Complexity Theory and Education in Times of Insoluble Problems

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Summary
COVID-19 has demonstrated the threats that systemic disruptions pose in our interconnected world. This paper explores the proposition that complexity or systems education is now vital to achieving greater levels of collective and personal resilience in the face of rapid non-linear change and potential catastrophic risks.

Keywords
Complexity
Risk
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COVID-19 is a complex problem, defying simple solutions and linear causal explanations. It shares these attributes with other urgent challenges, including climate change, ecosystem breakdown and vast inequality, all of which present inherently systemic and potentially catastrophic risks within our globalised civilisation. Such "wicked problems" (Rittel & Webber, 1973) are overwhelming the legacy assumptions, heuristics and practices of our technical-industrial social systems, including our education systems. We suggest that a shift from complicated to complex ontologies can serve as the basis for a new pedagogy rooted in an appreciation of systems-based interdependence; one which locates us all as participants "within" complex systems as opposed to external observers peering in (Senge, 2012). We argue that such a pedagogical turn is vital to ensure that future generations have the tools they need to understand and prepare for systemic risks. It is also an invitation to envision education as Bildung, focusing attention on our collective "responsibility for and participation in an evolving process of social maturation that reimagines culture, technology, institutions and policies for the greater good" (Rowson, 2019, p. 2).

Complex risks are here to stay. To borrow a phrase from the theologian Reinhold Niebuhr (1944/2011, p. 118), the students of today and decision-makers of tomorrow may have to accustom themselves to the work of "finding proximate solutions to insoluble problems." Indeed, learning how to work with complexity, rather than against it, may well prove to be the defining story of this century.

Complicated to complex: A shift of ontologies

Ontology is our point of departure. We cannot understand a problem without concepts and categories that allow us to give reality some basic organising structure. Our surrounding culture in the West is still based on "Mechanistic-Utopian" thinking (Rappleye et al., this issue). From this vantage, we look out onto the world and see "complicated" systems

which are closed and static, made up of components that are unable to evolve and adapt to changing conditions without external input. We assume that even the most intricate of these systems is ultimately "knowable through proper investigation, and [that] relationships between cause and effect, once discovered, repeat" (Snowden, 2005, p. 46). This leads us to hypothesise that these systems are amenable to rational scientific control and pareto-optimal, universally valid solutions. From such ontological beginnings, complicated theories are built and specific examples – a jet engine, a bureaucracy, an economy – can be examined. In terms of policymaking, "Science Will Win" becomes a compelling rallying cry (Rappleye et al., this issue).

Any such ontological position is open to question. It is important to note that ontology and the theories that follow are "merely assumptions that we can accept or reject on their explanatory power" (Lake, 2009, p. 4). We suggest that an ontological shift from complicated to complex is long overdue and central to an educational pedagogy equipped to give young people the concepts, categories and tools that they need to understand and respond to the "certainty of near-term non-linear changes" (UNDRR, 2019, p. 36). Much of what we care about consists of complex systems that are dynamic and constantly evolving, from large-scale natural ecosystems to small-scale social systems, such as schools or classrooms. Their elements act and interact in an open environment and without external input, giving rise to emergent, often surprising behaviour that cannot be explained solely in terms of the properties of individual elements. In other words, the whole is more than the sum of its parts; indeed, it is different from the sum of its parts (Jervis, 1997, p. 572).

By asserting a post-positivist philosophy of science, one where linear causality cannot be assumed, complexity theory does not reject complicated approaches but rather renders a more accurate picture of reality where the complicated and complex interact. For those inclined, complexity theory holds out the promise of syncretising holism and epistemological parsimony by allowing for ontologically diverse systems to co-exist (Kreienkamp & Pegram, 2020). Analytically, it directs our attention to determining "what works" in relation to more or less constrained or enabling contexts (Juarrero, 2000). Importantly, when it comes to problems playing out in complex biophysical systems, such as climate change or biodiversity loss, there are "no solutions in the sense of definitive and objective answers", but pathways forward may emerge through repeat observation, experimentation and experience (Rittel & Webber, 1973, p. 155).

Complexity and nature

Perhaps not so much a theory as a broadly applicable conceptual toolkit and a "way of knowing and thinking" (Morin, 2007, p. 25), complexity allows us to understand systems not simply in terms of their constituent elements, but in terms of how they interact with each other within the whole. It directs attention to primary reality (which we might also call Nature); that all complicated systems are inevitably entangled with complex systems. For example, corporations or industrial farms are largely complicated systems, but ultimately dependent on the integrity of a complex system called the biosphere – an insight long understood and long ignored (Meadows et al., 1972). However, as this quote from a UK Treasury report indicates, the citadels of "complicated economics" are now belatedly acknowledging the hard stop presented by Nature:

> Correct economic reasoning is grounded on our values…when we recognise that we are embedded in Nature. To detach nature from economic reasoning is to imply that we consider ourselves to be external to nature. The fault is not in economics; it lies in the way we have chosen to practise it (Dasgupta, 2021, p. 310).

