Understanding the environment: thinking styles and models

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Introduction

Communities everywhere are coming under increasing pressure from interlinked social, economic and environmental challenges. Many communities are coming together to tackle these challenges, and individuals with some expertise in exploring wicked problems will play an increasingly significant role. In order to allow effective collaboration in understanding the highly complex and interlinked forces at play, it is important to have community groups composed of individuals with complementary skills. The aim of this course is to explore your particular approach to engaging with complex situations, allowing you to discover your strengths and weaknesses.

This OpenLearn course provides a sample of level 2 study in Environment & Development

Learning Outcomes

After studying this course, you should be able to:

- identify the need to recognise and integrate a blend of cognitive styles and multiple intelligences as the basis for effective systems practice and thinking
- recognise that the way we engage with the world is through partial models of reality, and that these models are limited by different cognitive styles and 'traps'.

1 Course outline

1.1 Aim

This course's activities and resources readings explore fundamental characteristics of your thinking, and how these characteristics determine the way you see and engage with the world. The aim is to allow you to compare your particular thinking style with the 'systemic thinking' skills that this free course will encourage you to develop.

1.2 Readings

The following is a synthesis of what you will come across in Section 1's readings of the Resource Book.

Simple differences in the way we perceive our surroundings can have a significant effect on how we engage with each other. Resources Readings 1.1 and 1.2 investigate the different thinking styles that contribute towards how people see and engage with the world, especially the differences between analysis and synthesis.

In Resources Readings 1.1 and 1.2, I state that analytical thinking has been favoured within modern, Western society. This limits the way we engage with complex situations, and can sometimes create more problems than resolve them. However, I am not making a case for going to the other extreme and promoting the dominance of intuitive, holistic or synthetic thinking. Systems thinking is about striking a balance between analysis and synthesis.

I also recognise that there is more to life (and systems thinking), than any simple classification of people into analytical or intuitive categories. In Resource Reading 1.3 you are introduced to at least eight distinct 'intelligences' where I illustrate how each has a role to play in how you model and engage with your surroundings. Later on in this section, you will also discover how systems thinking relies on more than just the analytical and linguistic intelligences.

The **concept** of 'modelling' is an important aspect of systems thinking and practice and this block will build on the brief introduction to modelling you have had in Block 1, while preparing you for a specific form of mental modelling, the use of '**metaphor**', which you will encounter in Block 3. Resource Readings 1.4 and 1.5 re-introduce and expand on the concept of modelling which you have already come across in Block 1, while Resource Reading 1.6 explores the idea that all living organisms need to model their **environment** in order to survive. When a species' environment changes, it must in turn change its models, either by biological evolution or by the much faster **process** of learning at both the personal and collective level. Otherwise, the species' very survival could be placed in jeopardy.

Resource Reading 1.7 lists a number of 'shortcuts' that we, as human beings, take in the development and **communication** of our own mental models. Shortcuts are usually used to save resources (energy, time, materials, etc.) but these are not always appropriate when dealing with complex situations.

1.3 Activities

Activity 1A allows you to identify whether you favour analysis or synthesis as your principal cognitive style, while Activity 1B allows you to explore the implications of your preference. Activity 1C takes a slightly different approach with regards to the exploration of your cognitive style by carrying out an 'audit' of your multiple intelligences. Activity 1D focuses on potential cognitive traps that you might fall into when engaging with complex situations.

These investigations should allow you to gain a better picture of your personal profile – often, the complexity 'out there' is amplified by the complexity 'within'. Indeed, as the concept of 'modelling' tries to demonstrate, the particular way by which we perceive external reality is just as significant in determining the complexity of a situation as the 'real' structures and processes around us. It is not uncommon to come across a situation that is perceived by some people to be complex, while other people perceive it as entirely manageable and simple.

2 Section readings – Thinking styles and models

Reading 1.1: Introduction to thinking styles

What do you do when you want to examine something closely? There are essentially two courses of action that you can take. You could pull it apart and look at how it works, like a watchmaker diagnosing a watch brought in for repair. You could also look at the context within which the thing was founds and try to understand it in terms of its relationships with its surroundings, like a detective looking at a body at a murder scene.

Most people have the capacity to do both depending on the circumstances, but modern **culture** encourages us to specialise in specific fields, in which people investigate things in increasing detail while losing a sense of the whole. Take, for example, an investigation into a set of disabling symptoms. You make your way through a series of professionals – a neurologist, an ergonomist, a rheumatologist, an osteopath – and if they still cannot find anything, you end up with a psychiatrist! But there is nobody that pulls everything together and investigates how several factors may combine within a particular environment to result in a debilitating illness.

But neurologists have found that different parts of our brains contribute to different thought processes. Although the idea is disputed, it has been proposed that the left part of the brain focuses on logical thought processes and is most active when one is engaged in sequential/linear thinking such as language. The right part of the brain is usually associated with more holistic thought processes, such as music, spacial thinking and creativity (see Figure 1). Thus, everyone should have the ability to carry out **analysis** (the process of taking something apart in order to understand it) and **synthesis** (the process of making a whole out of parts). Of the two, synthesis is perhaps the more difficult because in order to make a whole out of parts, the **relationship** of the parts to each other must be understood. Because there is no sensible adjectival derivative of the word synthesis, most people use the term 'holistic' thinking. So the words most used to describe these two modes of thinking are analytical and holistic thinking.

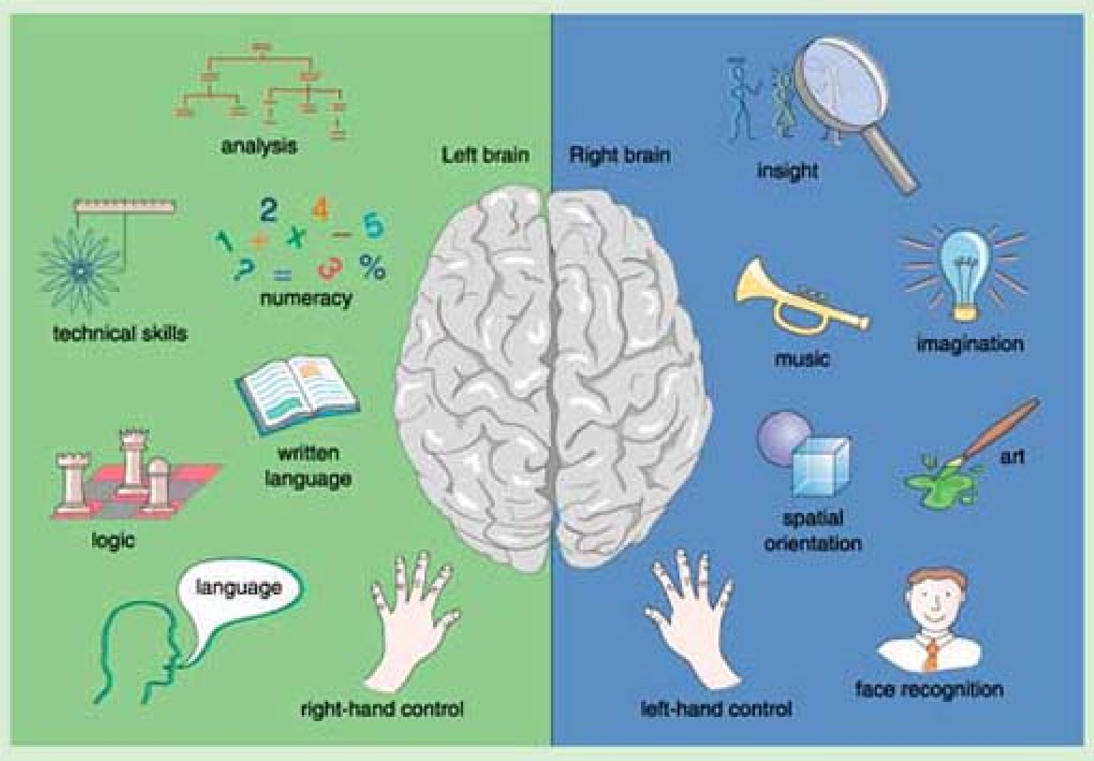

Figure 1 The different cognitive functions of the left and right sides of the brain

Brains and thinking processes have often been compared to muscles: some people are born slightly more athletic than others, but it is usually how those muscles are used during the person's lifetime which determines how fit they are. If people are encouraged to only exercise the analytical part of their brains then it is not surprising if they have difficulties in holistic thinking. Some educational experts have strongly criticised mainstream education's focus on analytical thinking, mainly through the strong emphasis on logical and linguistic disciplines such as mathematics and language. In an effort to broaden thinking about thinking away from this single focus Howard Gardner (Gardner, 1983) proposed a theory of **multiple intelligences**, initially presented in his book, *Frames of Mind*, but significantly extended since. He states that linguistic and logical **capabilities** are only two out of eight 'intelligences'. The others comprise spatial, athletic, musical, interpersonal (social), intrapersonal (self-analysis), and naturalistic (affinity towards all that is natural) intelligences. Thus, his assertion is that a balanced individual ought to try and dedicate effort towards developing all eight of their intelligences.

