COMPLEXITY, SYSTEMS THINKING AND PRACTICE

skills and techniques for managing complex systems

Dick Morris, Visiting Senior Lecturer, Faculty of Mathematics, Computing and Technology, Open University
Stephen Martin, Visiting Professor and Advisor to the Pedagogic Research and Scholarship Institute, University of Gloucestershire

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" I had a crisis of relevance and rejected the high ground of technical rationality for the swamp of real-life issues." Shon, 1995

Introduction

The journey towards sustainability is a 'wicked' problem involving complexity, uncertainty, multiple stakeholders and perspectives, competing values, lack of end points and ambiguous terminology (Martin *et al*, 2008). In a word, dealing with sustainability means dealing with a mess and most people avoid messes because they feel ill-equipped to cope. The health, agricultural, financial and ecological problems we now face are qualitatively different from the problems for which existing scientific, economic, medical and political tools and educational programmes were designed. Without the right tools, learners faced with these wicked problems may fall back on the same old inappropriate toolbox with at best, disappointing outcomes. Given the messy nature of the dilemmas and contradictions facing us there can be no single recipe and no definitive set of tools. Yet some ways of thinking and of doing things do seem more useful than others in this context. These approaches are as much about 'problem finding' and 'problem exploring' as they are about problem solving. Our contention is that learners cannot deal with the wicked problems of sustainability without learning to think and act *systemically*. There is a body of systems theory and practice, summarised and explained on the Systems Practice website (BBC/Open University, 2008). This has been developed and tested through thousands of learners over the past 30 years specifically to accommodate such situations. The approach explicitly acknowledges the tensions between our current way of living and its impact on the planetary life support systems upon which we depend. Yet despite its relevance, repeated advocacy for including systems thinking and practice in education curricula seems largely to have been to no avail. This needs to change.

Systems thinking and practice

Although the concept of sustainability relates to the whole biosphere, at its core it is concerned with *sustainable human lifestyles*. To achieve such lifestyles, we all need to make decisions about a whole complex of interacting requirements, for food, housing, livelihood, health, transport etc., where decisions about one aspect can have unexpected, and perhaps undesired, effects on others and on our wider biophysical environment. Choosing to work from home can save transport fuel, but could use an even greater amount of extra fuel for home heating. To be effective, we need to learn to consider our whole lifestyle *system*, not just separate activities.

This word system has become so much a part of our 21st century vocabulary that we often take it for granted. We refer to "the Transport system" (usually when it breaks down), "the Social Security System" (ditto), a "computer system" etc., without considering the full implications of the word. Really to *think and act* in terms of systems is often not easy, but is an essential part of our outlook if we are to develop our world in a sustainable manner. Learning to think in terms of systems, means moving away from our usual habits, so heavily influenced by the science-based model of post-Enlightenment European thought. Current thinking in science and its partner, technology, has produced enormous strides in our material well being, but is not without problems. A key feature of classical science has been using carefully controlled experimental conditions, looking in detail at the effects of one factor at a time. The success of this has unintentionally engendered a widespread popular belief that we can isolate a single cause for any observed event. This is typified by headlines suggesting that childrens' behavioural problems arise from food additives, traffic accidents or congestion are the result of inadequate expenditure on the roads etc. All too often, political or societal responses to events are based on such *monocausal* explanations. It's much easier for a politician or a manager to demonstrate that the supposed single cause is being tackled than to ask the much harder question as to whether this will really produce the desired result. The question of whether that result is indeed the best one in a wider context is even less likely to be asked.

A classic example arose from the series of rail crashes in England in the first years of this century. Tragically, several people were killed and the obvious 'cause' was problems with the rails. To avoid further loss of life, inspections and repairs to the tracks were instigated and draconian speed limits were imposed on trains. This certainly prevented further rail accidents, but also encouraged many people to abandon rail travel in favour of their cars. Given that the probability of an accident per kilometre travelled is a couple of orders of magnitude larger for car travel than rail travel, the decisions taken about the railways may actually have increased the subsequent number of travel-related deaths and injuries, rather than reduced them.

