SPEECH BY MR PETER HO, SENIOR ADVISOR, CENTRE FOR STRATEGIC FUTURES, SINGAPORE, AT THE OPENING OF THE NTU COMPLEXITY INSTITUTE ON MONDAY, 3RD MARCH 2014

The Butterfly Effect

Most of you would have heard of the “butterfly effect”. It is a term used in *chaos theory* to describe how small changes to a seemingly unrelated thing or condition can affect large, complex systems. In a somewhat polemical way, it postulates that the flap of a butterfly’s wings in Brazil could set off a tornado in Texas. The hot dry weather we are now experiencing in Singapore is already attributed to the butterfly effect.

The butterfly effect is a way of describing how large systems are impossible to model with any kind of accuracy because there are too many unknown variables to track. Events and actions in different parts interact with each other in complex ways, to produce effects that are difficult to determine *ex ante*. Instead their behaviour is emergent.

A good illustration of this is the turbulence of the 2008/2009 global economic and financial crisis that resulted from the collapse of the sub-prime mortgage sector in the United States. What started as poor lending decisions of a few imprudent financial institutions in the US led to large ripple effects around the world.

A butterfly fluttering its wings in some remote corner of the world does not cause climate change – at least I do not think so. But climate change is certainly the effect of many linked events, decisions and actions around the world interacting with complex global weather systems. Eventually, we feel the impact of these interactions.

Our Connected, Complex World

Lenin wrote, "Everything is connected with everything else". He might even have been aware that the ancient Chinese philosopher, Lao Tzu, had made much the same observation some one and a half thousand years ago, that "everything is connected and everything relates to each other".

This is a fundamental insight into the world that we live in. The world is complex, meaning that there are countless agents interacting with each other in ways that are, more often than not, hidden from view – hidden connections, hence the title of this Conference. Their complex interactions lead to emergent behaviour rather than predictable outcomes.

However, efforts to understand such complexities often rely on an assumption – that what is complex can be reduced to simpler subsets that are easier to model, and that when re-aggregated will produce results that approximate the real world.

A notorious example of this assumption – that the world is not a complex system, merely complicated, in which cause is linked to effect in a Newtonian fashion – was the influential Club of Rome report. It was based on a mathematical model of world population that forecast the imminent collapse of civilisation under the pressure of expanding population and shrinking resources – a Malthusian catastrophe of global proportions. The model was based on the work in control theory of a Dutch professor, Geert Jan Olsder. A Chinese mathematician, Song Jian, who was working on the control of missile trajectories, was so impressed by Olsder's work that he convinced the leadership in Beijing under Deng Xiaoping of its validity, and this led to China's one-child policy. The rest, as they say, is history.

Reductionism

Thomas Hobbes, one of the founders of modern political philosophy, argued that all phenomena, including human activity, could be reduced to bodies in motion and their interactions. This assumption gave birth to modern science. It led to the tendency to dissect the world and to favour explanations framed at the lowest level of scale – down to the atomic level, and even beyond, to quantum sub-atomic levels, to the Higgs Boson, the "god particle".

This approach is called *reductionism*. It is rooted in the belief that complex phenomena can be analysed in component – and simpler – parts. When the properties of these parts have been analysed separately, it is then possible to understand the properties of the whole in terms of the properties and the interactions of these components.

Reductionism has been central to the revolution in scientific thinking. But despite the enormous importance of this approach, and its incalculable contributions to human progress, a critical shortcoming is that it diverts attention away from the complex interactions among the components in the system. This gives the false impression that investigating the organisational features of things at a holistic level is less informative than investigating the properties of the components.

Indeed, outside the realm of science, reductionism has not been as effective in explaining phenomena in such areas as ecology and economics. For example, the economist Paul Ormerod wrote that "in orthodox economic theory, the agents involved in any particular market … are presumed to be able to both gather and process substantial amounts of information efficiently in order to form expectations on the likely costs and benefits associated with different courses of action, and to respond to incentives and disincentives in an appropriate manner. … The one thing these hypothetical individuals do not do … is to allow their behaviour to be influenced directly by the behaviour of others … and their tastes and preferences are assumed to be fixed, regardless of how others behave."