Systems thinking requires a similar balance, but focuses on understanding and engaging with the **systems** that surround us, such as ecological systems; social systems; technological systems; economic systems; and most realistically, systems that are made up of a combination of all the previous systems. Systems thinking requires analytical thinking to identify all the contributing component parts of a system under examination and to understand the relationship between components. Synthesis is used to identify how such a system comes together with other systems in the surrounding environment/ context. Systems thinking uses verbal communication to illustrate the logical sequence of events or describe components in increasing detail, while **visual communication** (e.g. diagrams) can be used to illustrate the relationship among component parts and how these can influence each other over time. Occasionally, when aspects of a system can be quantified, mathematics is used to precisely describe the **attributes** of components, and their relationship between each other and their **environment**. Interpersonal skills are needed to piece together the various different understandings that people have. And especially when dealing with living systems, empathy with our natural surroundings provides the much-needed reality check.

The following set of resources readings carries out a deeper exploration of analysis and synthesis, the multiple intelligences that we need to deal with the complex reality that surrounds us, the models that we create to simplify this complexity, and the different modes of **communication** that we use to inform ourselves and others.

Reading 1.2: Analysis and synthesis

There are two key approaches which guide the way we think and understand what surrounds us: **analysis** and **synthesis**.

Analysis focuses on the component parts of a situation, at heart the recognition of the differences between things. The process of analysis is the process of taking something apart and recognising the differences between the parts, and determining what the thing's parts are and do. Finally, the parts are reconstituted so as to understand the whole. It is often assumed in this process that the whole will be the same as the sum of its parts. That is, the properties of the whole can be determined by the properties of the parts. Analytical thinking has been immensely useful in resolving a wide range of problems that have clear causes. For example, most of the advances in health have been as a result of identifying simple causes of many diseases: viral and bacterial vectors; nutrient deficiencies; genetic mutations; and so on.

Analytical thinking has gained momentum since the Enlightenment, when there was a shift against mysticism, superstition, tradition, and revelation as the main ways of thinking about the world and what we do in it. The period within which this shift in thinking took place, the late seventeenth and early eighteenth century, was also called the 'Age of Reason'. This age promoted the use of logic and rationality, with Newtonian physics at the forefront of the revolution. People who favour analytical thinking promote the idea that most things can be 'reduced' to an atomistic interpretation, ultimately implying that the basic common denominator of analysis, physics, will be able to explain how everything and anything works. It is not surprising that it is physicists who coined the term 'Theory of Everything': the quest to find a single model to explain all fundamental interactions of nature.

But a singular emphasis on analytical thinking can also create more problems than it solves. A famous example illustrating the unintended consequences of just focusing on analytical thinking is the story of how pollution from coal burning has been dealt with. In the late nineteenth century, the burning of coal within industrial centres created significant air pollution in the immediate vicinity of the industry. The analytical solution to that problem was to build higher smoke stacks so that the smoke would fly over the populated industrial areas. This is surprising, since a Scottish chemist, Robert Angus Smith, had already identified the link between coal smoke and rain acidification back in 1852. Yet the engineers proposing higher smoke stacks were only concerned with resolving the problems of local smog, which higher smoke stacks duly solved. Soon though, significant areas of forest and water bodies downwind of these industrial areas began dying. Investigating scientists, still focusing on resolving the immediate problem, discovered that the high sulphur concentrations of coal smoke was acidifying rainfall over these downwind regions. The solution to the new problem, acid rain, was to install scrubbers within the smoke stacks which would remove the sulphur particles. Unfortunately, the sulphur particles in the atmosphere also act as water vapour condensers, thus promoting the formation of extensive cloud cover. This cloud cover helps to reflect solar radiation back into space, thus mitigating the effects of climate change. Another solution currently being promoted, yet again based on analytical thinking, is to spike jet fuel with sulphur. Some people are wondering what new problems this will bring.

A great example of an area where analytical thinking fails, is in understanding human emotions. The following quote from Jamshid Gharajedaghi's book (Gharajedaghi, 2006) on systems thinking illustrates the problem beautifully: 'I can love, but none of my parts can love. If you take me apart, the phenomenon of love will be lost.'

Indeed it often seems the case that with too much emphasis on analytical thinking, 'facts' are in, while 'emotions' are out!

Synthesis (holistic thinking), on the other hand, involves building a whole from disparate parts; a whole which at first maybe completely unclear, because sometimes this whole has properties that cannot be explained by looking at the parts. In order to synthesise different things we need to determine what similarities there are in two or more different situations, for example, consider living organisms. How can you distinguish something that is living from something that is inanimate?

There is no single mechanism that determines what is living and what isn't. We cannot explain life by 'pulling it apart' and then reconstituting it. Yet, we seem to be able to readily distinguish living things from non-living things. Synthesis is therefore about understanding ongoing processes that create recognisable patterns of behaviour. If I encounter different situations that produce a common pattern, I can then label this common pattern, and I can use this label again, and again. Coping with or surviving in new situations, situations we have not met before, depends upon our ability to synthesise. We can do this quickly and efficiently if we recognise commonalities with previous situations. This kind of synthesis clearly aids and speeds the **learning** process, and is a powerful tool in surviving in a changing world.

Many 'wholes' can only be understood by identifying their role or function in a 'larger whole' (the context or environment) that contains them. My labelling an oak tree and a blackbird as 'living' is the realisation that there is a pattern of 'living' behaviour in each of the two different entities, within the 'larger whole' of the ecological system, or **ecosystem**, within which they are both embedded. Synthesis, therefore, may very well involve identifying the whole that you wish to focus your investigation on, understanding the role or function of this whole within its context/environment ('the larger whole'), and then defining this whole according to the relationship with its context/environment.

The same thing can be looked at through analysis and synthesis. Take for example a lion. Analytical thinking would assume that a lion in the zoo is the same as a lion in the wild because they are exactly the same type of animal. But, holistic thinking reveals that the lion's role as part of savanna **ecology** is very different from the lion's role as part of a zoo. Studying the lion in its 'larger whole' – i.e. in the zoo – would tell you little about lions in the wild. Analysis tells you lions in the zoo and lions in the wild could be biologically identical, but synthesis would tell you that the animal in the zoo is not the same as the animal in its natural habitat. The two approaches can lead to two different conclusions. For example, as the study of the behaviour of animals has focused more on their actions within their natural habitats, we have been steadily revising upwards our understanding of animal intelligence.

Reading 1.3: Multiple intelligences

An individual's intelligence could be characterised by their ability to develop appropriate understanding for solving the problems that they perceive, or more generally, for surviving in their world in a way appropriate to their view of that world.

Since the Enlightenment, it has been important to acquire analytical proficiency, so society has especially favoured those individuals that had linguistic and/or logical-mathematical abilities. The ability to write well and to do accurate mental arithmetic was and still is a major obsession of most educational establishments. Yet many complex problems cannot be solved through analysis alone.

Resource Reading 1.2 explored another way of doing things through synthesis, which emphasises working through a problem by looking at the relationships amongst the issue of interest and its environment.

But there is more to the development and implementation of understanding than just analysis and synthesis. A large number of psychologists have attempted to investigate and classify people's construction of understanding and the way people put it into practice. Gardner (1983) proposed at least **eight intelligences**:

1. **Linguistic intelligence**. The ability to use a coherent narrative to communicate and organise thoughts. Lawyers are probably the most renowned practitioners of this intelligence.
2. **Logical–mathematical intelligence**. The ability to investigate issues deductively and recognise/work with numerical patterns. The profession that is probably the most obsessive in this regard is computer programming, where coding has to be carried out in a precise logical order and often requires advanced mathematical algorithms.
3. **Musical intelligence**. The ability to recognise pitches, tones, rhythms and compose these into recognisable patterns. In many indigenous societies I have worked with (which rely on cooperation rather than coercion in order to do things), music is a significant motivational force. Thus, the best leaders are those who have highly developed musical intelligences.
4. **Kinaesthetic intelligence**. The ability to coordinate one's movements. A vast array of professions require high levels of this intelligence, including athletes, craftspeople, musicians, dancers, surgeons and painters.
5. **Spatial intelligence**. The ability to recognise visual patterns and relationships. It might come as a surprise to realise how many professions rely on this intelligence, including artists; taxi drivers; designers; sailors; architects; and gardeners.
6. **Interpersonal intelligence**. The ability to empathise with others by recognising their intentions, motivations and desires. Educators, psychologists and politicians are professions which need to have high levels of interpersonal intelligence in order to do their work.
7. **Intrapersonal intelligence**. The ability to recognise one's own intentions, motivations and desires. Individuals with high intrapersonal intelligence are able to clearly articulate their feelings. Novelists and poets spring to mind as being highly developed in this regard.
8. **Naturalist intelligence**. The ability to detect changes in one's own environment. Many rural societies have highly developed naturalist intelligences through their ability to detect changes in, for example, weather patterns and the relative health of crops and domestic animals.

