How to Invent (Almost) Anything

David Straker and
Graham Rawlinson

How To Invent (Almost) Anything

Serious Innovation
using
Science and Psychology

by

David Straker and Graham Rawlinson

Formatted in Times New Roman and Arial by David Straker

Cover illustration by Heledd Straker

Contents

Preface

When you open a door you usually have some notion of what may lie behind it. You also have some intent in opening the door. Now you have opened this book, do you know why are you here? As authors we do not know your particular journey, so all we can do is to paint a picture of the rooms you are about to explore.

Some of the rooms in this book are quiet places where you can sit and relax, just taking in what you see, reflecting on it and pondering the meaning you find there. These are the reading rooms where you can learn about what goes on in our heads when we are trying to be creative, or the basic principles of science. There is no examination at the end, so take from them what you will and do not worry. Browse, pick up, put down, let your thoughts wander. If you put energy into challenging what we suggest then make it fun so you have more energy after the challenge than before. Do not waste your energy in fighting ghosts!

Some of the rooms are activity rooms. They have a different pace, a get-up-and-*do* pace. Do not go into these rooms unless you want to do something. Enter them only if you are safe from interruptions–you will not want to break away from an ideas session just at the point of that brilliant notion. Have things to record your activity, whether it is big sheets of paper or a tape recorder or even a video camera. Do not be embarrassed about taping your thoughts. This may seem crazy but it provides great material for reflection, learning and the next groundbreaking ideas.

We have all created many exciting ideas in our heads, and at the eureka point of discovery we thought that this was it! But in the cold light of the next dawn the glamour and glee may have faded, leaving ordinary-seeming ideas that die in the still glare of cold criticism.

Inventing is not just about the *thing* you invent; it is about passion, about excitement, about commitment. When you are doing your inventing, if you can see and steer your own internal state, creating and fuelling your own passion, you will find that you have the sustainable energy that is necessary to drive those ideas through from conception to completion.

To be a great inventor, you must thus be both a scientist and a psychologist, engineering both the world around you and the world within. This book supports this cause by painting its rooms from the deep blue of human and scientific understanding to the vermillion hues of action, challenge and excitement.

Inventing is like love. You can read about it, or you can do it–and there is a big difference between the two. Doing involves chase, teasing, courage, confusion, persistence, excitement and passion. And the more you do it the more you learn and the better you become. So–enter here the brave and determined. Choose a future that is full of stimulation, passion and invention. And most of all, Have fun!

Graham and Dave

Toolbox 1: Logical

Creativity and logic sometimes seem to be at the opposite ends of the spectrum. Far from it--logic is the first tool of all inventors. Many inventive and creative problems have been solved by cold, hard analysis and thinking. You do not always have to daydream and get into the fluffy stuff to solve every problem (although this does become necessary for those problems which do not succumb to the logical approach).

1 Analytical Invention

When we started to write this book, we began in the deep theory, but on reviewing it concluded that it would be more helpful to begin with something more immediately useful. If you read no further than this chapter and then go and apply the methods described here, you should be able to invent with the same approach as many great engineers and inventors of the past (although we hope you read on, of course, increasing your skills still further).

There is a whole range of approaches that can be used to create new ideas, ranging from a structured, analytical approach to softer, more conceptual methods. For many inventions, the analytical methods, though simple, are very effective and this is where we will start.

The basis of analytical invention is very simple. First, you decompose, breaking things down into manageable pieces and then you and examine, question and consequently improve the individual parts.

Decomposition

A standard scientific and engineering approach to problems is to decompose the item in question into smaller elements which can be dealt with on an individual basis. This general principle gives rise to a number of methods which are described below.

Chunking

The brain understands things in distinct chunks (see Chapter 8), building large chunks out of smaller chunks. Thus a tree is made from leaves, twigs and branches. We can use this principle of hierarchical analysis to understand many inventive situations.

The simplest method of chunking is to break things down into their individual parts, thus a keyboard may be broken down into keys, casing and connector, with the connector breaking down into sheath, screw, and pin assembly, and so on. The inventive eye can then be focused on very specific aspects, such as the force required to push the pins into the sockets or the ease with which the connector casing can be grasped.

We can also chunk up, looking at the big picture. This is particularly useful in the early stages of invention when you are asking questions like, ‘what is the *real* problem here?’ As you chunk up further, you will get to more general, broader areas. You can also then chunk back down through different branches to discover new areas of focus. For example, in Fig. 1.1, we chunk up from supporting a tent to the general problem of support, and then back down to specific alternative ways of providing support.

A trick of chunking is in the questions you ask as you chunk up or down. By changing the questions, you will discover different things. A simple alternative is shown in Fig.1.1, where you chunk down by asking ‘how’ and chunk up by asking ‘why’. You could also ask ‘What is the benefit of doing this?’ to chunk down, and ‘What problems are solved by doing this?’ to chunk up.

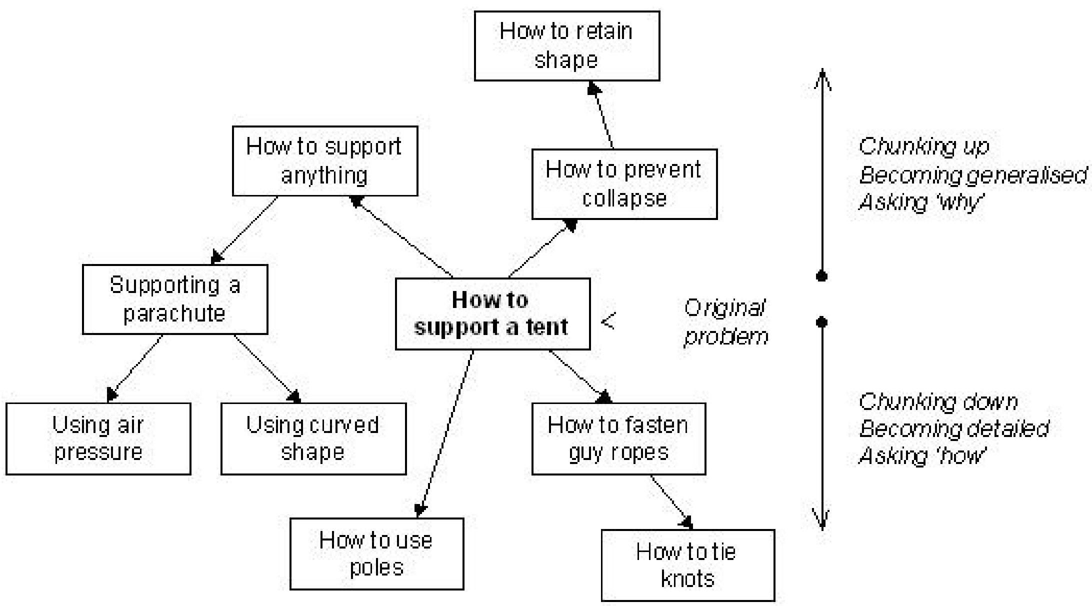


Fig. 1.1 Chunking

Chunking is a valuable technique around social or other intangible areas where you can get into more detail by asking such questions as ‘What, specifically?’ or ‘How does that happen?’ Thus Federal Express found its famous ‘Hub and spokes’ strategy by chunking up to look at the bigger picture and the overall purpose, then finding an alternative approach followed by chunking down in the details of how this might work.

Attribute Analysis

If you are looking at a chair and have chunked down to the legs, the next level of detail may be found by examining the *attributes* of the chair legs. These may include simple, measurable factors such as length, thickness and density. More complex attributes may also be considered, such as shape, connection method and load-bearing characteristics. You could even look at the aesthetic attributes, including texture, colour and attractiveness.

When you have identified attributes of interest, you can then find the values that the attributes can have, and then decide how you might change these. Some can be changed continuously, such as the thickness of a chair leg, whilst others are changed in discrete chunks, such as the use of either hardwood or metal for the legs.

When you are inventing for a particular marketplace, Attribute Analysis can be used in combination with other techniques, such as Customer Needs Analysis, to discover which attributes are particularly important (and hence where people would be prepared pay more).

Fig 1.2 shows how you can break down a problem area into parts, attributes and potential values which you can then change.

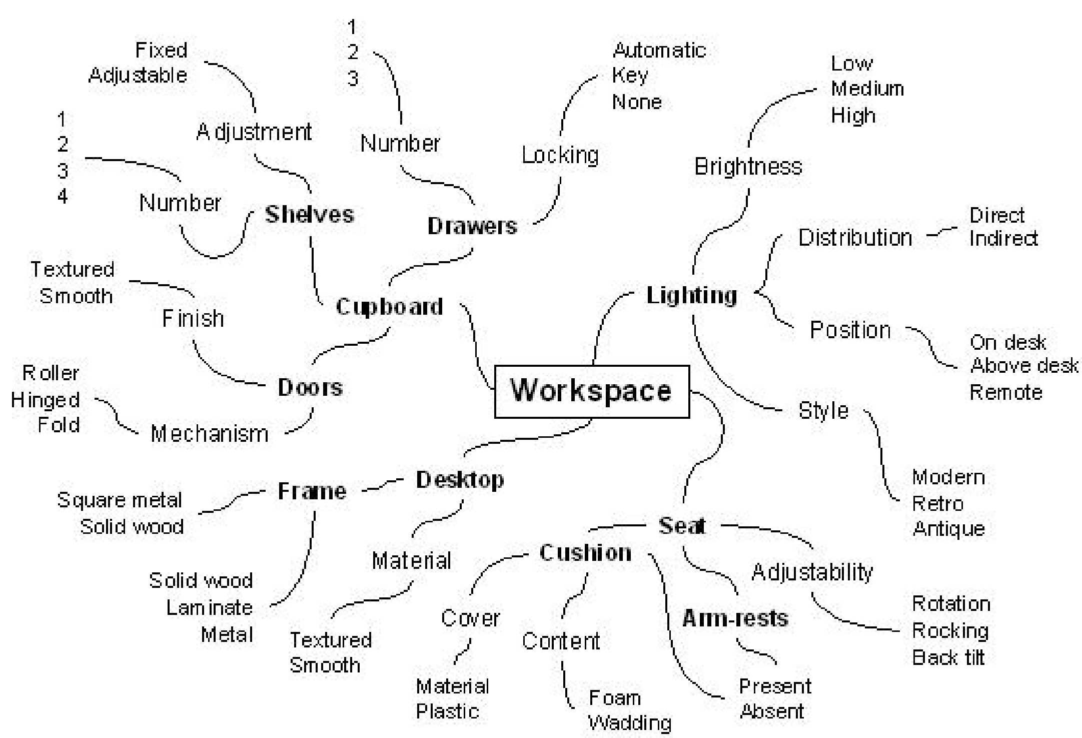


Fig. 1.2 Breakdown to find attributes and values

Service industries have many intangible attributes, and it could be said that this is virtually all that you have with which to invent. Deliveries have timescales and reliability, customers have satisfaction and loyalty, processes have cost and capability.