We have now exceeded the safe limits of four out of nine planetary boundaries required to support a safe operating space for humanity (Steffen et al., 2015). Climate change is increasingly recognised as necessitating radical forms of complex governance capable of "leveraging decarbonization in an interdependent fractal system" (Bernstein & Hoffmann, 2019, p. 919). Yet, our governing structures – including education institutions – remain wedded to understanding and managing complicated problems, where reasonable probabilities can be assigned, problems can be isolated and stabilised, and solutions are predetermined. This mirage of control is seductive but in the context of Nature, myopic and even dangerous. For example, without an appreciation of the complexities involved, carbon removal techniques such as large-scale reforestation projects can actually undermine climate change mitigation efforts (Di Sacco et al., 2021).

Underlying the Dasgupta Review (2021) lies a troubling admission that our established ways of "doing" governance are increasingly redundant in the face of biosphere destabilisation. The entrained assumptions, heuristics, models and practices which pervade our ever-more complicated technical-industrial systems are not working. It is vital that young people acquire conceptual tools and mental models attuned to complex problems if we are to achieve greater levels of societal and personal resilience in the face of rapid non-linear change. A complex pedagogy places particular emphasis on enhancing human judgement in situations where no simple directions of causality are apparent, similar phenomena play out differently across time and space, and behavioural patterns are contingent and relationship-based, rather than fixed and rules-based (Pearl & Mackenzie, 2018). Education must also attend to individual ethical orientation in a world of ecological interdependence, a world where there is no "outside;" no "view from nowhere" (Cilliers, 1998).

Education in times of insoluble problems

In light of the above, critical inquiry into entrenched paradigms of thought is vital, within teaching, learning and educational institutions. This is not to argue that every student, educator and educational researcher has to become an expert in complexity theory. Neither is it a call to reject traditional scientific methods and complicated analytical frameworks. Rather, it is to acknowledge the restricted applicability of linear styles of thinking – complicated task environments – and cultivating what Kuhn (2008, p. 186) calls "complexity habits of thought"; a greater sensitivity to the multiple interdependent characteristics of a predominantly complex reality. In other words, "[f]ormal rational thought is still taken as vital, but as one among many modes of human sense-making" (Davis & Sumara, 2005, p. 315).

In many ways, COVID-19 has been a real-life lesson in complexity, highlighting the cascading threats that systemic disruptions pose to our interconnected world. Reassuringly, complexity theory, originally confined to the natural sciences and cybernetics, is beginning to make inroads across the social sciences, arts and humanities, and has started to inform educational studies. An increasingly rich literature has shed light on the implications of complexity for learning, cognition and creative thinking (e.g., Davis et al., 2000; Bereiter, 2005; Osberg, 2015; Jacobson et al., 2016), teaching and the curriculum (e.g., Doll et al., 2005; de Greef et al., 2017; Heinrich & Kupers, 2018), efforts to promote educational change (e.g., O'Day, 2002; Peurach, 2011; Snyder, 2013; Bates, 2016), and the purpose and philosophy of education more generally (e.g., Mason, 2008; Cunningham, 2014). However, actual pedagogy in the classroom lags behind. It is rare to find curricula below university level which entertain a pluralist philosophy of science, even if the roots of complexity thinking go at least as far back as Kant's (1781/1998) "unknown causality."

How can we provide future generations with the tools they need to understand and prepare for future complex risks? While we cannot do justice to this vital question here, we emphasise its centrality to any pedagogy for the 21st century. The implications of complexity theory prompt us to consider a new vision of education as Bildung, one which not only enhances individual judgement in the face of radical uncertainty, but also encourages a process of character formation focused on preparing every young person to participate "in the creation of possible futures" (Davis & Sumara, 2009, p. 43).

The ontological proposition that we are surrounded by and, crucially, embedded in, a multitude of complex systems challenges the universal applicability of a traditional science that seeks "to fix knowledge in a permanent grid" (Cilliers, 1998, p. 118). In complex systems, "knowledge" cannot be inferred from law-like, observable regularities – it remains contextual, contested and invariably incomplete. As such, human judgement (Nowotny, 2013), experiential knowledge (Garavito-Bermúdez et al., 2013), and intuitive forms of reasoning (Kahneman, 2011) are crucial to ensuring that knowledge is infused with meaning. In turn, complexity may preclude control, but it does not rob us of agency. Indeed, acknowledging that determinism does not rule the world opens new vistas for voluntarism in the knowledge that we have genuine choices to make. It follows that ethical questions will not be resolved through ironclad certainties. An ethos of complexity demands that each individual be equipped to exercise discernment as to the best course of action under the circumstances.