So there are at least eight different ways in which understanding can be developed, communicated and put into practice. When systems thinking was evolving in the 1950s, 1960s and 1970s, the emphasis was very much on using linguistic and logical-mathematical intelligences. Complex computer models were developed to convey a systemic understanding of problems, and the most incredibly convoluted texts that I have ever come across were written in this field. Recently, a significant shift has taken place in systems thinking and practice, which now promotes the use of other intelligences. The resource reading on 'Visual communication' (Resource Reading 2.5) is an example of the use of spatial and kinaesthetic intelligences.

Reading 1.4: Introduction to models

What gets you out of bed in the morning? In my case, the moment I hit consciousness, I scan my memory for any immediate tasks I need to achieve. Do I need to get the kids to school today? Have I got any early morning meetings? Identifying which task is relevant determines my subsequent actions. Still not fully awake, I start following a sequence of well-rehearsed steps aimed at getting the appropriate task done. These 'well-rehearsed steps' could be described as the model on which I base my actions.

You are all familiar with the idea of a model, a doll representative of a human or a toy car representative of a car. However, the word '**model**' has a range of colloquial and technical interpretations, so I first need to establish the way in which I use the term. As a start, I would suggest that a model is a simplified representation of reality; the doll does not have all the features of a human, nor the toy car of the car. If when I got up in the morning and had to piece together all the various aspects which determine why I am following my particular sequences, I would never get anything done. So a simplified representation of reality is absolutely essential. But, what is reality? Without getting into deep philosophical water, it is important to recognise that in general, a model is usually a rather personal or subjective thing. It may be better to define it as a simplified representation of a person's or group's view of a situation.

I also need to stress that models are always intended for some **purpose**, and it is this purpose that decides how the simplification is made. The purpose of the doll, and the car perhaps, is to stimulate a child's imagination and help it become familiar with the world it will grow up into. The purpose of my 'getting out of bed' model is that it keeps me in right relation to both the physical world (the bed, stairs, breakfast, etc.) so that my body remains undamaged and properly fueled, and also to my social world (my family, employment, etc.) so that my social relations are maintained. Although you may not immediately think of them as such, you regularly use models in everyday life in order to achieve even the most basic task. For example, maps and plans are models of the layout of the roads, rivers, buildings or other features of our physical environment. An architect's sketch or an engineering drawing is a model of some artefact which is to be constructed. Its purpose is to communicate the design to those who will be building the artefact. Prior to constructing that artefact, we may be shown a scale model of it in order to test our reactions, or to see how it might operate. Photographs are models of the scene that the camera user saw when the shutter was pressed, perhaps taken to remind them of that special scene. Sculptures or paintings are also models, in that they are representations of some aspect of the world as it is interpreted by their creators, perhaps to make a particular statement to the world. The graphs and tables used to sell financial products are models of the expected performance of those products, and at the national level, government has a model of 'the economy' on which it bases decisions about tax rates, interest rates and other aspects of fiscal policy.

At a more fundamental level, the view I will take is that all our interactions with the world around us depend on our internal, mental models of how we perceive that world. It is worthwhile pausing for a moment to consider the importance of this. The preceding text has suggested several examples of different types of model to you, and at a very broad level, one of the purposes of this course is to introduce you to the sorts of model you are likely to use in thinking about systems that are different from those you habitually use. You have already seen how the ways in which we think and act are shaped by **mental models**, but as well as the internal representations discussed earlier, mental models also include language and linguistic models, in particular the metaphors that we use in thinking and talking about situations. Many of these are so common that we lose sight of the fact that they are just metaphors, such as 'getting to the heart of the matter', or 'the bottom line on this is ...'. **Verbal models** are important both as the external representation of our (internal) mental models, and probably as part of the thinking process itself.

Visual models too are extremely important. These models can be represented in two-dimensional and three-dimensional forms. Three-dimensional visual models usually use some physical material to represent physical aspects of a situation, as in scale models of new products or developments. For example, the shape or pattern may be similar, but the scale may be changed, or different materials may be used. Whichever is the case, there is usually a strong visual resemblance between the original and the model. There is also a wide range of two-dimensional representations which can be used in systems modelling. They include photographs, maps (see Figure 2) and plans, and other different sorts of two-dimensional diagrams such as **sign graph diagrams** (Reading 4.6) and **system dynamics diagrams** (Reading 4.7).

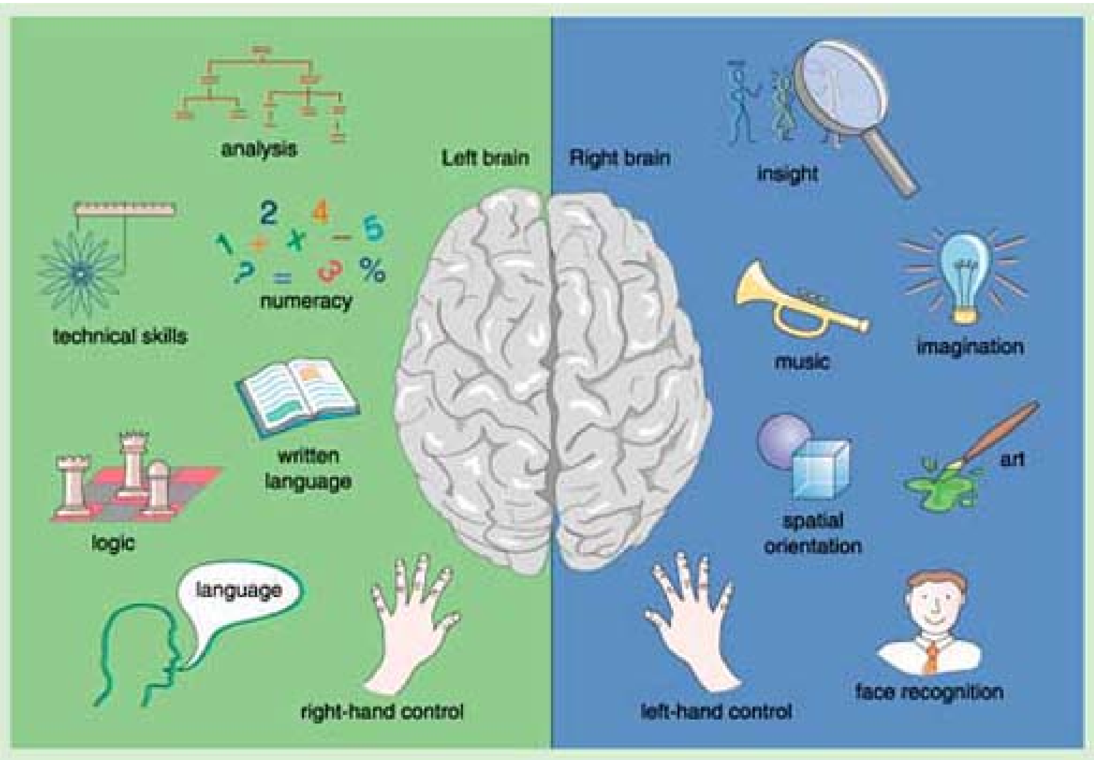

Figure 2 A map is a visual model of the landscape, representing spatial features which we require for navigation (Source: T863 *Techniques*, Figure 3 p. 13 and Figure 4 p. 14)

Quantitative (mathematical) models are models that can appear to be extremely powerful and sophisticated, and sometimes, 'modelling' is taken to imply only **mathematical models**. They make use of mathematical techniques to calculate numerical values for the properties of the defined system, and can be used to explore the results of different possible actions.

These different forms of modelling all require different skills, or as described in an earlier resource reading, **multiple intelligences**. Simplified representations of people's views of a situation can be communicated using all three modelling approaches, each having particular **roles** to play in particular circumstances.

Reading 1.5: Defining modelling

A **model** is always made for a **purpose**, and whatever that purpose is decides what aspects of the real entity are represented in the model. The aspects of the car which are modelled in a toy car and the aspects of the human modelled in a doll will vary depending on its purpose.

A model is a model because its form, the structure and organisation of its parts match in some way the form, structure and organisation of the parts of the entity that is modelled. The model is a **simplification** – that is some, but not all, aspects of the entity represented are present in the model.

The idea of a mental model is that it is just such a representation of an external entity stored within the brain or nervous system of a human. The notion of mental models as a way of modelling the thinking process was first proposed by Kenneth Craik (Craik, 1943) in his book, *The Nature of Explanation*, and is now a well established set of ideas (Johnson-Laird, 1983). The significance of Craik's proposal is explained as follows. Imagine a small robot, perhaps a tricycle, with a steerable front wheel, able to move around on the surface of a table.