Value Analysis

Value Analysis is an established part of the discipline of Value Engineering that is founded on the principle that when you use or make something, it should add clear value, and that the value created should be greater than the cost incurred. As Fig. 1.3 indicates, this can be done through identifying components and their cost, then comparing this with the functions they perform and the value thus created. For example, a volume control on a radio performs the function of changing the level of sound. Although quite cheap, it adds useful value.

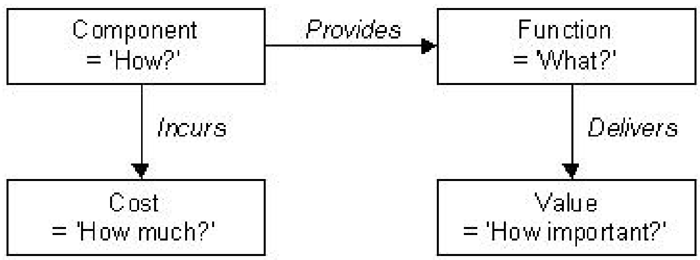


Fig. 1.3 Decrease the cost or increase the value

The general principle of value is a simple ‘return on investment’ idea. People will spend money on things that they think are worth it. These ‘people’ include those who invest in the company (and to whom lower production cost is of value) and end customers, to whom functions of the product or service you offer provides distinct value.

The first step of Value Analysis of a component is to identify the primary functions of a selected component. These may be either *use* or *aesthetic* functions and can often be identified by asking ‘What is the customer actually paying for?’ For example, a coat has a use function of ‘keep me warm’ and an aesthetic function of ‘make me look attractive’.

Secondary functions may then be discovered which support the primary functions. For example, secondary functions that support the ‘attractive’ aesthetic function may include shape, colour, and so on.

Further breakdown can then reveal the parts of the product, the processes that create them and the costs incurred in each, consequently enabling you to question and improve any of these, as in Fig. 1.4.

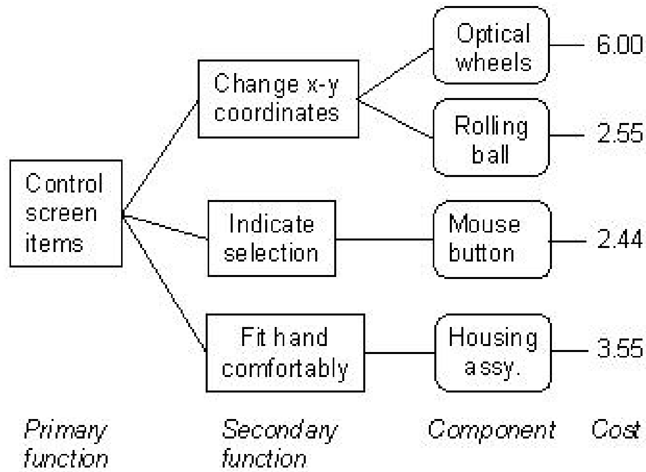


Fig. 1.4 Partial functional breakdown of computer mouse

Value Analysis aims to make visible that which is often intangible, which makes it a very useful technique for use in service and other people-oriented situations where value is particularly key and aesthetic functions may be as important as use functions.

Questioning

Once a problem situation has been decomposed into various constituent elements, questioning provides a way of discovering and challenging the deeper and unwritten detail. Questioning is also useful before or without decomposition, to expose assumptions and elements that have not been considered.

Purpose Analysis

A good question to ask when investigating a device or system of any sort is ‘What is it for? What function does it perform?’ This may seem an easy question but it can be surprisingly difficult to answer.

For example, if we ask ‘What is the function of a light switch?’ you might answer ‘To turn the light on and off.’ But this does not really give much of a clue to enable a creative spotlight to be turned on improving the light switch. We could chunk in and answer ‘to make an electrical connection’ which might lead us to electronic switching. We can also ask more radical questions such as ‘What if we did not have a light switch, leaving the light permanently on?’ It would run up the electricity bill, so an alternative purpose might be ‘To save electricity’. This could lead us towards dimmers or people detectors that automatically turn off the lights when nobody is there (who needs a switch?).

We can also ask the question ‘Why?’ when inventing around intangible situations, where the lack of a physical item can make the original purpose even more difficult to identify. What is the most fundamental purpose of the fire service, business consultancies or journalism?

Causal breakdown: the Cause-Effect Diagram

The most basic questions that can be asked around inventions are those often asked by children. ‘Why does that happen’ investigates causes (remember how we are particularly interested in causes because it allows us to forecast). If we ask ‘How can we do this’ we are also investigating cause: we now want to know *how* to cause something.

Many inventions are around causality. For example, the umbrella causes rain to be deflected from the person underneath. It also has undesirable effects, for example causing the person holding the umbrella to have tired arms, or that the ribs of the umbrella strike and hurt people nearby. By understanding causes, we can invent ways to cause desirable effects and prevent undesirable effects (and it can be argued that this is all that invention is about).

A simple method of drawing out causes is the Cause-Effect diagram, also known as the Ishikawa diagram (after its inventor) or the Fishbone diagram. In essence, it simply involves chunking down, not into parts but into causes. The desired or undesired effect is placed in a box to the right, major aspects of the situation form the major ‘ribs’, then causes are added by asking ‘how or why might that happen?’ You can then select one or more causes on which to work.

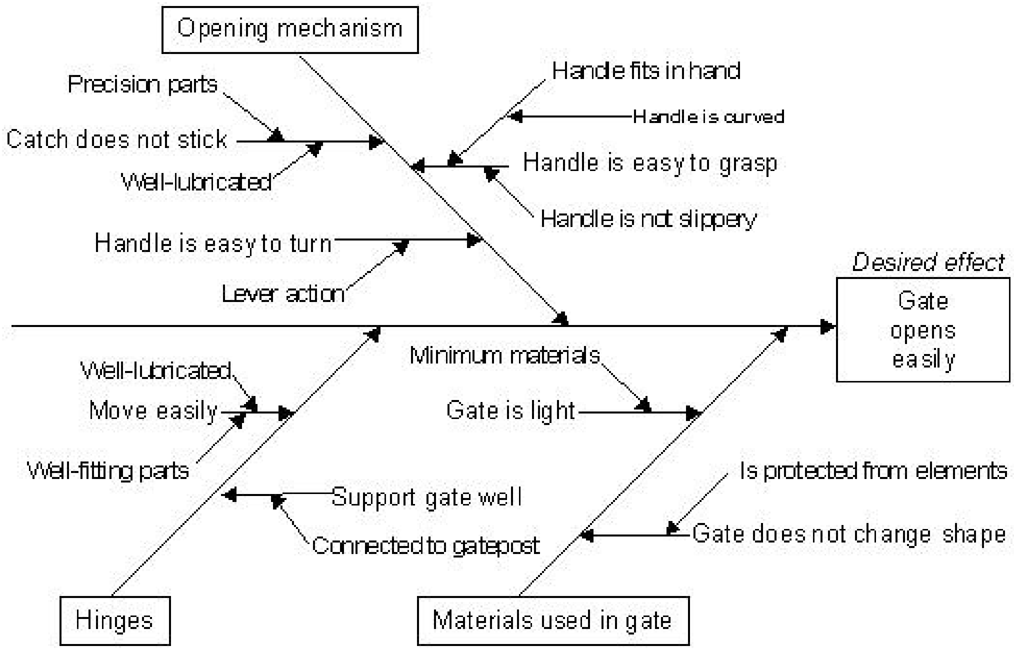


Fig. 1.5 Cause-effect diagram for desired cause

In the intangible area of social invention a Cause-Effect Diagram for investigating the breakdown of marriages might have areas such as ‘relatives’, ‘work’ and ‘relationship’ and could lead to such ideas as whole-family counselling or spouse-days at work.

Root Cause Analysis / Five Whys

When seeking causes of a problem, addressing the first cause you find does not necessarily lead to an effective solution. For example, when a medical plaster does not stick well to skin, asking ‘why’ may reveal that the adhesive does not bond well to sweaty skin. Telling people to dry their skin will work, but it will not lead to an invention for plasters that stick even to damp skin. To do this requires a deeper understanding of causes.

If you have young children, you will know that when they repeatedly ask you ‘why’, they can force you to think about real detail. In root cause analysis, we keep asking ‘why’ or otherwise seeking causes of causes to get to the heart of the true problem, so we are addressing the real cause, not just a symptom. If you do this five times (hence the name ‘five whys’) you will very likely get to the root cause along the way. Chaining arrows, as in the cause-effect diagram, can be a useful way of making these relationships visible.

Causal Chains: sequences of events

Causes do not always work in hierarchies and sometimes it is more useful to explore how things cause one another in chains and loops. Notice how Fig. 1.6 tells the story of the thinking around the problem: for a rigid gate, we could use metal, but that is heavy, so what if we put holes in it? Wire mesh is too floppy. Wrought iron would do this, but it is high cost. However, we could achieve the rigidity with a simple metal frame, with a plastic imitation 'wrought iron' effect.