Conventional education, primarily serving to ensure the acquisition of universally applicable knowledge, will no longer suffice. Reimagining education as Bildung emphasises the formational role that educational institutions play in enabling young people to become "active, informed, ethical participants in shaping our collective futures" (Hetland, 2013, p. 67). As Biesta (2012) clarifies, Bildung discards the uncritical socialisation of individuals into existing paradigms, for a reflexive, critical and emancipatory interrogation of human relationships with each other and their natural environment. This vision challenges the "hyper-economization" of science and technology education (Bencze & Carter, 2011), as well as the sharp division between the natural sciences and other parts of the curriculum, recognising that nature is not something "out there" to be manipulated at will, but dynamically interwoven with human systems and the lived experience.

Conclusion: Learning to live with complexity

As Rappleye et al. (this issue) highlight, science as an education project was originally conceived as a means to "tame the 'uncertainties' unleashed by Nature." This narrative is failing young people, many of whom are losing faith in the ability of scientific fixes to address the gathering storm clouds of global systemic crises (Cannon, 2019). COVID-19 has served as a reminder that human health and wellbeing is critically dependent on the proper functioning of natural systems that we neither fully understand nor control. The ontological realities of our globalised civilisation compel us to learn how to live "with" complexity, rather than wishing it away or fighting to reduce and eliminate it. For education, this is a challenging, yet intriguing, proposition. Complexity thinking offers neither universal solutions nor fail-safe normative proofs for a more sustainable world. Rather, it is an invitation to explore "diverse avenues for discovering what may end up being a multiplicity of answers that are differentially sensitive to and grounded in specific circumstances, conditions, people, times, and places" (Cooksey, 2001, p. 100). In one sense, it is a call to adventure. In another, it is an opportunity for intergenerational solidarity. Education reimagined as Bildung may be the most important legacy that the children of the Mechanistic-Utopian worldview can bequeath to future generations who will have no choice but to grapple with the interconnected nature of their shared predicament as humans qua "earth dwellers" (Byrd, 2009, p. 107).

References

Bates, A. (2016). *Transforming education: Meanings, myths and complexity*. London: Routledge.

Bencze, L., & Carter, L. (2011). Globalizing students acting for the common good. *Journal of Research in Science Teaching*, *48*(6), 648-669.

Bereiter, C. (2005). *Education and mind in the knowledge age*. New York, NY: Routledge.

Bernstein, S., & Hoffmann, M. (2019). Climate politics, metaphors and the fractal carbon trap. *Nature Climate Change*, *9*(12), 919–925.

Biesta, G. (2012). Becoming world-wise: an educational perspective on rhetorical curriculum. *Journal of Curriculum Studies*, *44*(6), 815-826.

Byrd, S. (2009). Intelligible possession of objects of choice. In L. Denis (Ed.), *Kant's 'Metaphysics of Morals': A Critical Guide* (pp. 93-111). Cambridge: Cambridge University Press.

Cannon, S. M. (2019, March 15). Climate strikes: Greta Thunberg calls for 'system change not climate change' – here's what that could look like. *The Conversation*.

Cilliers, P. (1998). *Complexity and postmodernism: Understanding complex systems.* London: Routledge.

Cooksey, R. W. (2001). What is complexity science? A contextually grounded tapestry of systemic dynamism, paradigm diversity, theoretical eclecticism. *Emergence*, *3*(1), 77-103.

Cunningham, C. A. (2014). *Systems theory for pragmatic schooling: Toward principles of democratic education*. New York, NY: Palgrave MacMillan.

Dasgupta, P. (2021, February). *The Economics of Biodiversity: The Dasgupta Review*. London: HM Treasury.

Davis, B., & Sumara, D. (2005). Challenging images of knowing: complexity science and educational research. *International Journal of Qualitative Studies in Education*, *18*(3), 305–321.

Davis, B., & Sumara, D. (2009). Complexity as a theory of education. *Transnational Curriculum Inquiry*, *5*(2), 33-44.

Davis, B., Sumara, D., & Luce-Kapler, R. (2000). *Engaging minds: Learning and teaching in a complex world*. Mahwah, NJ: Lawrence Erlbaum Associates.

de Greef, L., Post, G., Vink, C., & Wenting, L. (2017). *Designing interdisciplinary education: A practical handbook for university teachers*. Amsterdam: Amsterdam University Press.

Di Sacco, A., Hardwick, K. A., Blakesley, D., Brancalion, P. H. S., Breman, E., Cecilio Rebola, L., Chomba, S., Dixon, K., Elliott, S., Ruyonga, G., Shaw, K., Smith, P., Smith, R. J., & Antonelli, A. (2021). Ten golden rules for reforestation to optimize carbon sequestration, biodiversity recovery and livelihood benefits. *Global Change Biology*, 1-21.