One response to the need to think beyond single cause-effect relations has been the movement, particularly in some aspects of medicine, towards so-called *holistic* approaches. These look beyond monocausality, to embrace the whole range of factors affecting human health, such as diet, social relations, posture etc. and the complex interactions between them. This undoubtedly has its strengths, but can seem impossibly time-consuming and may even conceal or confuse simple solutions. Somewhere between the seductive simplicity of reductionist, monocausal explanation and the possibly unreal requirements of unbridled holism, we need to learn a pragmatic systemic approach that is both effective and efficient.

Dealing with complexity

Systems practitioners have found it helpful to differentiate between two categories of problems, namely *difficulties* and *messes*, although many problems do not fit these categories exactly and their characteristics overlap to varying degrees. Difficulties are problems which usually have a well-defined and clear boundary, involving few participants, short timescales, and clear priorities, with limited wider implications. Examples might be an engineering problem involving routing a pipeline over a river or mountain range or a scientific problem concerning the impact of water stress on the yield of a crop.

Messes are typified by more human-oriented issues where values, beliefs, power structures and habit play a major part . There is no well-defined problem or solution, timescales may be long and at best we can only seek to improve the situation as seen by the wide range of people involved. This is where a systemic approach can be more appropriate than traditional, scientific, technical or economic approaches.

Systems thinking and sustainability

Thinking about sustainability involves questions about what aspects of our existence we want to sustain, how much are we prepared to compromise with others' needs and what unexpected results might arise from our actions. To develop a systemic approach to these questions will require some agreement about basic definitions and techniques for systems thinking. One key definition, based on work in the Open University's Technology Faculty, is that a system:-

- is a collection of entities….
- that are seen by someone…..
- as interacting together……
- to do something.

The various elements of this definition make clear that a system is not a single, indivisible entity, but has component parts (which may themselves be regarded as systems and termed 'sub-systems') and that such components interact with one another to cause change. For example, questions about food supply are best understood in terms of a complex, interacting food system involving land, animals, machinery, people and organizations (Figure 1 at end of chapter), not just unconnected crops, retail outlets, consumers etc. Models like Figure 1 are systems diagrams of the way that things currently are, in this case, a diagram of the current food production system as seen by one observer. They act as starting places for learners to consider how whole systems, or components of systems, can be redesigned along more sustainable lines. Figure 2 (at end of chapter), from Ho (2008), for example, is a systems diagram that attempts to provide a model for a more sustainable sub-system within Figure 1, a zero-emission farm.

Perhaps the most difficult aspect of the definition is the second one – that the collection of entities is *seen by someone as a system*. While the components included within a system often have concrete form, it is a human decision to group them together as a system. In that sense, systems are purely constructs and different individuals will see different systems in a particular situation. For example, a farm can be seen as a system to produce food, to produce a profit or to maintain a particular landscape. To a consumer a supermarket is a source of food, whereas to its operator and shareholders it is primarily a source of profit.

Since we cannot simultaneously solve all the problems of global sustainability, learning to choose an appropriate system for debate and decision-making is crucial. We need to establish a *boundary* around the system that we are debating, and different conceptions of the chosen *system of interest* will carry with them different criteria for the success or otherwise of that system. These criteria are chosen by the human participants, they are not a given of some pre-existing system. Choosing an inappropriate boundary and with it, inappropriate criteria, can be misleading. For example, choosing to put a narrow boundary around a system of using animals for food production can suggest that this is grossly inefficient, since it takes about 10kg of feed to produce 1 kg of meat. However, if the system is redefined to include the available land, then a more appropriate measure may be the total amount of food produced from the total area. In this situation, some ruminant animals have an important role, to obtain useful human food from those areas that can only grow grass or other plant materials that cannot be used directly by humans. In our earlier example, a decision taken about the safety of *the railway system* may well have had completely the opposite affect to that intended when considered in relation to the wider *transport* system. Changing the boundary and the criteria can produce very different conclusions.