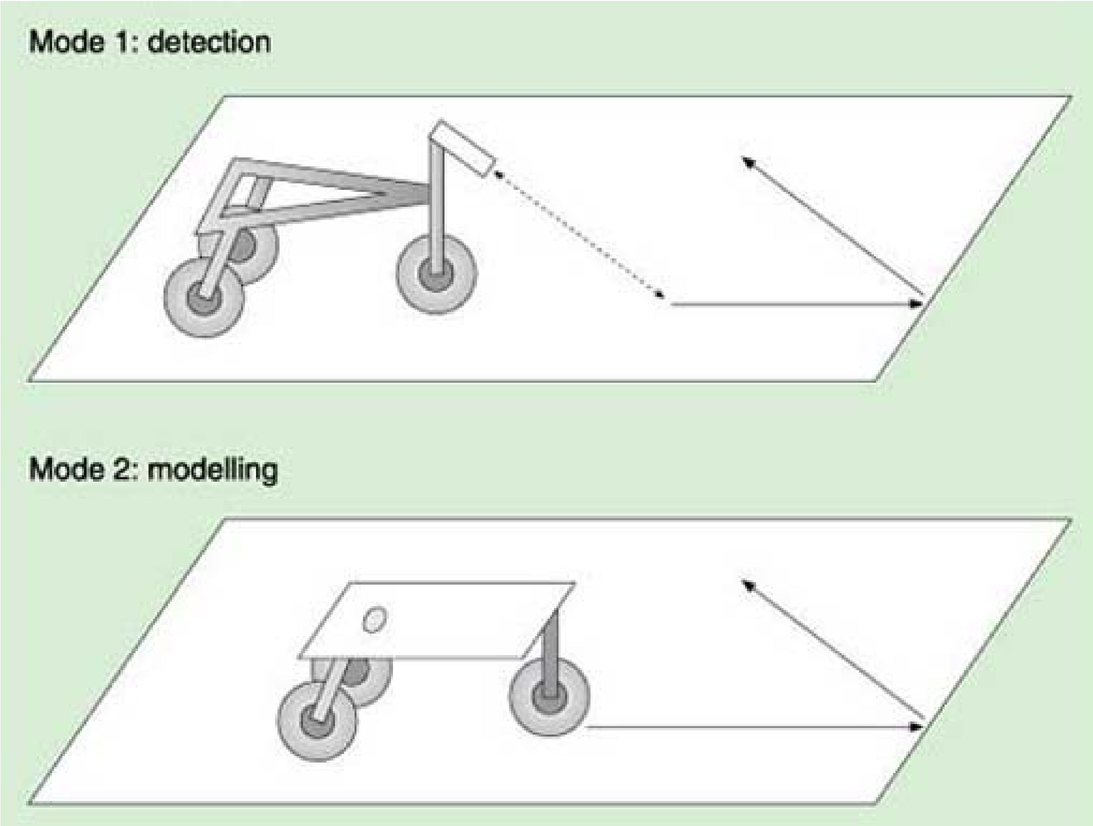

Figure 3 The Craikian automaton

There are two ways of building the robot so that it does not fall off the table. I will call them Mode 1 and Mode 2, as illustrated in Figure 3. The first and the simplest strategy is to build a detector on the front of the robot, which can detect the edge of the table when the robot reaches it. Then as the robot moves forward, this device continuously checks for the edge of the table. On detection the front wheel is caused to turn so that the robot moves away from the edge. This is the mechanism that most of us would come up with if asked to design such a robot, but there is an alternative, Mode 2. The second way is to build a more elaborate robot. On the tricycle we construct a model table, and on the model table a model robot. The model robot is geared to move across the model table at a proportionate rate, and so the robot 'knows' when it nears the edge of the table and can steer accordingly. Perhaps it is not an easy task to design the mechanical linkages required as I have described it, but with today's electronics and computing capability this could certainly be done. As long as no one knocks the robot, and all remains aligned, the robot will stay on the table as we require. Of course in time, with inherent errors accumulating (e.g. someone knocks the robot or the table) eventually the table and model table will become misaligned. So it is necessary to incorporate into our design something from Mode 1 to check occasionally that the table and model table remain aligned.

The information processing requirements of these two techniques are quite different. Mode 1 requires a large ability to process **information** from the outside world and minimal internal processing. Mode 2 requires a minimal ability to process information from the outside, but a sophisticated model building apparatus internally; all the evidence points to nature adopting a heavy reliance on the second strategy in humans. The information carrying-capacity of our external **sensors** is much less than that required to continuously-monitor our outside world. Incoming signals collected from the outside world using the five senses are used to build models over time, and the models are then used to process the incoming signals from the outside world. This system brings advantages, the most important being the ability to use relatively crude outside sensors, but then to be able to elaborate the information collected internally using accumulated experience, and therefore to be able to react quickly to complex outside threats.

As always, nature has developed a brilliant solution to a difficult problem, but the solution does have a downside. Sometimes our brains pick the 'wrong' model – an extreme example could be a police marksman seeing a criminal carrying a gun, rather than a law abiding citizen carrying a table leg. Your preconceptions, your expectations framed in the model you are using, determine what you perceive, and what you perceive determines how you respond. Acting too quickly driven by the wrong model can have dire consequences. Psychologists are coming to understand that this effect plays a crucial role in some driving accidents.

So far we have been thinking only in terms of humans creating models and modelling their environment in order to deal with it and survive. As humans, we have taken **control** of our environment to extraordinary lengths; we can now build air-conditioned or centrally heated buildings, and elaborate distribution systems to supply everything from food to entertainment.

But this way of thinking has much wider implications. Modelling to regulate and control our environment is an example of the more general problem of regulation and control. In 1970 the notion that modelling was at the heart of regulation and control was formalised. The Conant-Ashby Theorum (Conant and Ashby, 1970) fixed this idea of modelling in the sense that has been described, as essential to any understanding of regulation and control, and therefore essential to any **organism** in **regulating** its environment in order to survive.

Therefore, from the Craikian robot's point of view the model of the table provided is enabling it to survive in its table environment. You can see that from this point of view, within any living organism there are models of the relationship of that individual organism to its environment. This is the way in which an organism seeks to regulate this relationship, to survive and to make existence comfortable. In the simplest of cases, an animal having the ability to move from one place to another means it can change its environment. When threatened, a frog simply needs to hop away.

But even in the simple situation of the frog, it must be able to perceive and recognise a potential threat. For example, if something approaches it must be able to discriminate between a potential mate and a potential threat. It needs to model the difference. It used to be that the autopilot built into all airliners kept the airliner flying straight and level without any attention from the pilot, but it had no model of the aircraft's relationship to terrains such as mountains. To avoid this danger the pilot, who did have the model, had to intervene. This is now built in and autopilots have models of the land they're flying over. Together with GPS this is really useful for avoiding mountains. So being able to survive in a particular situation means having an internal model of that situation – if there is no internal model then the situation cannot be perceived and appropriate action cannot be taken.

So now you see that in order to interpret signals that are significant to it, an organism must contain internal models that enable it to perceive, interpret, and act upon those signals. Therefore, you can extend the definition of an internal model to encompass the internal organisation of a system which enables it to recognise and respond to a particular pattern of signals from the environment falling upon its receptors.

This internal organisation may involve the whole system or just a small part of it, and may be simple if the pattern to be recognised is simple, or complex if the pattern is complex.

Reading 1.6: Models in nature

Resource Reading 1.4 focused on different models that humans use to help them think through and act in a complex world. This provokes the questions: but what about other living things? Do they model their **environment**?

A mental model is an example of an **internalised model**, a model contained within a brain. This idea of an internalised model gives surprising insights.

Internalised models seem to be at the heart of life itself. One of the simplest examples is that of a protein molecule that can be said to model the shape of another molecule. This similarity of shape enables them to selectively interact. This is a mechanism that is one of the fundamental bases of life. A second example in a relatively simple life form is a bacterium that can detect a chemical gradient over its body length so that it can swim up the gradient to where food is plentiful. I can interpret this as the bacterium containing a model whose purpose is to enable it to find food. A more complex example is a fly that can detect and is sensitive to a small black moving patch, its model of another fly, a potential mate. So here you can consider models driving behaviour.

In more complex organisms models not only drive behaviour but are used for communication. Karl von Frisch (von Frisch, 1967) describes bees at work. When a bee returns to the hive carrying nectar from a newly-found source it needs to communicate this to other bees. Bees communicate using a model of where a food source is located.