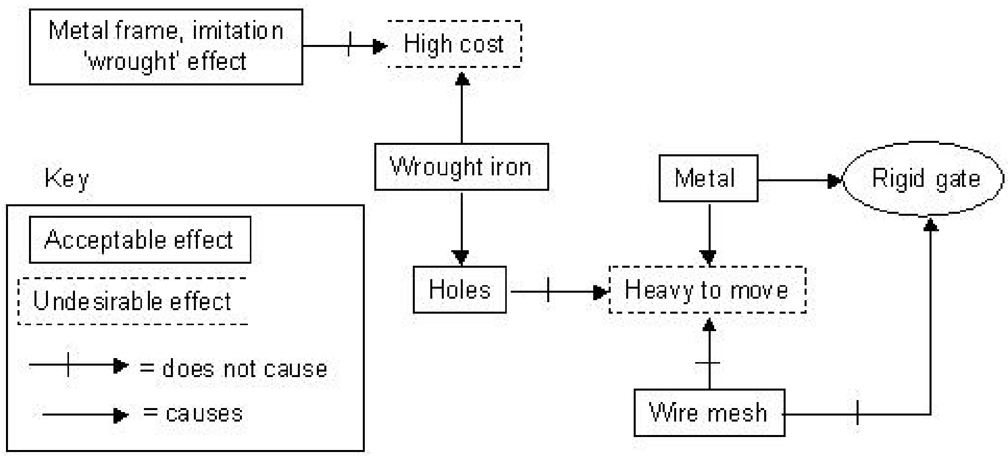


Fig. 1.6 Causal chain

Beyond causes, we can use further questioning to identify alternative solutions to our problems.

Critical Thinking

Critical Thinking is a general school of thinking that goes back to Socrates, Thomas Aquinas and Descartes. Its basic tenet is to think rigorously about any given topic (and its dread enemy is sloppy thinking).

To use critical thinking, consider the clarity, accuracy, relevance, depth, breadth and rationality of any arguments. Also understand the different viewpoints that may be taken, and how each may result in a different interpretation, based on different assumptions, concepts, goals and other information.

With critical thinking, you should discover and challenge all suppositions and test all arguments and conclusions. You should thus 'leave no stone unturned'. The inner critic that can be an enemy of a 'soft creative type' is the friend and mentor of the critical thinker (which is a strange paradox, as both can come up with creative and practical ideas).

Some of the questions you can ask in critical thinking include:

- What is your objective? What are you really trying to achieve?
- From what viewpoint are you considering the situation?
- On what information are you basing decisions? Where did this information come from?
- How clearly factual is the information? All of it?
- How logically are you analysing and arguing?
- What are the scientific bases? How soundly are they proven?
- What concepts are you using? How valid are they?
- What are the underlying assumptions? What are the implications of using them?

Bionics (also called biomimetics or biomechanics)

Nature has already solved a lot of problems through years of evolution and you can steal from this hoard of inventions by finding the principle behind your problem then asking where and how nature might have solved it. For example, solve optical problems by looking at the eye; for camouflage look at the colouring of many animals; if you have a cooling problem, look at rabbit's ears or sweat glands.

Nature has also solved many social problems—just look at the number of marital arrangements out there, ranging from lions, with a single male and many working females, to spiders where the make 'coming for dinner' has a whole new meaning. Whatever your problem, try asking 'What natural situations are like this?' and ' How has nature solved this?'

Constraints of invention

When both nature and people are inventing, we each need to make something which *works*, resulting in a form which fulfils a useful purpose. Buildings and other structures should withstand the weather and other external forces on them. There should be enough energy to complete the task.

However, there are always constraints. Nature has an amazing range of materials available and medicines are still being created from newly discovered Amazonian plants, but it is still constrained in the biological formation of fibrous and calciferous materials. Our harnessing of energy has allowed us to smelt metals, crack oil and otherwise generate a staggering number of materials, all with different and interesting properties that we can use in our inventions, but we still have constraints.

Human invention constraints are often around cost, either direct material cost or around factors such as time and ease of manufacture. Nature has, literally, all the time in the world; we are constrained by market windows. Nature's factories are biological and growth-oriented, resulting in irregular shapes. Ours are mostly constrained by machines and assembly, resulting in rigid, regular shapes. Financial cost is a human invention: nature's costs are only in the trade-offs between big and small, hard or soft.

One of our challenges, then, is to extend our invention skills to reducing time, costs and manufacturing methods. We can use nature as a source of inspiration, but also must recognise that it also has constraints, and when we copy it, we should seek only what it can give, and not be held back by its limitations.

5W1H

A simple set of questions that may be used in many circumstances is: Why? What? Where? When? Who? How? This may seem trivial, but they can be very powerful in the right hands. For example, when designing a new style of bookcase, ask:

- Why is it needed? *To keep books upright.*
- What does it do? *Apply pressure to sides of books.*
- Where is the pressure applied? *To end books only.*
- When is pressure applied? *When the bookshelf is full.*
- How can pressure be applied all of the time? *With long-travel, spring-loaded book ends.*
- Who can make these? *A spring-design company. There is one down the road.*

SCAMPER

This acronym comes from a revision by Robert Eberle in 1972 of list drawn up by brainstorming originator Alex Osborn to help stimulate new ideas. The letters stand for:

- Substitute?
- Combine?
- Adapt?
- Modify?
- Put to other uses?
- Eliminate?
- Rearrange?

These gives a wide range of alternatives and you can substitute for people, places, units, materials, processes, methods or purposes. For example, if you wanted to improve on a bicycle seat, you could substitute foam for the springs or rain-resistant materials for the seat.

Combinations of people, places, units, materials, processes, methods or purposes can be used. Maybe the bicycle seat could be combined with the pedals, so rocking of the body contributes to forward motion.

In adaptation you can copy from other ideas, nature, people or principles. Perhaps you could adapt an armchair for the bicycle so you could ride in comfort.

Modification can change size, speed, frequency, smell, position, weight, number, or any other variable. You can magnify to see the detail or enlarge, or minify to reduce, streamline or make small. Perhaps with a minimal seat, the bicycle rider would suffer less chafing of the thighs.

You can eliminate parts of the problem or the solution, time, effort, costs. What if there was no bicycle seat? For a sprint-racing cycle, this could save weight. If the seat were a part of the frame, you could eliminate manufacturing time and cost.

Rearrangement can be done with parts and patterns, time sequence or speed. Perhaps you put the seat on before you got on the bicycle, incorporating a snugly fitting seat into a pair of racing shorts.

You can combine any or all of these. For example, when redesigning a lighting display, you could:

- Substitute glass with plastic
- Combine the socket with the filter
- Adapt it to fit a range of fluorescent lamps
- Modify the shape to expand with lamp length
- Put the lamp to another use, such as providing local heating
- Eliminate visible cabling

- Rearrange the layout to fit the switch into a hidden handle

Verbs

SCAMPER is only a small set of ways to change things. You can easily find other ways to change, by selecting any number of verbs which modify the problem in some way. For example: stretch, heat, melt, grate, cut, erode, show, hide, shake, flatten, grind, carve, compress, simplify, reduce, revise, attack, paint, smell, soften, wrap, throw, *etc*.

Taking one of these, say ‘reduce’ and a problem such as ‘how to stop my coffee from spilling’, could lead to a cup with a reduced opening or putting less coffee in the mug.

SCAMPER and verb modifiers can also be applied to intangible invention. For example, Dell’s strategic invention of selling computers direct to the public could have been found by using the ‘Eliminate’ question on a picture of the standard industry supply-chain process.

Part A: Simple Science

Simple science? What is that? For many people, science is a far-from-simple anathema whilst for others it is akin to a religion, where your grasp of arcane concepts determines your place in the hierarchy. But the basics of much useful science are not difficult and a simple view can get you a long way.

Science is full of rules that say ‘you can do this but you cannot do that.’ In inventing, we do not like the word ‘cannot’, so our look at science is more about taking oblique, irreverent and sometimes downright unscientific views on it.

But why? Should we not use science as it is? After all, many great minds have worked for many years on giving us a sound set of rules. The answer is yes and no. Yes, science is extremely useful but, as we shall say again, you do not have to be a scientist to invent things with science. And furthermore, blindly accepting what you are given is not a sound basis for inventing new futures for the world.

Consequently, the next three chapters are about looking at science and thinking differently. We start with some simple fundamentals and then take an unusual peek at a scientific principle (friction) before attacking some everyday odds and ends from a ‘simple science’ point of view.

2 Simple Science

To invent physical things, it is helpful to know a little bit of science. Only a little bit? It would be reasonable to assume that that invention requires knowledge which is at the cutting edge of scientific advances or is at least degree-level. Occasionally this is true, but for many very useful and valuable inventions, it is not. In fact many great inventions were created by people who were working outside their original domain of knowledge. The experts in the field would have complained that these people were not *real* scientists and that they were probably not even practising *real* science.

Although some scientists would like you to believe otherwise, science is really quite a simple thing, especially if we start from the basic stuff. Going back to first principles gives us a number of advantages. Firstly, by being able to step back from existing bodies of knowledge, we can avoid being trapped by them. Secondly, the deeper level of understanding that working with fundamentals gives us enables us to invent on a more subtle and pervasive level. Last, but not least, basic science is easier to understand than the many complexities that have been built on top of it. Keeping it simple enables you to ask similar simple questions for many different situations. And simple questions are often the stimulus for new thinking.

So if you are a scientist, be prepared to forget some of your training. Unlearning can be more difficult than learning, but it is often very helpful to be able to look at things with fresh eyes. Inspiration can be found all around us, and nature is a rich, though not infinite source. We will be considering some of nature’s ideas and limitations in some of the sections below.

What is science?

A lot of science is presented as being about numbers. How strong is this bar of metal? How far away is this planet? How fast is the car going? Of course, numbers are important when you make something, because the parts need to be of the right size, strength and weight and so on, but numbers are not very helpful in the early stages of inventing.

To invent, it is best to put the idea of numbers to one side (which should please those who like science but hate the mathematics!) If you have a good, inventive design then it is surprisingly easy to find someone who can do the numbers for you, unless it is extremely complex or very, very new science.

Facts are also things you might want to park somewhere. Scientific facts are used to constrain and restrain, saying why you should not be doing things. Scientific facts define the boundaries, the limits of a system of knowledge. To invent, you must go beyond limits and shatter existing assumptions. This is simple science.