Doll, W. E., Fleener, M. J., St. Julien, J., & Trueit, D. (2005). *Chaos, complexity, curriculum and culture: A conversation.* New York, NY: Peter Lang.

Garavito-Bermúdez, D., Lundholm, C., & Crona, B. (2013). Linking a conceptual framework on systems thinking with experiential knowledge. *Environmental Education Research*, *22*(1), 89-110.

Heinrich, S., & Kupers, R. (2018). Complexity as a big idea for secondary education: Evaluating a complex systems curriculum. *Systems Research and Behavioural Change*, *36*(1), 100-110.

Hetland, L. (2013). Connecting creativity to understanding. *Educational Leadership*, *70*(5), 65–70.

Jacobson, M. J., Kapur, M., & Reimann, P. (2016). Conceptualizing debates in learning and educational research: Toward a complex systems conceptual framework of learning. *Educational Psychologist*, *51*(2), 210-218.

Jervis, R. (1997). *System effects: Complexity in political and social life*. Princeton, NJ: Princeton University Press.

Juarrero, A. (2000). *Dynamics in action: Intentional behaviour as a complex system.* Cambridge, MA: MIT Press.

Kahneman, D. (2011). *Thinking, fast and slow*. New York, NY: Farrar, Straus and Giroux.

Kant, I. (1781/1998). *Critique of pure reason*. Ed. and trans. P. Guyer & A.W. Wood. Cambridge: Cambridge University Press.

Kreienkamp, J., & Pegram, T. (2020). Governing complexity: Design principles for the governance of complex global catastrophic risks. *International Studies Review, viaa074*, 1–28.

Kuhn, L. (2008). Complexity and educational research: A critical reflection. In M. Mason (Ed.), *Complexity theory and the philosophy of education* (pp. 169-180). Oxford: Wiley-Blackwell.

Lake, D. A. (2009). *Hierarchy in international relations*. Ithaca, NY: Cornell University Press.

Mason, M. (Ed.). (2008). *Complexity theory and the philosophy of education.* Oxford: Wiley-Blackwell.

Meadows, D. H., Meadows, D. L., Randers, J., & Behrens III, W. W. (1972). *The limits to growth*. New York, NY: Universe Books.

Morin, E. (2007). Restricted complexity, general complexity. In C. Gershenson, D. Aerts & B. Edmonds (Eds.), *Worldviews, science and us* (pp. 5–29). Singapore: World Scientific Publishing.

Niebuhr, R. (1944/2011). *The children of light and the children of darkness. A vindication of democracy and a critique of its traditional defense.* Chicago, IL: University of Chicago Press.

Nowotny, H. (2013, October 10). The embarrassment of complexity. *Harvard Business Review.*

O'Day, J. A. (2002). Complexity, accountability, and school improvement. *Harvard Educational Review*, *72*(3), 293-329.

Osberg, D. (2015). Learning, complexity and emergent (irreversible) change. In D. Scott & E. Hargreaves (Eds.), *The SAGE handbook of learning* (pp. 23–40). London: SAGE Publications.

Pearl, J., & Mackenzie, D. (2018). *The book of why. The new science of cause and effect*. New York, NY: Basic Books.

Peurach, D. (2011). *Seeing complexity in public education: Problems, possibilities, and success for all*. New York, NY: Oxford University Press.

Rittel, H.W.J., & Webber, M.M. (1973). Dilemmas in a general theory of planning. *Policy Sciences*, *4*(2), 155-169.

Rowson, J. (2019). *Bildung in the 21st Century – Why sustainable prosperity depends upon reimagining education*. Centre for the Understanding of Sustainable Prosperity (CUSP).

Senge, P. N. (2012). *Schools that learn: A fifth discipline fieldbook for educators, parents, and everyone who cares about education*. Nicholas Brealey Publishing.

Snowden, D. J. (2005). Multi-ontology sense making: A new simplicity in decision making. *Informatics in Primary Care, 13*(1), 45–53.

Snyder, S. (2013). *The simple, the complicated, and the complex: Educational reform through the lens of complexity theory.* OECD Educational Working Papers, 96. Paris: OECD Publishing.

Steffen, W., Richardson, K., Rockström, J., Cornell, S. E., Fetzer, I., Bennett, E. M., Biggs, R., Carpenter, S. R., de Vries, W., de Wit, C. A., Folke, C., Gerten, D., Heinke, J., Mace, G. M., Persson, L. M., Ramanathan, V., Reyers, B., & Sörlin, S. (2015). Planetary boundaries: Guiding human development on a changing planet. *Science*, *347*(6223), 736–747.

UNDRR (2019). *Global assessment report on disaster risk reduction 2019*. United Nations Office for Disaster Risk Reduction.