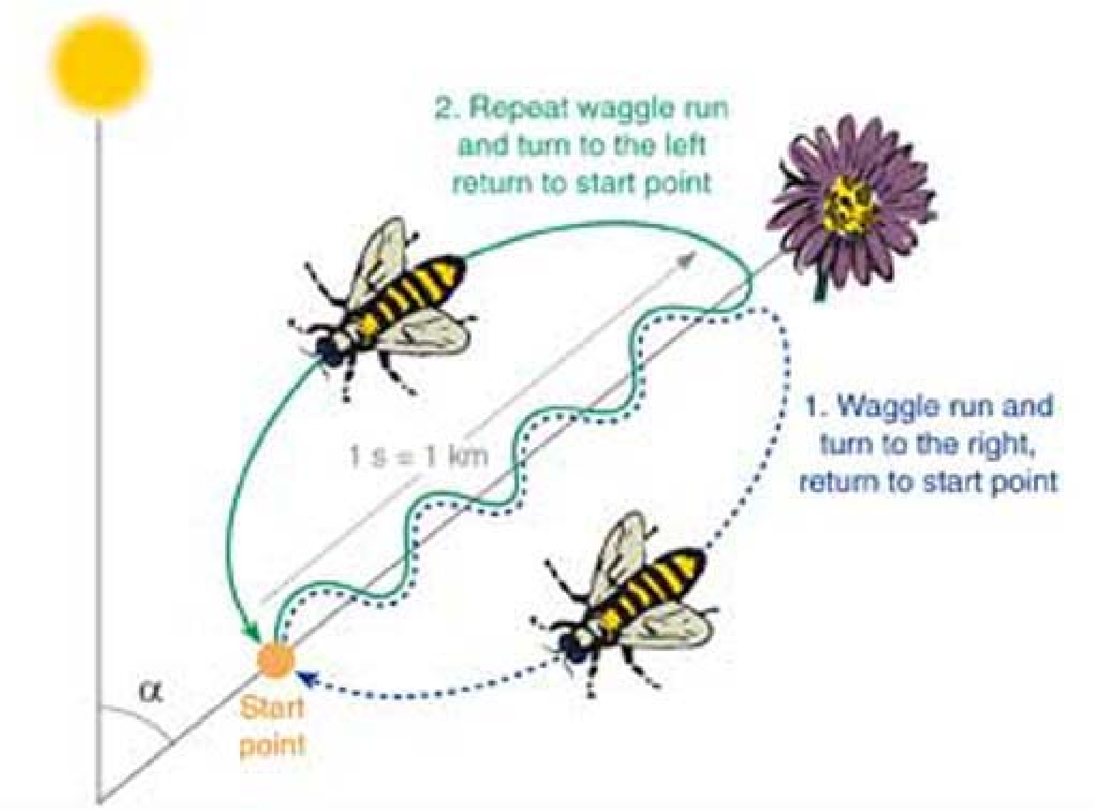

Figure 4 Bees at work, the 'waggle dance'

They dance a special dance usually performed on a vertical surface of the hive, communicating the direction of a potential food source and its distance from the hive to other bees around (see Figure 4). The distance the food source is from the hive is represented by the proportion of time the bee spends wagging its tail in the dance and the direction is represented by the angle to the vertical the bee adopts for the wagging portion of the dance. The spatial location of the source is modelled so that communication can take place. The bee converts its experience into the dance, and the watching bees reconvert what they see into action. The internal model is converted to an external manifestation and then reconverted to action by watching bees.

If a bee arrives back at the hive loaded with nectar and there are no available bees around to unload it and take the nectar back to the storage area, then it does a different trembling dance, the purpose being to attract more helpers to the storage task. These two dances keep the collection system in balance.

In the primitive animal world, the internalised models of an individual cannot change. Individual animals cannot learn, but of course the species can, since internal structures can and do change through the mechanisms of evolution to enable adaptation to a changing environment. In higher animals, i.e. species with advanced cognitive abilities, internalised models can change – higher animals have a nervous system that is plastic, and that can change through an individual animal's lifetime. So individuals can learn, can change internal models to match a changing environment. Clearly this is a necessary development to enable longer lifetimes for more complex individual animals – if the environment changes then so must the internal models to enable the animal to survive. Humans have developed this ability par excellence, and therein lies our supreme adaptability. Humans can change any of their mental models through **learning**.

Reading 1.7: The limits of mental modelling

We are constantly reminded in the media how intellectually and emotionally 'superior' we are to other species on Earth. The locus of this superiority is apparently our brains. By the time our species reaches adulthood, our ratio of brain size to body size (the 'encephalisation quotient') is three times greater than our closest relatives, the primates. This large brain allows us to escape what Christopher Wills (Wills, 1993) in his book, *The Runaway Brain*, called 'stupid-world', a place made up of animals unable to switch off their senses from the constant bombardment of immediate environmental stimuli. True, many animals are able to explore a situation, observe their impact on themselves and evaluate the effects, and then plan avoidance or remedial actions. But we have evolved this into a fine art. Our greatest difference is our ability, during our waking moments, to detach ourselves from the here and now (our actions and observations) and develop **mental models** of our surroundings (our reflections and plans).

Yet, we are not as clever as we think we are. In his 1956 paper entitled 'The magical number seven, plus or minus two: some limits on our capacity for processing information', cognitive psychologist George Miller (Miller, 1956) demonstrated that most of us cannot hold more than seven or so different items of information in our heads at any one time.

The fact that most people cannot hold more than seven items of information at the same time has major consequences. Our view of a situation will always be a simplification of reality, because we can only deliver and people can only absorb 'seven, plus or minus two' items of information at any one time. Thus, whether the delivery mode is oral, written, visual or mathematical, it is useful to think about developing a communication experience that does not overload the senses with more than seven items at a time.

A second issue in developing and communicating mental models, is that people frequently develop their models of reality based on existing ideas and opinions. Thus, we select information based on past experiences and current beliefs rather than looking for things that might contradict these. It is also appropriate to think of your listener's past experiences and current beliefs in communicating your mental model. This phenomenon of '**selective perception**' can be crudely described as 'people see what they want to see'. It is therefore very difficult to let go of your beliefs and experiences, even if there is mounting evidence that your mental model might be inappropriate.

One of the consequences of 'selective perception' is the self-fulfilling prophecy phenomenon. If you develop a mental model of yourself which says 'I am ugly and fat', then you will most probably avoid situations which focus on your physical appearance: swimming in public; dancing and wearing tight clothes; asking somebody out for a drink; and so on. As a result, you stop being invited out and may have problems finding a partner. Challenged, you might answer 'but that is because I am ugly and fat'. In this situation you are trapped in a vicious self-fulfilling mental model. And it is often impossible to escape from this trap because of another key human characteristic: face saving. It is amazing to see how many people refuse to admit they are wrong even though such an admission would allow them to move on with life. In fact, there is usually no such thing as a clear-cut right or wrong answer – just partial perceptions of reality.

A third issue is the tendency to focus on the detail rather than the bigger picture. It is far easier to specialise in a particular area we are familiar with rather than sweep in more information we are not particularly comfortable with. For example, most of my scholarship involves engagement with ecological research and literature, although it would probably benefit my understanding of the complex reality out there if I also engaged with other disciplines, including economics – but the idea of reading a book in economics is certainly not at the top of my 'to-do list'. As a consequence, most mental models are piecemeal and rarely address the full complexity of the problem at hand. Although related, the tendency to specialise is a distinct issue to that of 'selective perception'. We can select information based on past experiences which have led us to specialise in certain fields and/or opinions. In essence, our wish to specialise our mental models is mostly due to impatience – we want to quickly arrive at the root cause of a problem, whereas in reality there is seldom a single overwhelming factor which controls the outcome of a situation. Once again, there is no right or wrong answer, just a partial perception of reality, this time resulting from specialisation.

A fourth issue to consider is '**group think**'. Solomon Asch (Asch, 1963), a world renowned gestalt psychologist, carried out a fascinating experiment to investigate the effect of groups on individual decision making. He placed a group of people in a room and presented them with two cards: one of the cards had a single straight line drawn on it; the other one had three lines of differing lengths, one of which was identical to the line on the first card. The group's simple task was to select the line in the second card which matched the line on the first card. All the individuals in the group, except for one, were secretly asked to provide the wrong answer. Sometimes the group was asked to provide their opinion before the unsuspecting individual's turn and sometimes after the unsuspecting individual provided an answer. The results were startling. Those individuals asked to provide their opinion after the rest of the group, gave a wrong answer 40 per cent of the time. Those individuals asked to provide their answer before the group, always got it right! Thus, some ignored the blatantly obvious in favour of accepting the opinion of the group. It is fascinating to observe these phenomena in society, where individuals are induced to carry out acts in a group setting that they would never do on their own.

The fifth issue is the **difficulty** in dealing with dynamic situations that do not correspond to our perception of space and time. In his book, *The Blind Watchmaker*, Richard Dawkins despairs with our limited capacity in dealing with unfamiliar timescales:

> ... our brains are built to deal with events on radically different timescales from those that characterise evolutionary change. We are equipped to appreciate processes that take seconds, minutes, years or, at most, decades to complete. Darwinism is a theory of cumulative processes so slow that they take between thousands and millions of decades to complete. All our intuitive judgements of what is probable turn out to be wrong by many orders of magnitude. Our well tuned apparatus of scepticism and subjective probability-theory misfires by huge margins, because it is tuned – ironically, by evolution itself – to work within a lifetime of a few decades. It requires effort of the imagination to escape from the prison of familiar timescale ...
>
> (Dawkins, 1986)

Even the issue of space is a major challenge. It is only relatively recently that our species has come to terms with the fact that the Earth is round and not flat. This realisation is almost out of reach of our cognitive abilities. The fact that below me, rather than to my right (I am looking out of a north-facing window), is my 'upside down' Australian colleague still boggles my mind.