What Ormerod is saying is that traditional economics does not take into sufficient account the complexity of the real world. The foundational assumption – that agents or people behave in a rational way and are not influenced by the behaviour of other agents – does not explain the effects of complexity in today's economic systems. Intuitively, we know that the contrary is true, that people are influenced by the behaviour of others. The herd mentality that drives markets into bull or bear frenzies reflects this condition. In the real world, taking terminology from complexity science, agents – people – are not independent actors. They are interdependent – interacting and influencing one another in complex and emergent ways.

Complexity Science

However, it is only quite recently that this reductionist bias has been counterbalanced by efforts to study the overall properties of complex systems. The sciences of the twenty-first century have begun to turn away from just focussing on micro properties. They are beginning to look at problems of complexity, acknowledging that the principles governing the properties of higher-level entities are often quite distinct and unrelated to those of the components that constitute them. The Santa Fe Institute was a pioneer in this approach.

Stephen Hawking said "I think the next century (the 21st century) will be the century of complexity". New tools are needed to deal with this complexity.

Conventional efforts to model complex systems, like the Club of Rome's model of economic and population growth, have often gotten it badly wrong. They use mathematical formula to link parts of a complex system together, wrongly or naively assuming that these parts interact with each other in a Newtonian fashion, with clear link between cause and effect. Unfortunately, we now realise that complex systems defy such deterministic analytical models. Indeed, a real challenge is to discern when systems are complex, and when they are merely complicated.

Complexity science abjures reductionism for the study of how systems interact with systems, how agents interact with agents, and then how these lead to emergent rather than causal results. Complexity science tools include agent-based modelling, which examines how autonomous agents interact with one another and influence system behaviour. These tools, applied to economics and to other areas like urban planning, provide fresh useable insights that deterministic models have failed to produce.

Interdisciplinary Collaboration

The organisational analogue to this new emphasis on complexity science is interdisciplinary collaboration. It is a counter-reductionist approach in which the complexity of the problem is reflected in the complexity of the organisation that is trying to solve it. In a research or an academic setting, this approach means that silos should be collapsed in favour of interdisciplinary collaboration.

Last month (February), when launching three new undergraduate degrees, President Bertil Andersson said that NTU would continue to focus on science, engineering and technology. But he also stressed that "it cannot be technology alone. It has to be technology plus. The disciplines cannot be studied in silos. They are all interconnected and it is at these disciplinary interstices that many of the new discoveries are being made and Nobel prizes are won."

But it is hard to counter the deep instinct in academia to focus on a single discipline, bred out of centuries of reductionism, and instead move towards interdisciplinary collaboration. I suspect that the younger universities will be more open to this collaborative approach than the older universities which are steeped in tradition and which have been organised in vertical silos for decades if not for centuries. After all, there is a Nobel Prize for chemistry, physics, economics and medicine, but none for complexity – yet.

Nonetheless, interdisciplinary collaboration is imperative for solving the big challenges of today, in science and technology, in the social sciences, in the economy, in urbanisation, and in the environment.

For more than thirty years, the Santa Fe Institute has been at the vanguard of this quest to collaborate across traditional academic silos. It brings together researchers from universities, government and industry, from physics, economics and anthropology to grapple with complex real world problems.

In Singapore, the emphasis on interdisciplinary studies is more recent. But NTU's commendable efforts to build a capability in complexity science are an acknowledgement that academic silos should be collapsed in favour of interdisciplinary collaboration. And it is not alone. The new Singapore University of Technology and Design emphasises the design approach, bridging technology and creativity, science and art. I see it as a major experiment in how universities should be organised in future.