For inventing it is best to think of science as a process of asking questions. As the great physicist Niels Bohr said, “Everything I utter must be understood not as an affirmation but as a question.” To ask a question, think carefully about the models, theories, frameworks or patterns you are using to understand both the current problem and the potential solution, then question any and all of these. Questioning highlights what you do not know, and what you do not know is an opportunity, waiting for discovery and invention.

Science can also be viewed as simply being about identifying the patterns in the universe and codifying these into models and equations. If you can see patterns that nobody else has seen, you have invented a new science! Tools for inventing are process tools for working with patterns. These process tools provide individual activities and whole phases of action you can use to go from an initial idea to a complete invention.

Although tools are very useful, the best scientists do not let their process tools get in the way of open enquiry as they use both structured and unstructured methods of investigation and development. When they see potential winning patterns, then like chess grandmasters, they redouble their efforts to find even better patterns.

At its most simple level, science can be viewed in terms of *energy (including forces), matter, space* and *time*. In this chapter, we will look at these factors and start to think about how they can be used in inventing.

Science and energy

At the most basic level of science, there is energy, which we can either store or use. The most fundamental storage of energy is matter, as Einstein identified in his famous equation $E=mc^2$, where E is energy, m is mass and c is the speed of light. It does not take much material to create a very big bang. Energy moves through a medium (such as magnetic or electric fields) in waves.

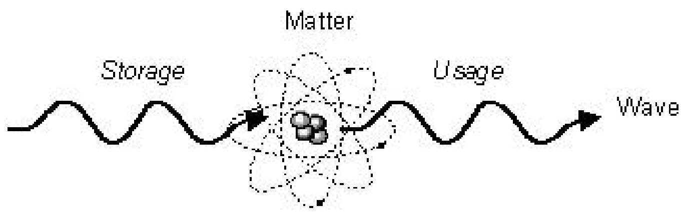


Fig. 2.1 Energy storage and use by wave-matter conversion

We can also store energy by position, such as the potential energy gained when I put a can on a shelf. Energy can be stored as a potential where there are fundamental forces that attract or repel objects, as in Figure 2.2. The attraction that holds the can on the shelf is, of course, between the earth and the can. The energy is stored in the distortion of the gravitational field.

This ‘potential’ stored energy can be found in batteries, springs, capacitors, balloons, fluorescent displays and many other devices. It is one of the amazing things about nature that the same patterns and even mathematical formulae appear across many different physical domains.

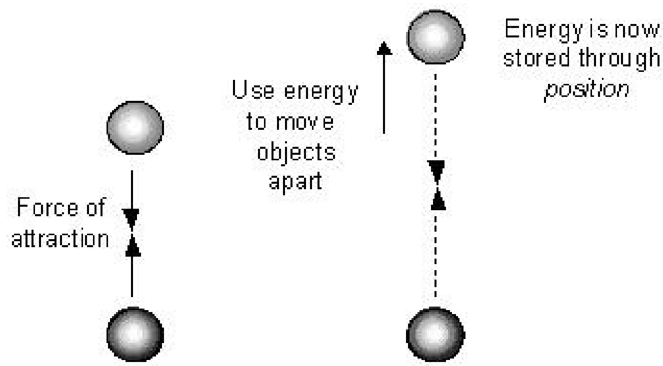


Fig. 2.2 Energy storage and use by movement

We cannot see stored energy, and it only becomes apparent when we use it, where it can be sensed in terms of movement, heat, light and the effects of electricity and magnetism. We can simplify these into two forms: movement and waves. Heat comes from the movement of atoms, whilst light, electricity and magnetism are all forms of electromagnetic radiation.

Although it seems that energy is used, this is not really true. When stored energy is used, it does not disappear, it is simply converted from one form of energy to another, and much inventing goes on around this conversion. When I start my car, I want the fuel to be converted into direct movement, not heat and sound (which is vibration of molecules), although it would not matter if intermediate forms of energy are used: it is the leakage of these that causes the problem. If we could convert energy efficiently, we would make life easier and also be more ecologically sound.

Inventing with energy

To invent with energy, you can start by taking the energy situation in your problem and breaking it down to find the attributes. Fig. 2.3 does some of this breaking down for different forms of energy. Let us consider some of the aspects of this diagram (which deliberately decomposes in different ways):

- The long list from ‘light’ shows some *attributes* of light, which can be changed. For example if increasing light in a room, you could increase reflection with more metallic surfaces.
- The long breakdown chain from ‘electromagnetic’ leads to specific elements that can be changed, for example sunglasses could work by using an optical bandpass filter to select only specific frequencies.
- Stored energy is linked to force. Although they are not strictly identical, imagine holding a spring squeezed in. The energy stored is felt as a force. Where you need a force, think about how you can input some energy and then hold it in place.
- Energy can be combined with other elements of simple science: the use of energy over time is work (so you can change work by changing energy or time).

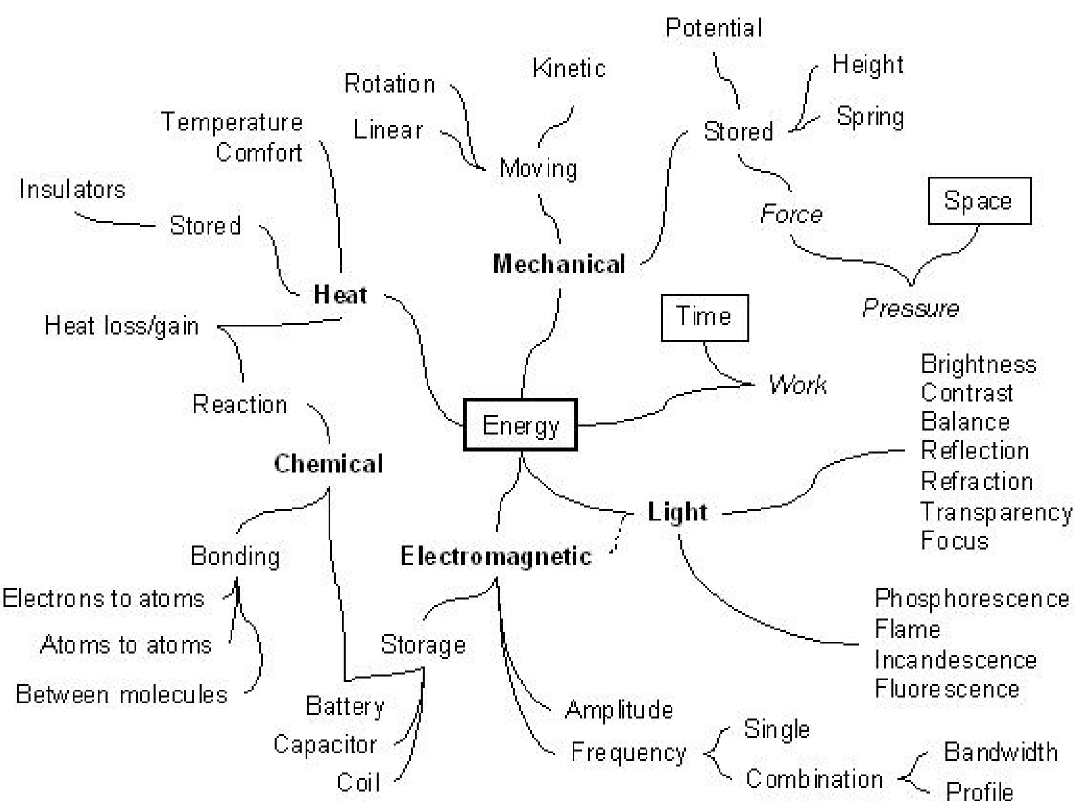


Fig. 2.3 Energy breakdown

There are many ways we can play with energy by taking any of the attributes, storage methods or decomposed detail and changing them in some way. We can change energy from one form to another, or perhaps we can prevent the energy from converting or escaping. In any situation, ask questions such as, ‘Where is the energy? What is it doing? Where is it going? When is it going there? How can I change these?’ Look at Figure 2.4 and see if you can play with the energy created in these devices to improve them or invent something different or unusual.

Exercises like this, by the way, are not trivial: they stimulate the mind, giving it practice for the real inventions you have. They can even occasionally lead to new and profitable inventions! Do not worry about making your ideas useful at first. Many great inventions were not useful in their initial incarnation.

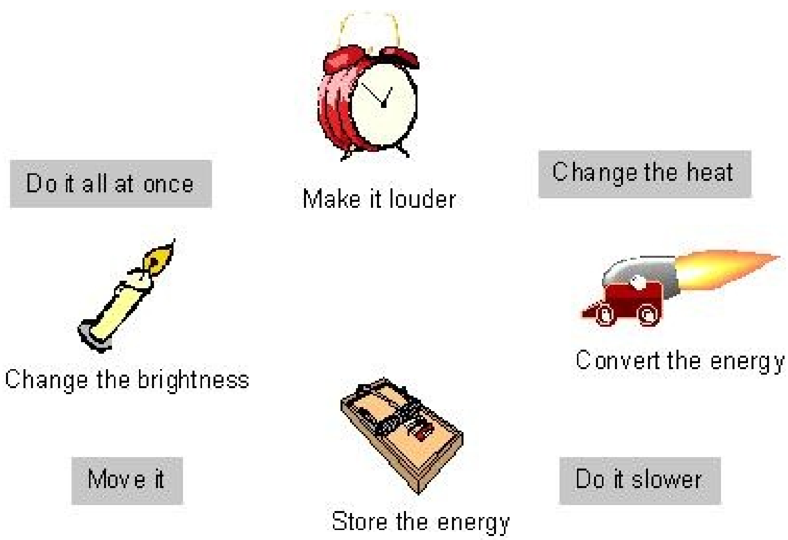


Fig. 2.4 Playing with energy

Science and force

A large part of science, (and particularly in areas where inventing is significant) is about the use of energy in interaction between objects, whether it is atoms within a bending bar or friction between the bar and the table on which it is placed. How many forces do you think can act between two objects? In fact there are only four, as in Fig. 2.5, and even better, two of them are probably not available for you to change, leaving two forces available for simple scientific inventing, electromagnetic and gravity (which we cannot change except by changing the mass of things so the main one we use is electromagnetic).