Our inability to deal appropriately with a wide range of temporal and spatial scales is probably why we have such immense problems in understanding and redressing major threats such as climate change. We can react to situations that we understand and that affect our lives directly, but it is not always so easy to do this in situations where the event has not even happened and there is no direct understanding of how these events will affect us over time and space.

The final issue (and I have left this one until last on purpose) is our limited attention span. Although I have not yet reached the 'magical number seven', I would not be surprised if your attention has started to wander – as I write this I am certainly feeling like taking a break! It is no coincidence that most meetings, lessons, films, sports events and other activities that require one's attention rarely last more than one and a half hours; and even these periods are broken up into smaller units with peaks and troughs of mental activity.

Although we need to concentrate in order to develop our mental models, the fact that most people have a time limit on how long they can concentrate is a good thing. Historically, we needed to occasionally detach ourselves from our mental exertions and scan the environment for predators and/or enemies. Some individuals have the luxury of being able to concentrate for an extended period of time only because we have evolved a society which looks after them. Increasingly, we are delegating the 'looking after' to technology, in the form of washing machines, industrial agriculture and food processing, online shopping, etc., so a greater proportion of society and individual's time can be dedicated to mental modelling.

But this does not change our biological limits – we still need the same time that humans always have for developing our own mental models and understanding the models of others.

So, recapping on the issues that you need to be aware of when developing and communicating your mental models:

1. You can only hold seven (plus or minus two) items of information at any one time.
2. You develop your mental models based on past experiences and current values.
3. You tend to focus on the detail rather than the bigger picture.
4. Given the option between choosing your own judgement and that of the group you are part of, you have a tendency to be strongly influenced by the latter.

5. You have a limited attention span, so any mental model must be developed or communicated within units spanning no longer than one and a half hours.

3 Section activities

Activity 1A: Identifying your cognitive style

Research in cognition – the way we see, understand and engage with our surroundings – associates certain aspects of our behaviour, such as sociability, with the level of activity within different parts of our brains. Some researchers have proposed that activity in the right hemisphere of the brain is mostly concerned with synthesis (the simultaneous integration of many inputs at once), and is especially concerned with spatial orientation and visual imagery. They also have evidence that the left hemisphere of the brain is engaged with analysis (the sequential processing of information), and is therefore active during logical thought processes such as writing and mathematics. Although there is now significant evidence that different regions of the brain perform distinct functions, I would like you to think of the differences between the behaviour determined by left and right hemispheres of the brain more as a **metaphor**, in recognition that this differentiation is an oversimplification of the functioning of what is an extremely complex organ.

Activity 1

In 1996, cognitive scientists Christopher Allinson and John Hayes (Allinson and Hayes, 1996), presented a test to differentiate those individuals that are predominantly intuitive thinkers from those that are predominantly analytical thinkers (which they ascribed to the dominance of the right hemisphere or left hemisphere of an individual's brain respectively). The Cognitive Style Index allows people to identify where they are along the intuitive/analytical gradient. There are also a range of free online tests which you can take, such as Holisticmessenger, which will give you a good indication on your cognitive style.

Answer

This is how Allinson and Hayes distinguish between intuition and analysis:

> Intuition, characteristic of the right brain orientation, refers to immediate judgement based on feeling and the adoption of a global perspective. Analysis, characteristic of the left brain orientation, refers to judgement based on mental reasoning and a focus on detail. These right-left patterns are not merely transient; people seem to have a rather permanent stylistic orientation to the use of one hemisphere. Intuitivists (right-brain dominant) tend to be relatively nonconformist, prefer an open-ended approach to problem solving, rely on random methods of exploration, remember spatial images most easily, and work best with ideas requiring overall assessment. Analysts (left-brain dominant) tend to be more compliant, favour a structured approach to problem solving, depend on systematic methods of investigation, recall verbal material most readily and are especially comfortable with ideas requiring step-by-step analysis.
>
> (Allinson and Hayes, 1996)

Activity 1B: Exploring your cognitive style

In this activity the aim is to explore the implications of your cognitive style with regard to your thinking and actions.

Activity 2

1. 1. Do you feel that your Cognitive Style score, and the corresponding cognitive style feedback, is an appropriate representation of how you see yourself?
2. 2. Do you feel that the spread of Cognitive Style scores within the participant population is representative of the range of cognitive styles present in society in general?
3. 3. What challenges do you think you face personally, and society faces in general, with regards to adopting a balanced approach to thinking involving both analysis and intuition?

I would like you to consider these three questions and make notes before reading my response below.

Answer

As stated in the introduction to this section, systems thinking is about striking a balance between analysis and synthesis. If you got an indeterminate score, then you may be able to use both styles of thinking, which should give you a head start in systems thinking and practice. Others, including myself (I got a very low score), will have to struggle a little bit against our natural predispositions or, preferably, actively seek to work with people on the other side of the divide in order to achieve the appropriate balance.

Fritjof Capra, one of the most radical and influential systems thinkers of our time, was even more explicit on the need for balancing analytical and intuitive approaches:

> The rational and the intuitive are complementary modes of functioning of the human mind. Rational thinking is linear, focused, and analytic. It belongs to the realm of the intellect, whose function is to discriminate, measure, and categorise. Thus rational knowledge tends to be fragmented. Intuitive knowledge, on the other hand, is based on a direct, non-intellectual experience of reality arising in an expanded state of awareness. It tends to be synthesising, holistic, and nonlinear. From this it is apparent that rational knowledge is likely to generate self-centred, or yang, activity, whereas intuitive wisdom is the basis of ecological, or yin, activity.
>
> This, then, is the framework for our exploration of cultural values and attitudes. For our purposes these associations of yin and yang will be most useful:
>
> - Yin: feminine; contractive; responsive; cooperative; intuitive; synthesising.
> - Yang: masculine; demanding; aggressive; competitive; rational; analytic.
>
> Looking at this list of opposites, it is easy to see that our society has consistently favoured the yang over the yin – rational knowledge over

> intuitive wisdom, science over religion, competition over co-operation, exploitation of natural resources over conservation, and so on. This emphasis, supported by the patriarchal system and further encouraged by the dominance of sensate culture during the past three centuries, has led to a profound cultural imbalance which lies at the very root of our current crisis – an imbalance in our thoughts and feelings, our values and attitudes, and our social and political structures.
>
> (Capra, 1982)

I would like to end this activity by making a final 'plug' for balancing your thinking by putting a little bit of trust in intuition. The educational system, and society as a whole, has always stressed the need for 'rationality'. This is often expressed through requiring you to 'think things through before acting'. This is all very well for engaging with simple problems, where the number of things to consider are few and you often have enough time to 'think'. However, complex situations are often characterised by information overload and/or the need to make decisions quickly. Our species has therefore evolved the ability to make decisions subconsciously i.e. through intuition, specifically to deal with complex situations.

I have therefore purposefully devised some activities within this course that will overwhelm those individuals who insist on an exclusively analytical approach. These activities will simply not be resolvable through analytical thought alone. What I do not want you to do when you encounter these activities is spend an excessive amount of time thinking things through and thus encounter what is commonly known as 'analysis paralysis'! The analytical solution to dealing with complexity is to focus on a narrower and narrower part of the problem i.e. going into greater and greater levels of detail. In systems thinking, however, you need to observe the 'big picture' before you can evaluate which particular components and relationships are important. So, please trust your intuition in the initial exploratory phases of investigating a complex situation. Don't close your mind prematurely to new information because your analytical side can no longer cope – allow new information to 'wash over you' without judgement. Absorb it subconsciously and open your mind to the **emergence** of spontaneous relationships.

For those of you interested in the power of intuition to resolve complex problems, I would heartily recommend reading *Blink: The Power of Thinking Without Thinking* by Malcolm Gladwell (2006) and/or *The Decisive Moment: How the Brain Makes Up its Mind* by Jonah Lehrer (2009).

Activity 1C: Carrying out an 'audit' of your multiple intelligences

In this activity you will explore your strengths and weaknesses with regards to various intelligences, and how these may influence the way you model reality.

Activity 3

First of all, you need to familiarise yourself with the various multiple intelligences outlined in Resource Reading 1.3. I would like you to do this by identifying examples of your own expression of these intelligences, and how you would rate yourself according to each of these faculties. Maybe you could develop a mathematical model by assigning a number between 1 (pretty lousy) and 10 (genius) for each of the eight intelligences. You could then create a visual model by drawing a 'radar' or 'spiderweb' diagram where all of the eight multiple intelligence axes meet at one central point and radiate outwards to resemble the spokes of a bicycle wheel. On each of these axes draw a scale of 1 to 10, mark your individual scores on each one of these axes and then join up the marks.

What does your 'wheel' look like? Is it a nice, large, well balanced shape? Or, are you in for a bumpy ride?

