for further change is being held in check by strongly entrenched patterns of current behaviour. Eppel et al. (2011) discuss this aspect of complexity dynamics in more detail. Fullan envisaged this as a time of lateral capacity building while an innovation becomes embedded in its system context (a class, a school, a cluster, a region, a whole nation etc.). During this time of consolidation and capacity-building 'adaptive challenges' will begin to emerge. These are challenges that go beyond the system's current capacity or way of operating (Fullan, 2004, p. 4). When this happens, some external input or stimulus is likely to be needed to support the next rapid development phase.

This way of using the metaphor highlights the complex nature of change that can be happening when nothing seems to be happening. Deep change often begins, and is embedded below obvious changes in action/practice or even our conscious attention levels. The profound implications of a change and the foundations of new growth supports can be laid down during this time, even as we struggle to see a clear way forward.

Two examples that illustrate s-curve dynamics and their power to inform next steps

In the recent Curriculum Implementation Exploratory Studies (CIES) project, we tracked progress with implementation of the New Zealand Curriculum (NZC) over a period of several years, in a

number of so-called 'early adopter'[i] schools (Cowie et al., 2009; Hipkins, Cowie, Boyd, Keown, & McGee, 2011). The s-curve was useful for describing the change dynamics we documented over the three years of the project. It was clear to us that implementing the NZC did not just begin overnight when the published document arrived. The schools in the study were already embarked on processes of self-review and change. The NZC gave this journey a timely burst of new energy and ideas. However, by Year 3 the ongoing curriculum action was less obvious and dramatic. Most CIES schools seemed to have reached somewhere around the top of the s-curve—where change appeared to have stalled. At this time, change could be renewed, or some reversals could occur (Cowie, Hipkins, Keown, & Boyd, 2011). Framing the curriculum change journey like this caused us to ask: What is happening? What is needed to ensure that schools' processes of enacting the NZC stay broadly on the track of the dotted line and enter new growth phases?

Some possible answers to this question became apparent in our analysis. The new National Standards policy introduced to primary schools in New Zealand in 2009, acted to divert some school leaders' and teachers' attention away from the NZC. Alternatively, progress with implementation sometimes stalled in the third year of our study as schools began to ponder the positioning of the key competencies in the NZC. The key competencies had been very well received, as indeed had the whole visionary 'front end' of the curriculum framework. Both had provided an engaging and productive focus for school and community reflection on their vision, goals and ways of working. Other research commissioned at the same time as CIES, for example the Monitoring and Evaluating Curriculum Implementation (MECI) project (Sinnema, 2011) said the same thing. However, both our own CIES research and the MECI project identified challenges for knowing what to do next, so that the visionary features in the front part of the curriculum would be woven together with the more 'business-as-usual' content of the learning areas in the back half of the document. This was the point at which progress with implementation could stall. It became clear that meaningful integration of new features such as the key competencies, or innovation in assessment to support the broader curriculum goals, would take considerable time and thought. These seemed to us to be areas where more support would be needed before a second rapid innovation and growth spurt could begin.

The Ministry of Education responded by funding development of a small suite of resources that modelled the reciprocal nature of relationships between key competencies and learning areas (http://nzcurriculum.tki.org.nz/Key-competencies/Key-competencies-and-effective-pedagogy).
However, many schools still seem to be unaware of this support material. Anecdotal evidence suggests some may have remained on this particular plateau for some years. Interestingly, momentum does now seem to be building for a further growth spurt related to interpretation of what might be key competencies and new conceptualisations of the disciplines, which raises some interesting questions about the dynamics that have been in play during the seemingly quiescent years, and about what has now changed. We will come back to these questions when we discuss the insights that have emerged from the collection as a whole.

The second example comes from the *Laptops for Teachers* evaluation study which traced teacher use of government subsidised laptops over the first three years of provision to the teachers of Year 9 to 13 (Cowie, Jones, Harlow, McGee, Cooper, et al., 2008), 7 and 8 (Cowie, Jones, Harlow, Forret, McGee, et al., 2008), 4 to 6 (Cowie, Jones, Harlow & Forret, 2010a), and 1 to 3 (Cowie, Jones, Harlow & Forret, 2010b) students. In a number of regions, the research team surveyed teachers and conducted focus groups with teachers from each participating cohort. For all cohorts, the pattern of reported laptop use and change was the same. Between Years 1 and 2, the researchers reported substantial change in terms of confidence and awareness of the potential for use of laptops, modest gains in the proportion of teachers using laptops for tasks such as report writing and emailing, and greater gains for tasks such as Internet searching. Across Years 2 and 3, the reported changes were maintained or there was a further smaller gain. Many of the teachers said the third year was a period of consolidation of their knowledge and practice. Further examination revealed that across these later years of apparently little change teachers had actually revised and raised their understanding of what it meant to be a beginning, experienced and expert user of the laptop.