We are all stakeholders (with different emphases, timescales, and skills) in some sustainable, human-oriented system, but we are unlikely all to have the same vision of what it is, what we expect from it and how it functions. To share our visions, and to debate futures, we need to learn ways of explaining what we regard as the system of interest and its key features. We need to learn how to create some *model* of a relevant system which is necessarily simpler than the whole, complex situation itself, but still shows the important aspects. It might be possible to create this model in words, but it may be quicker and more powerful to use some sort of diagram. Words have to flow in a sequential manner to make sense and one of the features of most systems is that the interactions between entities are often looped or recursive, where A may affect B which in turn affects C, but C can also affect A. In such a situation, a diagram can literally be "worth a thousand words". In the same way that a map highlights a selection of important features of the landscape, an appropriate diagram can make clear the key features of our interpretation of a system. Diagrams can provide the means for sharing different understandings of the world around us and of the potential outcomes of our actions within the multiple, complex systems of which we are a part.

Techniques for thinking systemically

Two simple diagrammatic forms that learners can find useful here are *Systems maps* and *Multiple-cause* (alternatively, *causal loop*) *diagrams.* Further detail and hints on learning to use these is provided on the Systems Practice website. A systems map uses closed shapes to represent the relatively unchanging components or subsystems that the person drawing the map regards as important in the system that s/he see in some situation. The spatial relationship between the shapes can be used to highlight some of the structural links between these aspects. So, the farms, food processors, the food distribution network and the supermarkets in Figure 1 are components of a food supply sub-system, and might be grouped together on a map of a larger economic system. Multiple cause diagrams (Figure 3 at end of chapter) highlight more dynamic aspects of a system, using arrows to indicate that one factor causes another to change, or causes some event to occur. Such diagrams can be developed into more formal, even computable, models of systemic behaviour. However, for many purposes, a diagram alone is more than adequate.

Systemic practice also involves learning a whole range of participatory diagrammatic, verbal and computational methods to draw out different perceptions of a situation, but this is only a start to the process. Learning to move towards sustainability requires us to think not only what *is* in a situation, but also to consider what *ought to be.* This is the role of critical systems thinking, and requires the learner consciously to face up to ethical issues. One widely used methodology requires consideration of the *customers* involved in a situation. Critical systems work explicitly recognises that this is too limited, and requires that we learn to take account of both *beneficiaries* and *victims* of any actions, rather than subsuming these into the economic class of customers. Systemic practice can also be characterised as a process of social learning, whereby those involved change both their common understanding of their situation, and their behaviours that arise from this understanding. Learning thus becomes embodied in action and vice versa. This will change the situation, so that understanding and action need continually to develop together. Hence a final key characteristic of systemic practice is that it is iterative, never assuming that we have found the answer, because the questions associated with sustainability are always going to change. We must be properly prepared to recognise, and to be part of these processes of systemic change.

BBC Open University (2008) *Systems practice – managing complexity.* www.open2.net/systems/index.html

Ho, Mae-Wan (2008) Food without fossil fuels *now*. *Institute of Science in Society Report.* www.i-sis.org.uk/foodWithoutFossilFuels.php; also appearing in *Science in Society* 38, 8-13 [diagram reproduced with permission from Figure 3, members version]

Linking Thinking. www.wwflearning.org.uk/data/files/linkingthinking-302.pdf [a flexible suite of learning and teaching resources designed to generate new perspectives, introduce systems ideas, and develop relational thinking]

Martin, S., M. Martin, R. Jucker, and C. Roberts (2008) Education and sustainable development – learning to last? In J. Larkley and V. Maynhard (Eds) *Innovation in education*. VB: Nova Science Publishers