How do you think each of these intelligences affect the way you model the world verbally, visually and mathematically? Which intelligences are predominantly analytical, and which are based on intuition? Is there a correspondence between your cognitive style index and your multiple intelligence audit?

Answer

Most good educational institutions encourage their students to develop themselves in all of these intelligences. Indeed, Howard Gardner's Theory of Multiple Intelligences has been an inspiration to curricular development in many schools all over the world. Unfortunately, as we progress with our education, we are very soon encouraged to specialise within one of these intelligences, as illustrated by the examples I provide in Resource Reading 1.3. Most radar diagrams of multiple intelligence audits therefore end up lopsided and unbalanced. Yet, a systemic understanding of complex situations ought to include verbal, visual and mathematical models. Even musical intelligence can occasionally intuitively evoke visual imagery, and is frequently associated with kinaesthetic intelligence to reinforce the communication of a visual model, and/or linguistic intelligence to reinforce the communication of a verbal model.

It is therefore not surprising that many people feel extremely uncomfortable when engaging with systems thinking and practice for the first time. For all their adult lives, most people have been encouraged to specialise and become experts in the execution of particular skills and specific fields of knowledge. Systems thinking and practice goes directly against this trend, and instead encourages you to become a Jack-of-all-trades.

It might be particularly interesting for you to investigate further the score you gave yourself for 'naturalist intelligence'. There is a clear link between this intelligence and what Fritjof Capra calls 'ecological thinking':

> It is now becoming apparent that over emphasis on the scientific method and on rational, analytic thinking has led to attitudes that are profoundly anti-ecological. In truth, the understanding of ecosystems is hindered by the very nature of the rational mind. Rational thinking is linear, whereas ecological awareness arises from an intuition of non-linear systems. One of the most difficult things for people in our culture to understand is the fact that if you do something that is good, then more of the same will not necessarily be better. This, to me, is the essence of ecological thinking. Ecosystems sustain themselves in a dynamic balance based on cycles and fluctuations, which are non-linear processes. Linear enterprises, such as indefinite economic and technological growth – or, to give a more specific example, the storage of radioactive waste over enormous time spans – will necessarily interfere with the natural balance and, sooner or later, will cause severe damage.
>
> Capra (1982)

For most other intelligences I would recommend that people should seek others with alternative cognitive styles and intelligences in order to achieve a more balanced and potentially more comprehensive view of a complex situation. Of course, this goes against most people's instincts, which is to seek like minded people. This may indeed simplify the model of the complex situation you are engaging with, but it may not be a true reflection of the actual complex reality. However, when it comes to naturalist intelligence/ecological thinking, I would recommend that we all try our best to progress this intelligence – for personal well-being and that of humanity and planet Earth as a whole.

In systems thinking and practice we highlight the importance of judging where to place the **boundary** around your system of interest (which delineates the area that you actually wish to focus on when investigating a complex situation). Many investigations of complex situations, including systemic explorations, simply limit themselves to the natural or social realm, as typified by the classic division between the natural and social sciences. However, the perspective proposed in this course emphasises the interconnectedness between natural and social systems within all systemic investigations. Indeed, one could argue that social systems are a subset of natural systems. This is the main reason why you will be asked to calculate your personal ecological footprint in Activity 3C.

Ecological footprinting is increasingly being used to not only assess personal impact on natural systems, but also to reveal the impact of households, communities, organisations and nations as a whole. Of particular relevance to this section is the idea that getting into the habit of monitoring your ecological footprint beyond the requirements of any particular activity is one of the simplest steps that can be taken to increase your naturalist intelligence.

Activity 1D: Exploring your thinking traps

In this activity the aim is to reflect on how typical cognitive 'traps' may influence how you engage in complex situations.

Activity 4

Based on the insights gained from reading Resource Reading 1.7, rank each **thinking trap** in order of increasingly significant negative effects when it comes to engaging with complex situations. How do you think we can avoid falling into these traps?

Answer

As a response to this activity, I can outline several 'traps' that worried me when developing the learning design of this actual free course:

1. First of all, I acknowledge that my values and past experiences have had a fundamental influence on the material. Many teachers are able to distance themselves from their beliefs and seek alternative points of views and examples to include in their teaching. This is probably my greatest failing – I simply cannot bring myself to justify top-down reductionist approaches for engaging with complex situations, especially when it comes to managing our environment!

2. It was easy to get carried away in explaining particular concepts or developing particular activities, losing sight of the overall purpose. I estimate that almost half of what I wrote had to be scrapped or summarised, although this is not unusual when engaging with original work.
3. I was mostly able to avoid the trap of going along with a group's judgement, simply because there was limited group work when it came to the first design iteration of this free course! On the other hand, I have since had a lot of feedback from both students and tutors, and I have to confess that it has been difficult to differentiate between general concerns with the course's design, and those concerns that applied to a minority of a rather vociferous group of individuals.
4. But most significantly, the breadth of the topics that I cover (from ecology to politics to cognitive science to systems thinking, etc), the number of assets that I make use of (study guide, activities, printed Resource Book readings, audio-visual programmes, Diagramming Resource, discussion fora, etc.), and the variety of values, learning styles and experiences in society, meant that the number of things that I had to keep in mind very quickly escalated beyond the magical number seven (plus or minus two). This, therefore, required constant iteration through the material while attempting to look at it from different perspectives. The ultimate aim was to develop a coherent model of inter-relationships between activities, readings and other assets, and amongst participants. Yet, I could only manage to hold a few ideas in my head at any one time. I soon realised that I had created a free course that was in itself a complex system!

   The implication is that I will have to use a range of systems concepts and techniques to optimise this complex learning system over the long run. In fact, I am planning to constantly update and improve this course as a result of your feedback and new insights gained from my scholarship. This iterative approach is, in essence, a constant 'learning process' of observations, evaluations, plans and actions. **Cybernetic optimisation**, a key concept behind the feedback relationship so apparent in the learning process, is one of the most powerful tools we have available for understanding complex situations, and you will be learning more about this process, and associated concepts such as the **feedback loop**, as you progress through this course.

Conclusion

This free course provided an introduction to studying Environment & Development. It took you through a series of exercises designed to develop your approach to study and learning at a distance, and helped to improve your confidence as an independent learner.

Glossary

action learning
: The process of undertaking the steps of planning, acting, observing and evaluating in order to understand and engage with a complex situation.

actuator
: In the control model, the part of the system that can effect a change.

analysis
: A method of understanding something by dividing it into parts and making sense of the parts.

attributes
: The properties of a thing that identify and characterise it.

balancing feedback
: Feedback that dampens change. Also referred to as ‘negative feedback’.

boundary
: The line or region which distinguishes what is in a system from the wider environment around it.

capabilities
: The capacity of an element of a system to affect the wider system.

change
: Modification of system structure and/or processes.

channel
: In the Shannon–Weaver model of communication – the medium or link through which a message is sent.

chaos
: A situation which shows no predictable pattern of organisation and/or behaviour.

closed system experiment
: Where an experimental system has to function without any exchange of energy, matter and information with its environment.

communication
: The exchange of meaningful information – an important mode of learning in humans, through which experiences can be widely shared.

communication structures
: The organisation of communication channels, such as the organisational chart in a company.

comparator

In the control model, a comparator compares the output of a process against a goal such as an indicator.

concept

A coherent idea abstracted from practical situations.

control

Control refers to the function of a system which regulates its outputs or maintains it within certain bounded behaviour. Control can arise from within or without a system.

culture

The explicit and implicit social rules that shape the way people behave.

cybernetic optimisation

Action by a system initiated in order to achieve a particular goal which causes some change in the environment towards achieving that goal. The change in the environment is fed back to the system via information/energy/material flows which in turn changes the way the system then behaves: stronger action if the goal has not been achieved; or the cessation of action if the goal has been achieved.

cybernetics

The science of control from the Greek word for the steersman of a ship.

delays

Where the feedback in a system takes a significant time to reappear as an input. This can have a profound affect on the dynamics of the system.

diagramming

A formal approach to visual modelling using a range of techniques for exploring the organisation of information in two dimensions, e.g. on paper or on a computer screen.

difficulty

Bounded problem with a limited timescale, clear priorities, limited applications. It can be treated as a separate matter, with a limited number of people involved who know what needs to be done, know what the problem is and know what a solution would be (contrasted with **mess**).

diversity

A measure of the degree of differences between things – for example the number of different species in an ecosystem, or the different types of businesses that a pension fund has invested in.

ecology

The study of the relationship amongst living organisms and between these and their environment.

ecosystem

The organisation of species and their surrounding environment into a self-sustaining whole.

eight intelligences

Howard Gardner's theory that there are eight different ways in which people develop, communicate and put into practice their understandings.

emergence

Higher-level properties emerge from systems of lower-level components in such a way that the high-level properties could not be predicted from knowledge of the components in isolation.

environment

In systems terms, this refers to those factors outside of a system with which it interacts or which affect how it operates.