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[i] By "early adopter" we mean schools that were known to have begun exploring and giving effect to the New Zealand Curriculum (NZC) as soon as the final (and in many cases the draft) version was available.

It did not matter how individual teachers assessed their capability. What mattered was how well the various pieces of the initiative came together to support ongoing use and experimentation with laptops. All of the following needed to converge: teacher confidence and expertise; teacher perceptions of the usefulness of ICT; relevant professional development; school leadership that supported both laptop use and culture for change; and access to a reliable ICT use infrastructure. Each of these parts of the school system came together to shape the opportunities and incentives teachers had to use their laptop. For beginner users, help to use the laptop, including prompt technical support, was important when they were 'stuck'. With more experienced and knowledgeable users, attention turned to the development of lesson materials, the knowledge of resources to support this, and the pedagogical skills to make use of these resources. Teachers who were able to prepare multi-sensory materials, shifted their focus to the need for continuous access to the relevant technologies and to models of innovative use of ICT for teaching and learning. Competent teachers who were able to make active use of their laptop for teaching and administrative purposes were interested in opportunities and training on how to share their enthusiasm and expertise with colleagues. As Fullan (2005) argues, it is only when we adopt a multi-faceted and multi-level systems approach to change that we are able to understand what is happening on the plateau and how to foster and support sustained systemic innovation.

In this collection of papers Mark Osborne makes the case that innovative learning environments provide unique opportunities to accelerate the generation and diffusion of innovation. He identifies the following as central to rapid diffusion of innovation: high levels of observability and trialability of ideas; effective communications; and supportive social systems. . Innovative learning environments provide a good example of the complexity of change dynamics. As Mark points out, such environments simultaneously demand pedagogical innovation *and* provide the conditions that support its rapid uptake.

Wendy Dent and Jane McChesney similarly argue that change involves a series of change foci. Their focus is on a period of substantial changes in the mathematics curriculum in one primary school in Christchurch. The pivotal drivers of change they identify include equity of mathematical learning and opportunities for all students to learn to be a mathematician. Similar to Mark Osborne, they identify a dynamic interaction between the ongoing need to put effort into change and the positive feedback that can come from the change environment per se (in their case this feedback came from rapid learning gains in mathematics for students who had not previously been as successful.)

Sally Boyd reports on the findings of a two-year evaluation of the *Positive Behaviour for Learning School-Wide* initiative. She argues that building a culture that enables a school to sustain a change momentum involves a complex mix of factors including: the leadership approach and culture of each school; the design of the initiative they are implementing; and the system of supports that schools can access relating to this initiative. She concludes that schools engage in multiple change sequences as they simultaneously maintain some practices whilst growing others. In a direct reference to the apparent plateau phase of the sigmoid curve model, she shows how schools might actually be engaging in strategic actions to ensure key practices and systems are maintained and consolidated.

Janet Bourne, in her article, offers insights from the perspective of someone charged with facilitating change. Her goal was ensure any change was sustainable and she took action to ensure this from the start of her involvement with the school at the centre of her study. Here again, we are alerted to the complexity and the dynamics of any school change process. Not only may the change process follow the sigmoid pattern of substantial change followed by a plateau but teachers and schools may be moving along and interweaving multiple processes (curves) of change with different but complementary foci. Janet's narrative illustrates ways in which experienced advisers can accommodate these known change dynamics in the sequence of learning encounters they plan and orchestrate over time.

In reflecting on these articles we have been reminded of the challenge schools and teachers face in pursuing change. There is a need to attend carefully to the way changes might be being embedded and elaborated over the period of time. To outsiders a slowing of change might look like a stall in progress, but for insiders it may be that the multiple agendas for change that exist in most settings at any one time are being explored and the associated changes in practice are being shared. For all those involved the question that persists is how to ensure any change agendas and practices might come together

productively. Rushing on to a next change initiative too soon might well be counterproductive. Just as importantly, neglecting the dynamics at play under the seemingly still surface might cause 'next' support opportunities to be overlooked and/ or misunderstood.

We began seeking articles with an interest in what happens after a period of substantial change followed by a plateau in ostensible development—What had initiated the original momentum for change? What would prompt the next substantial development? What kinds of policies, activities and practices would produce a regression? To a large extent these questions remain for us. We would welcome further discussion on these questions, drawing on your own experiences of change trajectories that trace the shape of a sigmoid curve, and the associated underlying dynamics.

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