Shon, D. (1995) The new scholarship requires a new epistemology. *Change* 27:6:26-34

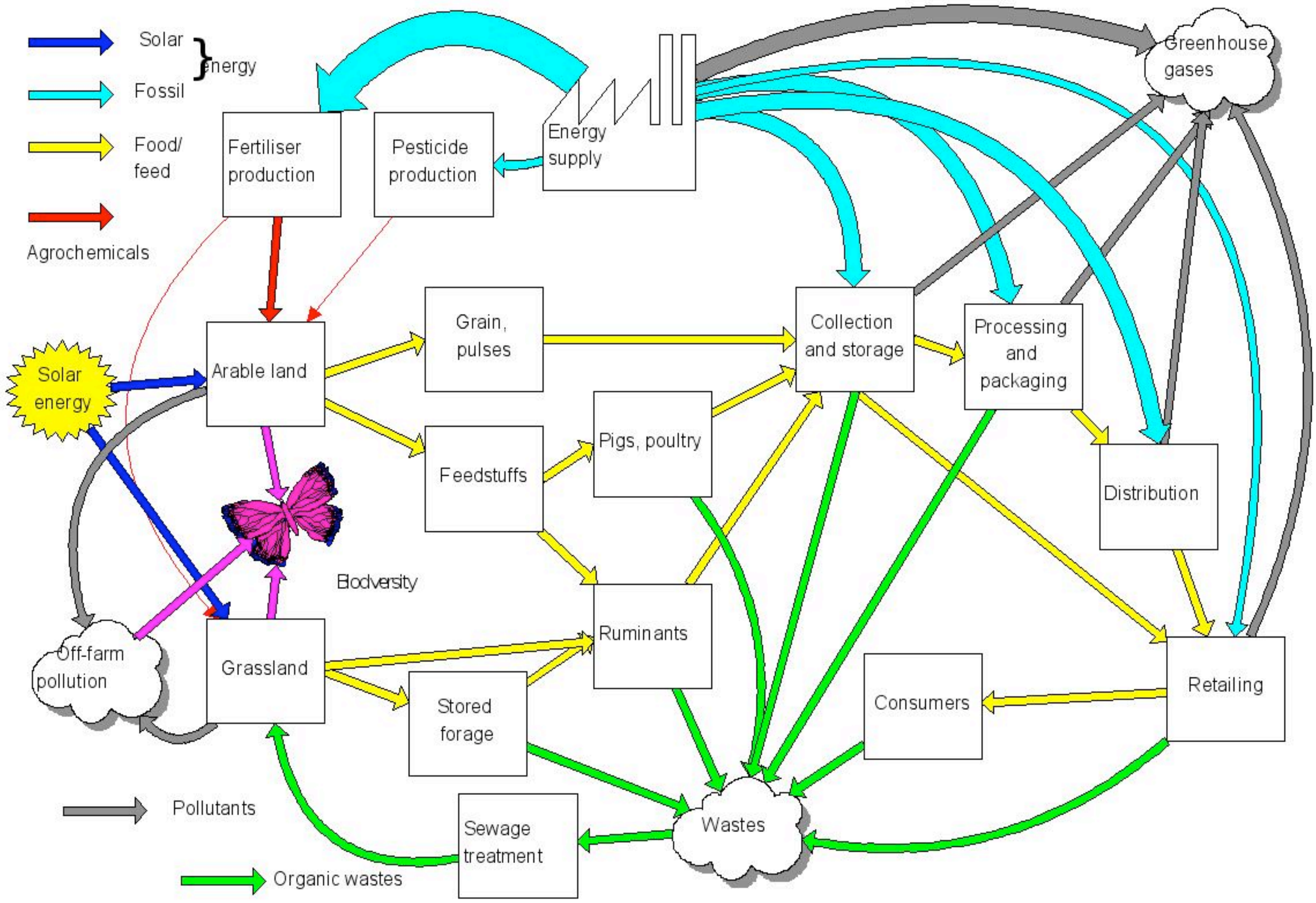
Solar
energy
Fossil
Food/
feed
Agrochemicals
Pollutants
Organic wastes
Fertiliser production
Pesticide production
Energy supply
Greenhouse gases
Solar energy
Arable land
Grain, pulses
Collection and storage
Processing and packaging
Feedstuffs
Pigs, poultry
Distribution
Biodversity
Off-farm pollution
Grassland
Ruminants
Stored forage
Consumers
Retailing
Wastes
Sewage treatment