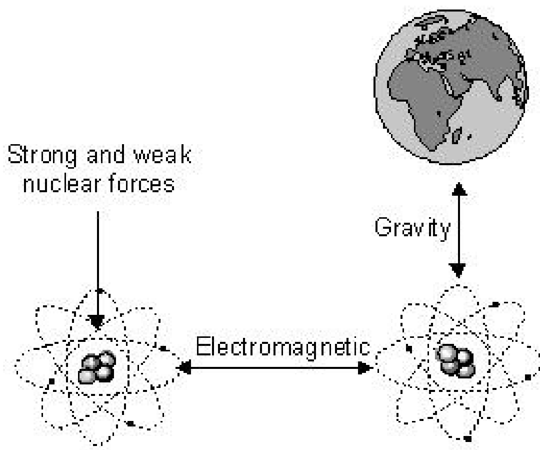


Fig. 2.5 Four forces

Strong and weak nuclear forces

The strong nuclear force is the strongest force and binds the central parts of an atom together (the protons and neutrons). The weak nuclear force is weaker than the electromagnetic force but stronger than gravity. It affects things inside the atom only and its role is really at the level of quantum physics, (by that we mean complex and small!). Fortunately, for both Strong and Weak forces, their effect is just about zero beyond the distance of the width of an atom so unless you are going to make some pretty big nuclear devices you probably will not be changing these. Except for physicists, these forces can be forgotten about when inventing.

Gravity

Gravity is more than the downward pull of bodies towards the earth, as *all* bodies attract one another. It is also a very weak force for small or distant bodies, although we do not think about gravity as being weak because we can feel it in our bodies and things we pick up may feel heavy. At a long distance it is the greatest force. For example, there is massive electrical activity in the sun which does not attract metal on earth anywhere near as much as the sun’s gravitational pull.

Gravitational attraction and consequent force is connected with size, which is why the Earth is pulled by the Sun, and distance, which is why the Moon is held in by the Earth and is not pulled away by the Sun. By the time we get down to the size of people and inventions, the force is much smaller.

The bottom line is that although gravity may be a consideration for your inventions, you cannot change it (although as an example of how assumptions can always be challenged, at the time of writing, research is going on into the use of gyroscopes that change their weight when rotating very fast. Perhaps one day we *will* be able to invent with gravitational forces.)

Where gravitational effects *can* be played with is in the mass of items. Mass can be changed with different materials, shapes and construction methods such as the judicious use of holes.

Electromagnetic forces

Electromagnetic forces are not just about wires: they are also about how one object holds on to another. Electromagnetic forces are familiar to anyone who has rubbed a balloon on their pullover and stuck it to the ceiling. These are forces that we can play with, and we will discuss them later on.

We are surrounded by electromagnetic fields, which affect how things are attracted or repulsed. These forces also bind atoms and molecules together, and in our world of physical things it is only the electromagnetic forces that count.

When materials are pushed against one another they resist the push through the electromagnetic repulsion in the atoms and molecules. As you push on a material the fields are being pushed together and they resist. Every object resting on another is distorting it by displacing molecules, usually only very slightly. No material is absolutely rigid because it could not be. The force back has to be created by something and that force is electromagnetic. When the force is removed, the material, if it has been elastically distorted only, will spring back to shape.

In chemical bonding, the electrons in the shells of the atoms are shared, which creates a fair to very strong bond, but it is still an electromagnetic force. The glue that sticks your fingers together is the glue of electromagnetism!

When any two objects are placed in contact with one another, the electromagnetic fields of the atoms at the surface of contact will interact with one another, typically resulting in some degree of attraction. A similar attractive effect occurs when molecules are mixed or in solution, such as the way water molecules bonded loosely with salt to make a saline solution.

Inventing with forces

Inventing with forces often has to do with either trying to make things stick together or trying to separate them. Many large businesses are built on how things stick together, not only around adhesives, but also in such diverse subjects as paint and furniture. 3M, for example, uses bonding inventions for everything from sandpaper to Post-it Notes. Modern aeroplanes are largely stuck together with glue, which help make the plane much more rigid than if nuts and bolts had been used.

The bonds that can be played with include the attachment of electrons to atoms, the attraction of molecules to one another within a single substance and the interaction of different substances when brought together. Electronic, chemical, material and mechanical inventions all deal with bonding forces to different degrees.

Electromagnetic forces are involved in all the bonding, pushing and pulling that goes on between atoms and materials, whether they are solid or liquid or gaseous. The invention battleground is the electromagnetic field. Even light, which as a photon is the smallest constituent of an electromagnetic field. In fact, in quantum physics, the force of electromagnetism is created by the exchange of photons, though not at the wavelength we see.

Inventing with forces at the most fundamental level means thinking about the electromagnetic effects. We can also think about ways to apply forces at higher levels, such as with hammers or clamps. We can change the energy source, for example using electrical or chemical methods. After constant problems with compressed air for vehicle airbags, a chemical explosion was found to be simpler, cheaper and more reliable.

If we combine force with other aspects of energy, matter, space and time, we can find other ways to use the force. Applying the force over a period of time will require a greater energy reserve. Pulsing the energy as in a jack-hammer can be very powerful. The required force may be reduced if the area of effect is reduced, as with a knife blade or the tines of a fork.

To play with forces, think about the different aspects of the force, how you can change them, how you can combine them with other things. Vary the source, time, area, location, direction and more. Use springs and levers, explosions and attacks. Change push into pull and press into pulse. Just playing and experimenting can reveal useful surprises!

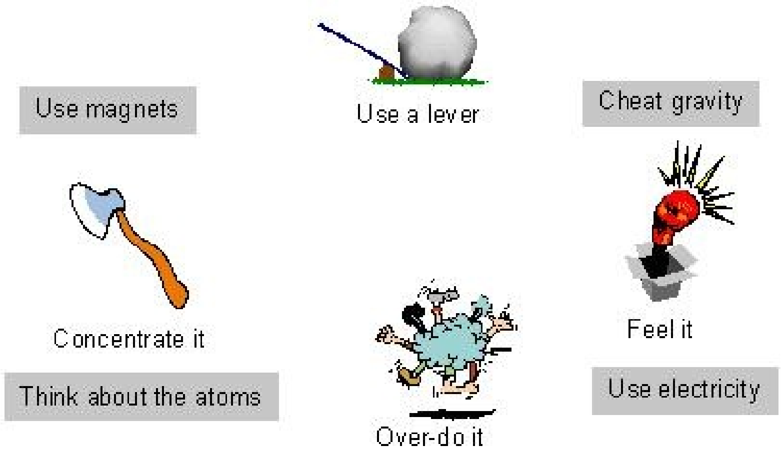


Fig. 2.6 Playing with forces

Science and matter

Matter means material, the stuff from which we make our physical inventions. This is an area in which nature has done many experiments and where we can find many inspirations (in fact, copying nature has been given a name: bionics). For example, Alexander Graham Bell used the human ear as a model for the telephone and principles of frog’s eyes were used in an aircraft altitude indicator.

Atomic thinking

A very basic way of inventing with matter is to think of what is happening to the atoms and molecules. A nice and unscientific way of viewing atoms is as little sticky balls, which usually like first to stick to one another. Crystals stick in nice patterns, but mostly the sticking is fairly untidy and atoms will slide about as the material is flexed. In liquids and gases, of course, the atoms move about even more.

One of the interesting things that happens with atoms is at the surface or edge of things. Here, they only have around half the normal number of similar atoms to stick to, which tends to make them panic somewhat. This can result in strange surface effects such as microscopic deformations or bonding to what ever is next to it (this is how adhesives work). Surface atoms are also exposed to attack by external atoms and energies. The surface atoms will even sometimes shake free of the parent material and float away (as in evaporation) or the may be stolen away by more attractive external atoms or simply knocked off by the odd passing molecule of water of air or even a bird’s foot. When this happens, energies that are released can exacerbate the situation (or may be utilised by canny inventors!).

Molecules act like big atoms, but add to the complexity of the situation as they can now take different shapes, such as long thin molecules that can form flexible but strong fibres. They also can break up when they meet other molecules that react with them, or are exposed to energy sources such as ultraviolet radiation.

Mass and density

Matter has mass, but not weight, as weight is an effect of gravity (in space, things are weightless, but their mass is unchanged). Weight is also a force and hence has a direction. For most purposes, we do not need to differentiate between mass and weight, but it is still worth knowing the difference.

Matter has density, which may be consistent through the object or may vary thought it. This is an area where we have a greater range of options than nature: our flesh and internal organs are made up of a very similar sort of flexible material, while bones and teeth are similar types of calciferous substances. A result of this is that most natural bodies end up with a fairly standard density.

In inventions, the weight need not be proportional to size, as we have a much wider range of options in the materials we use and the holes and spaces we can create within.

Flexibility and rigidity

Nature is, on the whole, pretty floppy. It achieves rigidity in the skeletons of its structures, but mostly it finds flexibility a more useful proposition for many purposes. The human world, on the other hand, is full of rigid structures. When nature puts rigidity on the outside, as with the crab's shell, it also limits the ability of its inhabitant to grow (in fact, the only natural shape that allows ongoing growth is the snail's spiral shell). We are not constricted by such concerns.

When you need flatness, it is a dilemma if you also want lightness and rigidity. Nature overcomes this effect in several ways, for example when it wants to keep a leaf open. Simple curvature quickly makes a flat item more rigid. Solid veins on the underside of the leaf may hold it open. Folded ridges also work, for example where a fold down the middle also helps long thin leaves. Insect wings use all three principles for unbeatable lightness and strength.

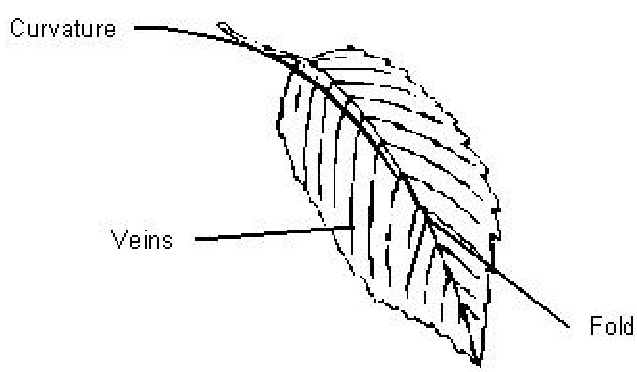


Fig. 2.7 Achieving rigidity in a light structure

People generally design things to be rigid and unmoving, whilst nature tends to design things to bend, but not break. Rigidity in structures leads to hot spots of high internal forces and vulnerability to external forces. With careful design, the structure may be allowed to move in a way that shifts forces, safely channelling them into the ground and away from weak points. Thus earthquake-proofed buildings can move and vehicle suspension absorbs much of the bumping that plagued earlier rigid carriages. Veterinarian John Dunlop used the flexibility of a rubber hose to ease the ride of his child's cycle and thus invented the pneumatic tyre.