Complexity and Government

The imperative for horizontal collaboration exists beyond academia. Some of the biggest challenges that governments face today involve the emergent outcomes of complexity. They include wicked problems such as climate change, population and urbanisation. There are many stakeholders, but they have conflicting perspectives, different opinions and divergent interests. Please one and you upset many others. Solve one problem and another will arise.

No single government agency is really equipped to deal with such wicked problems on its own. Professor Scott Page of the University of Michigan, who was in Singapore recently (in January), argues that diverse teams are better able to solve such wicked problems, because each person offers a different perspective, a different mental model, and therefore a different representation of the problem.

The exploitation of diversity in government as part of the process of tackling the wicked problems of complexity is analogous to breaking down academic silos in universities. In Singapore, we call this the Whole-of-Government approach.

However, the Whole-of-Government approach has to overcome the deeply-ingrained bureaucratic instinct to operate within silos, rather than horizontally across organisational silos. This is a big hurdle, because it requires a fundamental change of mindset, into a culture in which officers consider the spill-over effects of what they do and their impact on the policies and plans of other agencies. This mindset also requires a willingness among agencies to work together to achieve common outcomes.

This mindset is so important to good governance in a complex operating environment that the Whole-of-Government approach is a priority of the top leadership in the Singapore Public Service. Today, there are inter-agency platforms that have been established to share information among ministries, statutory boards and other agencies, in order to take in different ideas and insights, so that wicked problems can be viewed in their manifold dimensions. Coordinating bodies now deal with cross-agency strategic issues, like the National Climate Change Secretariat and the National Population & Talent Division.

The logic of breaking down silos extends beyond government into working with citizens to jointly understand and solve problems. For example, the Urban Redevelopment Authority recently held an exhibition of its 2013 Draft Master Plan to gather feedback from the public in order to fine-tune plans for Singapore's urban development. The exhibition attracted about 2,000 visitors daily and was organised with a website and iPads to obtain public feedback.

Another example is Our Singapore Conversation, a year-long process involving more than 600 dialogue sessions and nearly 50,000 participants. This process surfaced fresh insights for government – and for citizens – such as the desire for broader definitions of success or greater assurance about health care and retirement, that would otherwise have been much more difficult to obtain.

The Design Approach

The "design approach" is another way of dealing with complexity. It is not about fashion. The Singapore government is now experimenting with the design approach which puts its planners and policy-makers into the shoes of the stakeholders – in the people and private sectors – to gain better insights into the impact of policies and plans. The design approach, in which we think from the view of end-users, whether it is someone with disabilities or a mother with triplets, will help us better design policies and their delivery to the customer. I would argue that it is conceptually not dissimilar to interdisciplinary collaboration, and I would take this one step further and argue that its logic is rooted in complexity.

Last year, a government Administrative Officer – Agnes Kwek – chose the road less travelled. Instead of taking the conventional path of a post-graduate programme, she arranged for a one-year secondment to world-famous design firm IDEO. Now with the Land Transport Authority – where the problems are undoubtedly complex and wicked – she will be part of the vanguard in government that will lead a new design approach to the development of public policy.

NTU Complexity Institute

The establishment of the Complexity Institute today is an important milestone on the long road to interdisciplinary collaboration in NTU. I congratulate the NTU for its conviction that the future is in complexity, and for transforming a Programme into an Institute.

The NTU Complexity Institute has a strong affiliation with the mother lode of complexity science – the Santa Fe Institute – and the presence of several complexity luminaries here today reflects these connections.

The road that NTU has taken toward interdisciplinary collaboration and the formation of the Institute parallels the evolution of thinking within the Singapore government, notably our push for a Whole-of-Government approach, collaboration with citizens and design thinking. I hope that the Institute's research programme will find resonance in the work of the Singapore government. I hope that the Complexity Institute will have the ambition of helping to address the pressing challenges arising out of complexity that the nation, government and society in Singapore face today.

I wish the Complexity Institute every success – and I hope that all of you will give it strong support.

Thank you.

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