Figure 1

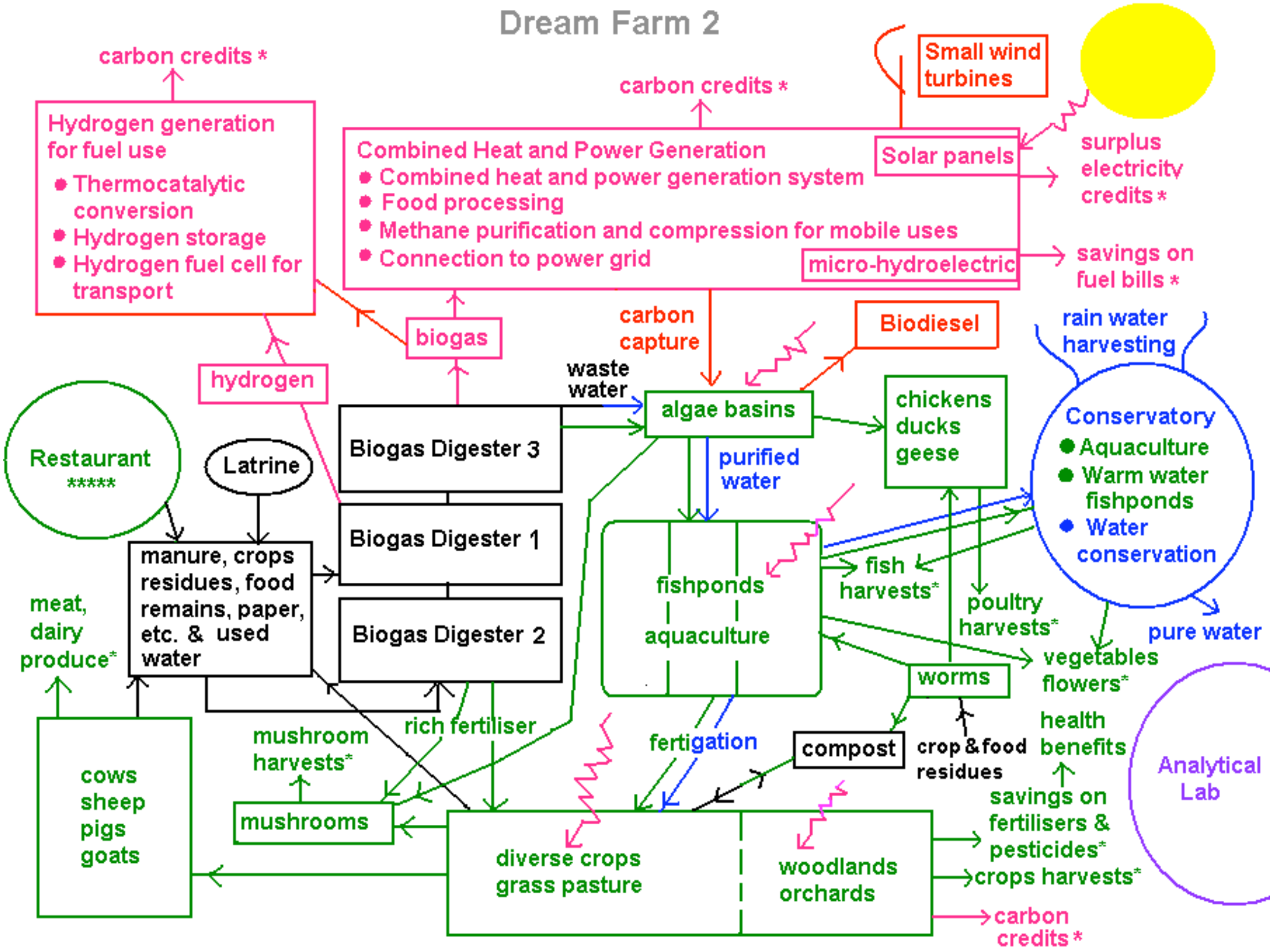

Figure 2: Dream Farm 2 by Mae-Wan Ho (2008)