As mankind continues to copy nature in our inventions, we are gradually adopting more flexibility. For example, in the chilly future of smart weapons, self-steering bullets use contracting tendons to change the direction of the little nosecone to ensure the bullet hits its mark.

Inventing with matter

Notice how we categories objects in terms of how they respond to external forces and energies: things can be dense or non-dense, hard or soft, rigid or flexible, brittle or ductile, opaque or transparent, and so on. What are the properties of the materials you are using? How could they be changed? What properties would be more desirable? Use and extend Fig. 2.8 to help this task.

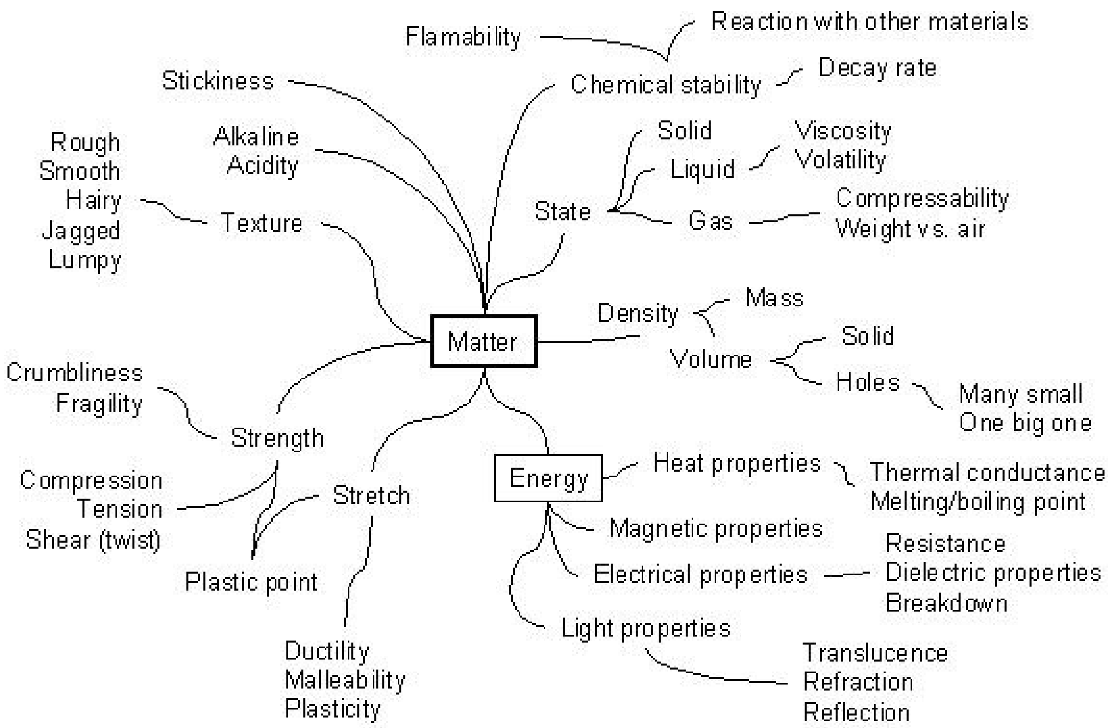


Fig. 2.8 Thinking about matter

When inventing with matter, also think about the forces and energies around your invention, such as light, heat, gravity and magnetism. How do these affect things? How can you change the materials used to eliminate undesirable effects? How materials be used to *take advantage* of these effects?

A useful viewpoint is often to zoom into the atomic or molecular level and ask what is happening here. How are the bonding relationships changing? What is happening at the surface? Consider the effects between molecules, between atoms and even within atoms. Are electrons being pulled away by electrostatic or electromagnetic effects? Are chemical energies being released or absorbed? What reactions are occurring?

Play with your materials. Having fun is a serious business. Just trying things can lead to surprising results. Use half-formed and even random ideas to see what happens.

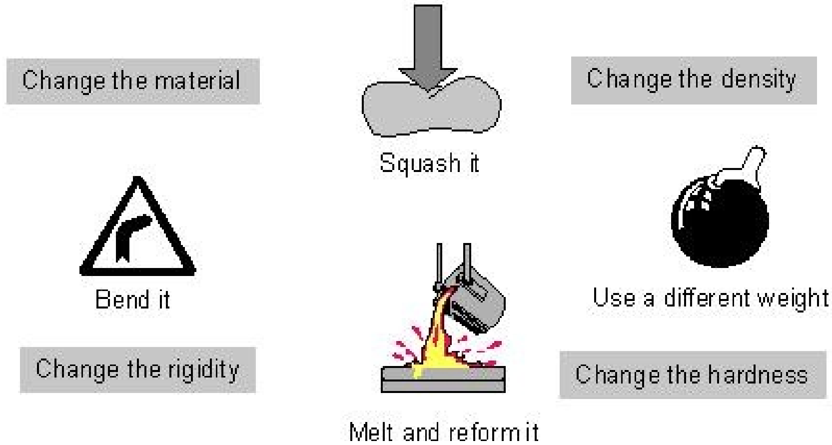


Fig. 2.9 Playing with materials

Science and space

Things use space in different ways. Something with many spikes uses space differently to something with a smooth surface. A solid object uses space differently to a hollow object. The gaps and empty spaces in things can be there to make something lighter (consider all the holes in a chair) or to enable things to fit together (the hole in a nut is designed so a screw will fit snugly into it).

Shape

Think about the overall shape of your invention. Why is it that way? Nature, again, is a rich source of stimulation and ideas about shape, from the hooks on burrs to the hollow bones and feathers of birds.

Shape has several functions. Firstly, shape connects. The body of a car serves to hold together all of its parts. Shape also contains and separates, protecting what is inside or outside from one another's adverse effects. A house is shaped to protect its contents from the weather, to contain the heat and with separate rooms, each with a different use. Shape interfaces with other shapes, like a nut and bolt fitting together or a bayonet shaped to impale the human body (not all shapes are good).

Shape may have aesthetic functions, too. What makes a Ferrari more attractive than a Ford? Much of this is to do with shape and the associations we have with it. Curves, especially in the right proportion, may remind us of the human form. Sharp angles and unusual shapes may catch our eye and appeal to our sense of novelty.

A space invention

Let us use some of the analytical inventing from Chapter 1 whilst keeping in mind the basic principles of inventing with matter, space and shape.

An aeroplane has wheels and tyres. What is the purpose of the tyre? When the aeroplane is taking off you want grip, but not much, to steer it at low speeds. After a certain speed the engines will send you where they want to send you.

When the plane is landing, then much more grip is needed to help slow down the aeroplane from very high air-speeds. So, I want low grip for take off and high grip for landing. I can use an ABS system for landing but this may add weight. Can I get grip with little or no extra weight?

The next level of questioning is ‘Why does the tyre grip the runway?’ Well, it depends in part on the contact between the tyre molecules and the runway surface. This is affected by *how much* tyre is touching the runway. So maybe I can have a lot of contact on landing and little on take off.

How can I change how much tyre touches the runway? By changing the shape of the tyre. How can I change the shape of the tyre? By changing the pressure in the tyre or through squeezing of the tyre, maybe with the rim/hub.

Size

Things can be large and small and anywhere in between, although in any application there tend to be breakpoints and viable ranges along the scale from microscopic to massive.

When size increases, volume and surface area do not change at the same rate. Double dimensions and the volume goes up by a factor of eight. At a constant density, this equates to bigger meaning much heavier. It also means greater heat insulation and retention as heat is lost from the surface, and a deep core will only change its temperature slowly.

In the animal kingdom, it is probably not a coincidence that humans are about half way along the scale. Small animals find it easier to jump, fall, fly and hide, whilst larger animals can defeat predators and lose less heat (and so need to eat less for their size). In the middle, we get the best of both worlds.

In the fight against gravity, small wins. A small insect falls more slowly and can rise more easily. The only problem that it faces is going forward: small wings need to fight hard against air resistance. Birds have found the best balance with longer wings and hollow bones.

Flight is an example where mimicking nature is not necessarily the best answer. Years of flapping-wing machines proved fruitless. The Wright brothers successfully took to the air by using large and doubled-up wings to get lift and a powered propeller to get the extra forward speed needed to get sufficient lift for the additional weight. Birds learned long ago the balance point between size and flapping flight. It took man’s ingenuity to overcome the problem of size by turning it into an advantage: big wings mean lots of lift.

Boundaries and corners

Boundaries define things. They exist where one thing stops and another thing begins. The boundary is where interactions occur between the two things, such as electrolysis, oxidisation, refraction and other effects. Interactions may involve temperature, physical force, light, chemical reaction or any other energy system. Larger boundaries usually lead to larger interactive effects, such as when heat transfer is increased with the greater surface area of a heat exchanger's fins.

The boundary may have different types of surface texture, being rough, smooth, hairy, feathery, jagged, and so on. Nature is pretty good at textures, most of which have highly evolved purposes, from the insulation of hair or feathers to the sharpness of the different kinds of teeth. We often copy these effects in our inventions, from the hollow fibres of insulating materials to grinding and cutting shapes.

Humans like flat surfaces and they appear everywhere in our world, but nature has little use for flatness as it is a very weak shape. If you compress a flat shape, it will either bend or break. We also like sharp corners, which nature avoids as it knows that this is a point of weakness. Squeeze a folded item and it will collapse and possibly fracture along the fold, especially if the fold has a sharp, clean edge. Put a smooth fairing into the corner and its strength will increase significantly.