environmental footprint

The impact of something (such as a person, a city or a sports event) on its environment. Subcategories of an environmental footprint include ecological, water and carbon footprints.

epistemology

A study of the way we know what we know (how knowledge arises out of a combination of beliefs and facts), its history and its limits.

equifinality

When a system always ends up in a single final state, whatever its starting point.

equilibrium

When system components do not show any apparent change in quality and quantity.

extinction

The permanent and irreversible disappearance of a lifeform.

feedback loop

Where an input of a system is affected by one of its outputs – for example in communication when communicating with someone who is communicating back.

flows of energy, matter and information

This refers to the way that systems interact with their environment and amongst its components – for example a system could be closed in terms of matter, but open in terms of energy. Some components provide other components with energy, matter and/or information.

group think

The tendency for individuals to fall in with the thinking of those with whom they are closely associated, even if they might individually disagree.

hard complexity

Complexity that arises from the dynamics of a situation, where the presence of large numbers of feedback loops and/or **variables** makes prediction difficult.

hierarchy

The nested nature of systems: systems encompass **subsystems** while simultaneously being part of **supra-systems**.

homeostasis

The dynamic equilibrium through which living systems maintain the conditions for their ongoing existence.

indicator

A characteristic of a system which is used as a measure for control.

information

Matter and/or energy which is not of direct use by a living organism apart from having the potential to change the organism's behaviour – for example, the triggering of moths' reproductive behaviour resulting from a full moon.

information and communication technologies

Technologies that allow the recording, storage or sharing of information.

input–process–output

A process-based way of looking at what a system is, concerned with defining a system by what it does rather than the objects it is constituted from.

interdependence

The way that different system components (such as organisms in an ecosystem) play roles that supports other components which in turn support themselves.

internalised model

A model developed by a living system in order for it to cope with its environment without constantly sensing it. It may only be detectable implicitly through the living system's behaviour.

interpersonal intelligence

The ability to empathise with others by recognising their intentions, motivations and desires. Professions which require a high level of this intelligence include educators, psychologists and politicians.

intrapersonal intelligence

The ability to recognise one's own intentions, motivations and desires. Professions which require a high level of this intelligence include poets and artists.

kinaesthetic intelligence

The ability to coordinate one's movements. Individuals which require high levels of this intelligence include athletes, craftspeople, musicians, dancers, surgeons and painters.

learning

The capacity to change or create internalised models in response to experience.

learning cycle

A sequence of steps that describe the different aspects of learning. There are a number of different types of learning cycle, such as Kolb's learning cycle. Many of them feature observation, evaluation, planning and action, or their equivalents.

linear sequential thinking

Thinking based on a precise sequence of information that goes into greater and greater detail.

linguistic intelligence

The ability to use a coherent narrative to communicate and organise thoughts. Professions which require a high level of this intelligence include lawyers, writers and actors.

logical–mathematical intelligence

The ability to investigate issues deductively and recognise/work with numerical patterns. Professions which require a high level of it this intelligence include software programmers, engineers and scientists.

mathematical communication

Mathematical communication uses quantification (numbers and functions) to share or highlight experience.

mathematical models

Models where the essential dynamics of a situation are represented through numbers and mathematical patterns.

mental models

Essentially the same as internalised models, but referring specifically to humans.

mess

Unbounded problems or sets of problems with: a longer, uncertain timescale; priorities which are called into question; uncertain, but greater implications. It can't be disentangled from its context, and more people are involved who don't know what needs to be known, who aren't sure what the problem is, and don't see 'solutions' (contrasted with difficulty).

metaphor

The use of an unrelated word or phrase to represent and model another object or situation. For example, the term 'war on terror' depicts the process of addressing a particular criminal activity as a military intervention.

model

A simplified representation of reality which has a purpose.

Modes

(of delivery) Medium or type of communication.

multiple intelligences

The idea that there is more than one way of solving problems – for example right and left brain thinking or Gardner's eight intelligences (linguistic/logical-mathematical/musical/kinaesthetic/spatial/interpersonal/intra personal/naturalist-ecological).

musical intelligence

The ability to recognise pitches, tones, rhythms and compose these into recognisable patterns. Professions which require a high level of this intelligence include composers and musicians.

naturalist intelligence

The ability to appreciate ecological **interdependence**, including the nested nature of our society within the greater Earth system.

negative feedback

Feedback which operates to reinforce **stability**. Also called balancing feedback.

network

The organisation of components as a system which facilitates the flow of information, matter and/or energy.

object

A discrete entity, or one that is perceived to be so. Used to categorise **flows of energy, matter and information**. This is especially relevant when these manifest levels of structural and/or process stability. For example, a stone or a flame can be objectified because their material composition, energy levels and capacity to convey information are stable enough over time for categorisation.

open systems

A system which exchanges energy, matter or information with its environment.

oral communication

Verbal communication through sound.

organism

A living system with a distinct boundary which distinguishes it from its environment.

overshoot

The point where one or more of a system's components are using resources over the rate by which these can be replenished. The inevitable consequence of overshoot is the collapse of the component(s), and the potential collapse of the system as a whole if at least one particular component is playing a vital role in system processes.

positive feedback

Positive feedback reinforces change.

process

The way in which information, matter and/or energy flows through, and are modified by, a system's components.

purpose

An anticipated outcome that directs system structure and processes.

quality of life

Quality of life indicators widen attention beyond monetary wealth to health and happiness.

quantitative (mathematical) models

Models where the essential dynamics of a situation are represented through numbers and mathematical patterns.

rates

The measures of changing system component quantity or quality relative to time.

receiver

The means by which communication is received.

reductionist thinking

Thinking based on the idea that a thing can be characterised by the attributes of its components.

redundancy

Multiple complementary components or functions such that removing one instance does not result in system failure because the others can keep going. For example, the removal of one kidney out of the two will still allow the individual to continue a healthy life.

regulating

Taking control of something.

relational logic

Reasoning based in the relationships between things which are disciplined, rule-bound and repeatable so that decisions are defendable and explainable.

relationship

Interaction between components within a system.

resilient

Able to cope with stresses and shocks by recovering readily.

resistant

Able to cope with stresses and shocks by not being affected much in the first place.

roles

The typical functions that system components carry out - for example a species in an ecosystem.

selective perception

A phenomenon where people pay attention to things they are familiar with or to evidence that supports views they already hold.

sensors

The means to detect signals or a change in state. In the control model, a sensor monitors the outputs of a process.

shared models

A common interpretation that enables effective communication.

sign graph diagrams

A diagram that represents the operation of causality in a system's dynamics.

simplification

A model is a simplification of reality that does not pay attention to all the aspects of a situation, but is relevant to understanding and engaging with the situation.

soft complexity

Complexity that arises from a lack of certain information about a situation – for example when there are intractable differences in the way that a situation is perceived by those involved in it.

spatial intelligence

The ability to recognise visual patterns and relationships. Professions which require a high level of this intelligence include artists, designers, and taxi drivers.

stability

Unchanging system structure and/or processes, usually applied in situations where the system's environment is changing.

status

A measure of a system, its structure, processes and/or components with the aim of identifying change or stability.

stocks

In a model, a quantity of something that can increase or decrease.

subsystems

Components of a system, which are themselves systems.

supra-systems

The systems within which your particular system of interest is nested within.

survival of the fittest

Continuation of a particular component within a system which through competition and cooperation can access enough resources to maintain itself or replicants of it, while other components become extinct through lack of resources.

synthesis

Trying to understand something by considering its relationship to other things. Also the process of making a whole out of parts.

system dynamics

The study of the patterns of feedback in complex systems.

system dynamics diagrams

A **diagramming** methodology used in **system dynamics** modelling.

system performance

A comparison between the behaviour of a system as detected through an indicator and what is expected.

systems

An interconnected and interdependent set of components with coherent organisation, often characterised by nested subsystems, emergent properties, communication, and control which is dynamic, adaptive and self-preserving.

systems thinking

A style of thinking that balances rational and intuitive, synthetic and analytic, thinking.

technique

Standardised and formal approaches for executing certain tasks.

thinking trap

A learned and/or biological limitation in the way that we model and act in the world which does not result in the best outcome for addressing a particular problem.

tipping point

This is where small changes within a system result in no notifiable overall change until a certain threshold is reached, after which the system changes radically, and sometimes, irreversibly. A simple example of a tipping point is the boiling of water – very little happens as the water temperature rises, but once the 100°C threshold is reached, there is a sudden transformation of liquid water into vapour.

transmitter

The means by which communication is sent.

unit of measurement

A standard measure in which something is quantified.

variables

Independent and distinct factors which influence the rate of change of a stock's level as represented through a system dynamics diagram.

verbal models

Models where a situation is described in written or spoken words.

viability

The capacity for ongoing existence.

visual communication

Visual communication uses two-dimensional pictures, three-dimensional objects and spatial representations to communicate experience.

visual models

Two or three dimensional forms where a situation is described through graphical symbols and spatial relationships.

written communication

Written communication uses written words to communicate experience.

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