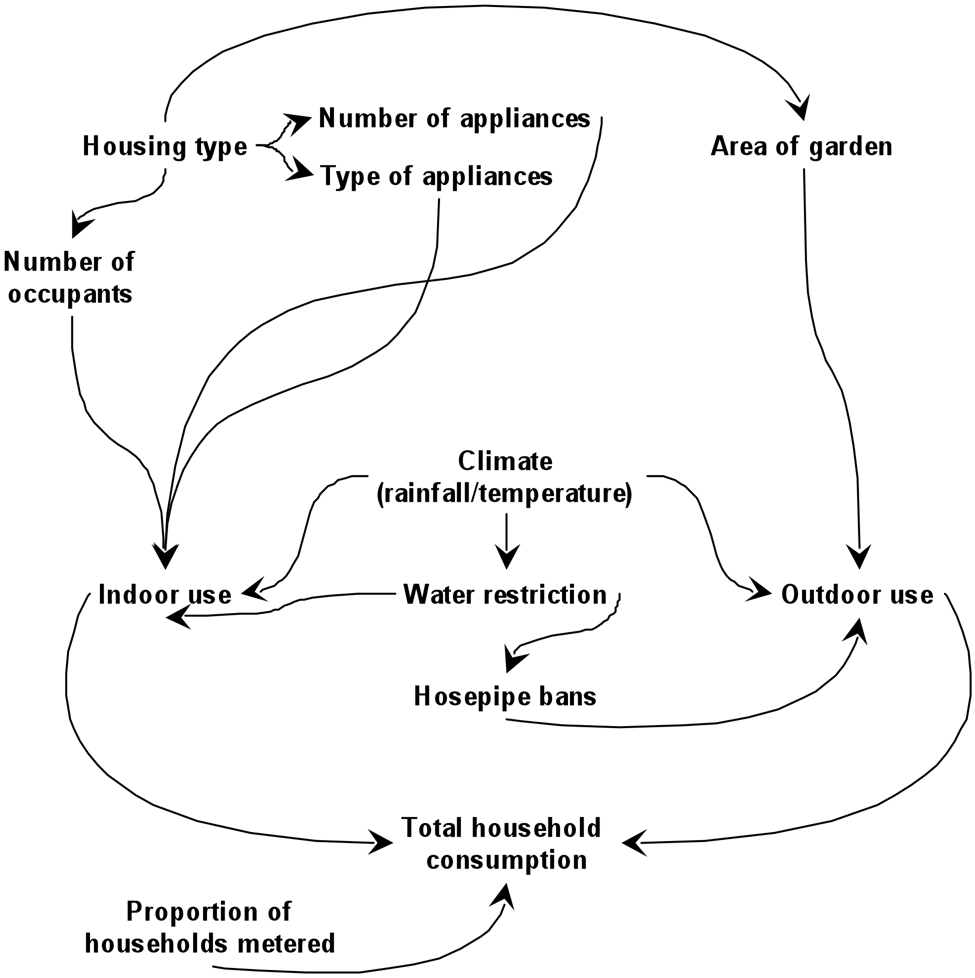

Figure 3 - A multiple cause diagram of the factors affecting domestic water use