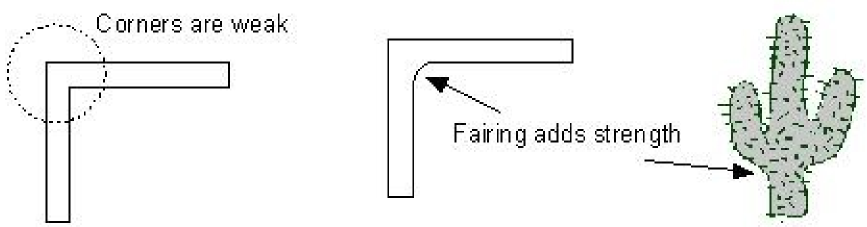


Fig. 2.10 Strengthening corners

Inventing in space

When inventing with space, consider how space could be added to or taken away from your device. How will space changes affect its strength? How will it affect its aesthetic qualities? Architects and top designers make great use of space to create elegance and style, for which they can charge high fees. Quite literally, they are selling nothing (although it is a rather *nice* nothing). Figure

2.11 gives some space attributes to consider.

Many shapes are as they are because it is easy to make them that way, rather than because of how they behave. Edges are straight because it is easy to cut straight edges. Holes are round because it is easy to drill round holes. Plates are round because of the rotation of the potter's wheel. A simple way to invent is to look at the things around you and ask *why* they are shaped that way. Is it is because it was easy to make it that way or because works best that way?

Why is a cup shaped like it is? The edge of the cup from which we drink is round. Beyond the ease of manufacture and the way that this fits our mouth quite well, this is also a good shape for controlling the flow rate of the liquid we are drinking. To get more flow we simply widen our mouths and the flow rate increases quite quickly. So we can use this shape to drink just a little sip or to take big gulps. If you have ever drunk from square glasses you will realise how nice and friendly the round shape is!

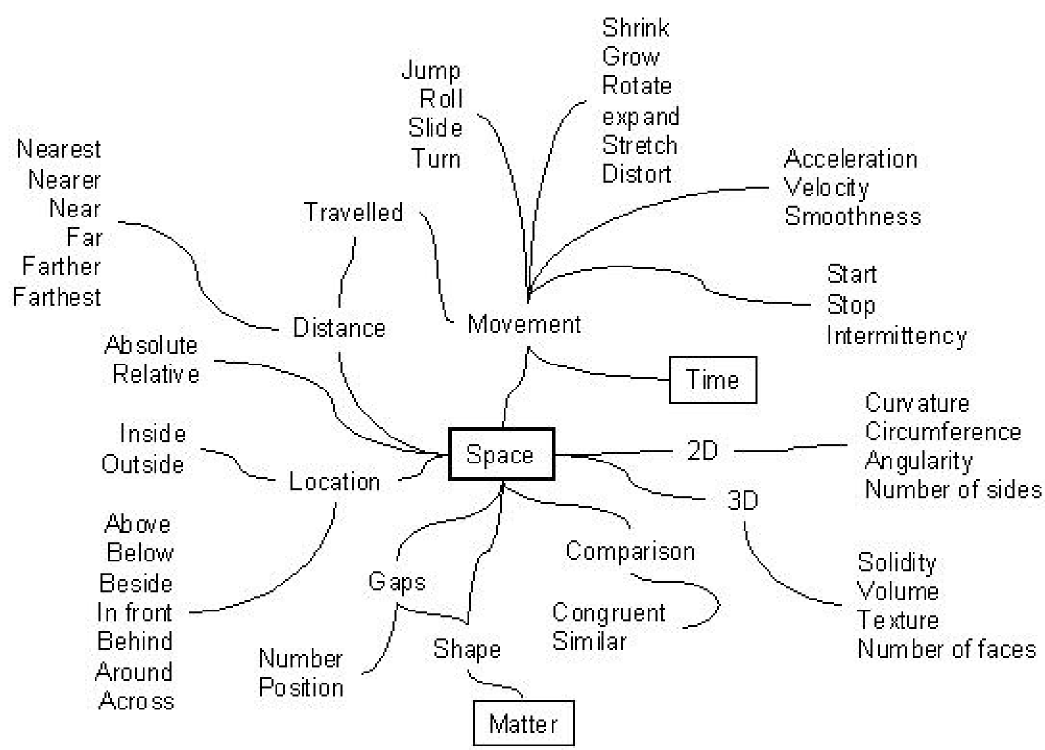


Fig. 2.11 Inventing in space

Many, many, many inventions are simply about changing the shape of things to make them do what they do better. Although the basic idea may be to change the shape, the critical part of the invention may well be in the manufacturing process, such as in new milling methods and tools to cut shapes more accurately. The ongoing improvements in robotics, use of materials and other manufacturing system all give opportunities to make things differently or more cheaply and thus add greater value to the finished product.

If, when examining an item, you already have the best shape, you can still invent by asking yourself whether, if it was a different shape, it could be used for additional functions. For example, you could shape the end of a key to be like a screwdriver blade. This might result in the problem of the key cutting holes in your pocket, but rather than reject the whole idea this simply becomes the next target for innovation.

Play with space. Look at it as negative matter: how do the spaces between the shapes alter things? Create virtual space using glass or other transparent and translucent materials. Change the shape of the space and the space around the shape. Move around the space: how do things appear from different perspectives? Zoom in and out, up and down, around and within. See it from your customers' viewpoint: what does space mean to them? If you are designing books or websites, look at the balance of white space to text and pictures. Make nothing a tool in your invention kit.

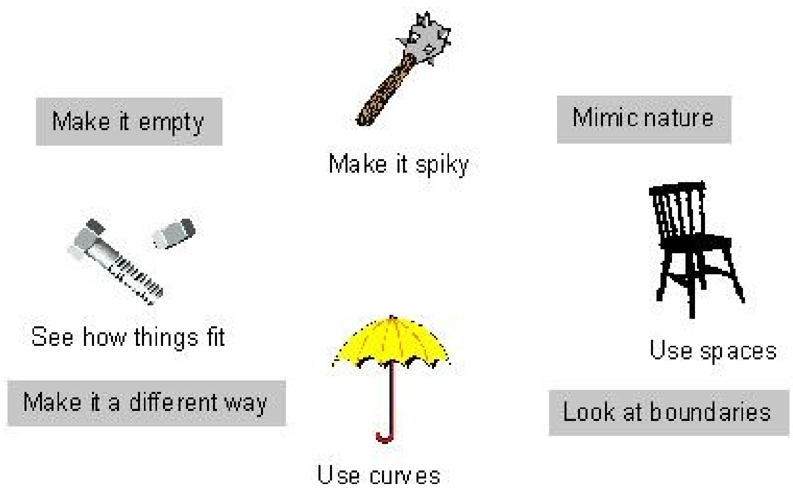


Fig. 2.12 Playing with space

Science and time

Surely time is fixed? It would seem that we cannot change time unless we are thinking about relativity and make time go slower by moving faster. Time is a much-ignored resource in inventing, yet is one of our most precious commodities. Rich or poor, we all have a similarly short span, and the inventions around us can help or hinder us from making the best of that period.

When things happen, they do so in defined order, which we can change. Many designs are put together as static models before we set them going. We can design in new ways by asking ourselves if some of the functionality (this word is important and we will use it a lot) can be delivered at different times. In computers, magnetic tape allows us to store a lot of information cheaply, but it is a serial device. Even hard discs and CD-ROMs are have latency and seek-time, delaying the processor's request for data. The day that someone invents a static method of storage that is just as cheap, dense and robust, will be the day that moving storage will begin to die out.

We might want to use something at a given time, but the current situation prevents us from doing so. Consider drinking a cup of tea or coffee. You may want to drink it right away, but it is too hot, or you may want to drink it later, but it has gone cold. Now imagine that you could balance out those two, for example using some form of heat storage or exchange that removes excess heat from the delivered liquid when you tip the cup and puts it back in later. Perhaps you could do this by running the liquid over heat-absorbing surfaces as the cup is tipped, and returning the stored heat later on into the liquid once it has cooled down.

Inventing with time

To invent with time, build on Fig. 2.13 to discover how time affects what we do and where we can improve the quality of people's lives through letting them make better use of their time. You can change the order in which things happen, how they relate over time, when they start and stop and whether they happen at all.

What happens when you are watching a television program and the phone rings? You have two things that you want to do at the same time. Could you link the phone to the video system, so picking up the phone mutes the TV sound and starts the video recorder? What if the TV could tell the phone to tell the person to call back in 40 minutes when the show finished?

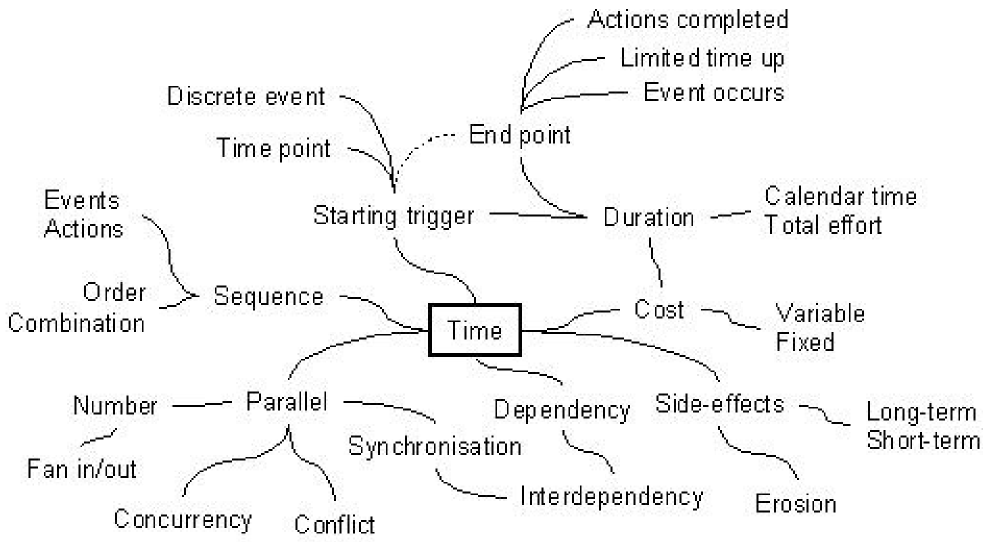


Fig. 2.13 Inventing with time

Play with time. Can you speed up time or slow it down? Many people would pay handsomely for even the *perception* of changing time. I would like waiting in queues to speed up and eating chocolate to go very slowly. Could you give me something interesting to do while waiting? How could you change the composition of food to make the taste linger longer?

Think about fantasies and visions. What would an ideal world look like in ten, twenty, fifty years time? Go into the future and look back: how did you get there? What are the steps? How could you shorten the sequence by doing things in parallel or not at all? How could you share time with other people?

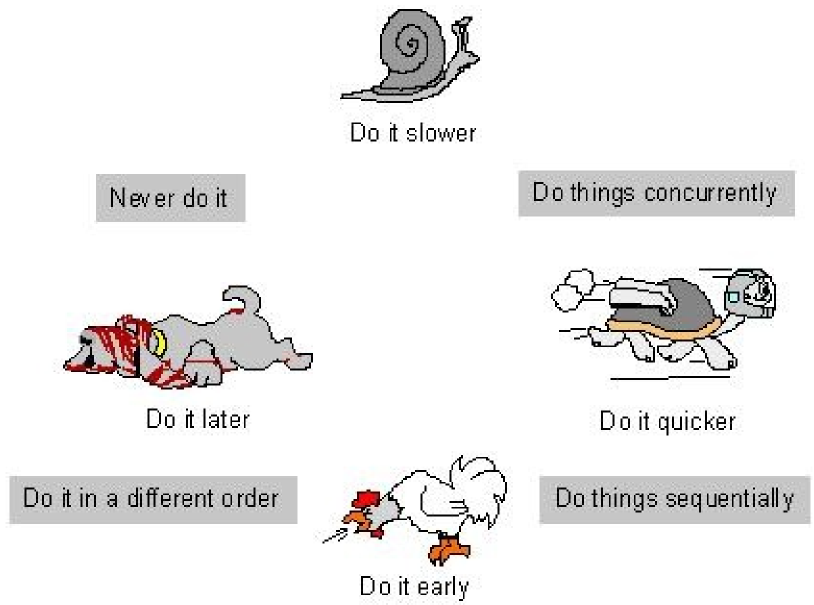


Fig. 2.14 Playing with time

Simple science in non-science

Invention happens in very non-scientific areas. You can invent new processes, business strategies or social systems for how people interact and work together. Happily, the four simple science principles work just as well in these arenas.

Energy

Energy in human situations often translates into effort, enthusiasm and persistence. Some tasks are just boring, which is a low energy mental state. Inventing with energy in social situations could means finding ways to make things more interesting and exciting, so the unsatisfying energy of pushing people into action is eliminated as the pull of enthusiasm is created.

Whenever we act, we use energy. Can you think of times when you waste energy? Travelling to work is a big waste for many people. The internet could provide opportunities to work on-line from home, or perhaps from a local all-purpose office where you can rent space, phones, photocopiers *etc.*

Sometimes we would like to use more energy, such as when we are exercising. Charity marathons are social inventions that help people to exercise together and also feel good about helping those less able than ourselves.

Matter

Things are matter. Inventing with matter means thinking about the tangible things we use. Non-material invention is more about how we *use* things, rather than creating those things. For example, I could invent a new way of constantly backing up my computer, perhaps by writing a program that transmits what I type, as I type it, to a remote computer. Then, even if my house explodes, my work will not be lost!

There are also various forms of ‘virtual matter’ around which you can invent. These are the intangible things, such as money, computer programs and customer satisfaction, which are nevertheless very real and worthy of significant attention.

Space

How well do you make use of the space around you? Do you have a loft full of useless rubbish? How about your garden: is it well laid out? We have three dimensions in which to play, although we sometimes only use two. A well laid-out garden uses all dimensions well. Living well includes making good use of the spaces we have available to us.

Space is often a critical factor in organisations, where office space is measured in cost per square foot. Saving space or making better use of it is a high value activity. Moving things and people (i.e. travelling) are also about space and can be very expensive. Space innovations can be about the movement of stock and parts or about the geographic positioning of facilities, for example in relation to customers and suppliers.

Other attributes of space can also be used in non-scientific inventions. Organisations have shape, functionally, geographically and in other ways. They have boundaries at which interactions occur with outsiders. You can even use physical metaphors for social effects, for example the 'texture' of a company might describe its culture ('Are we bristly when we should be smooth?').

Time

Time is the one thing that all people have in equal measure, although we do not all use it in the same way. For busy people, saving time is critical. For those at leisure, the enjoyment of time is more important. Many service industries are founded on around time-oriented inventions.

'Time is money' is a common saying, but it is more true than many realise. We give our time to an employer, who gives us money. We can then spend that money to save our own time on activities like growing and cooking food. A trick to invent around is the speed at which these conversions happen. I would like to make money quickly, but spend it slowly.

Many situations can be changed by altering when things happen, and for how long they happen. Undesirable things, such as cutting the grass, may be put off or done less often. Desirable things may be done at a time when we are relaxed and more able to appreciate them.

Doing things at the same time allows bad things to be completed at once or good things to be intensified, such as theatres have combined with restaurants to extend an evening's pleasure. Or we can spread things out or book concerts months ahead so we can look forward to them for a longer time.

In combination, these four simple science principles can be very useful. For example, we can consider how time may be traded off against space, or how things may be done using less energy. When we are concerned with how and when things are moved, and the time factors involved, we are using all four simple science principles.

New investment methods could be invented by considering how money may be automatically moved around, over time, in the virtual space of world banking systems. Looking at how and when people meet, and the energies of their interactions, could improve whole societies.

Invention so-what

Knowing some simple science is a powerful thing. So is remembering that most (if not all) great innovations came from people who were either outside or new to the area of invention. If you are a scientist, forget or challenge your training. Learn to ask great questions. Spot scientific assumptions and openly question them.

Everything is made up of energy, matter, space and time, so question all aspects of each of these, individually and in combination. Here are just a few of the many questions and considerations you can take into mind.

- What are the energy effects?
  - How is energy stored? What other storage could be used?
  - How is energy converted? Into what form? Can less be used?
  - What are the attributes of energy that can be changed?
- What are the forces involved?
  - What are the electromagnetic effects?
  - What happens at the atomic or molecular level?
  - How can you use less force? Can you trade force for time, space or energy?
- What materials are you using?
  - What is happening to the atoms and molecules? How are relationships changing?
  - What is happening at the surface? How is it interacting with its environment?
  - How heavy and dense is it? Would it help to change these?
  - How strong is it? Will it withstand pressure, twisting or stretching?
  - How flexible is it? What are the effects of this? What happens when it is stretched?
  - How chemically stable is it? Is it reacting with the air or other parts?
  - How smooth is it? What are the friction effects?
- What shape is it?
  - How big is it? What if you changed the size? Or in one dimension only?
  - What happens at the boundaries? Could you change the texture?
  - Where are the weak points? Could you strengthen them?
  - To what degree is the shape dictated by the way it is made?

- How can you invent with greatest currency of all: time?
  - How can you save time? Can you change serial to parallel?
  - How do things start and finish? How do they change in between?
  - What are the dependencies? Where are the dead spots where things are waiting for one another?
  - Can you change the perception of time? Can you make it more enjoyable?

3 A Simple Science Lens

In the previous chapter we took a basic view of simple science, looking at it through the lenses of energy and force, matter, space and time. In this chapter we continue our challenging journey showing how we can look afresh and in detail at a single scientific principle, for which we have chosen friction.

Please note that this is not intended as a complete treatise on the subject nor does it cover all parts of science. What it does aim to do is indicate how you can look at scientific subjects in simple, unscientific and unconventional ways that allow you to see things differently and consequently make use of them in your inventions.

Friction might be considered as being well understood, but scientists are still debating this point. In fact, as with pressure, it can be said that that friction doesn't exist! This may seem to be a rather alarming statement, but let us consider the real situation. In fact we will use friction as a particular example of looking in detail at what at first may seem to be a simple and well-understood problem.

If you have a bowl of fruit and you want to invent a way of making it more green, you could think of is as an 'inventing with light' problem and, before thinking about what you might change, ask what kinds of different light there is. For example, you could make it more green by adding green things to the bowl, you could remove some of the red and yellow fruit, or you could even put it next to a green plant.

Friction is like the colour in the fruit bowl: it is made up of several different things. To change friction, we need to identify and understand these different components.

A good, creative starting point is to review the definition and get a fresh view of the problem. The *Concise Oxford English Dictionary* describes it as 'resistance a body encounters in moving over another.' So it is about what stops things that are in contact with one another from moving relative to one another.

Bounce

Think of a heavy supermarket trolley going over rough concrete. Although the wheels help you move it, the trolley still has to rise and fall over the bumps, and the size and shape of the bumps will change how much force you need overall to move the trolley forwards.

Now zoom into the microscopic view of a block of wood being pushed along a table (Fig. 3.1). The same thing is happening! The molecules from the wood and the table are snagging against one another making the wood bounce imperceptibly on its way. With a larger, heavier block of wood, you might be able to feel the juddering. All surfaces have some bumps, unless they are so fine they have one nearly smooth layer of atoms (and then other factors, such as electrostatic forces, are important).

So a way of reducing friction is to smooth out the bumps. Oil partly works this way, filling in the gaps between the bumps. Sometimes, you may want to increase the friction, such as when you need a rug to stay where it is and not slide across the floor. In either case, you may want to change the size and shape of the bumps or the effect they have, both on the thing that is being pushed and on the surface on which it is moving.

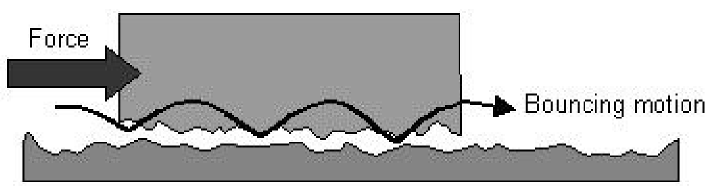


Fig. 3.1 Friction bounce

Elasticity

When two objects try to move against each other, if one has parts which will move elastically then it may effectively reduce resistance as the flexible parts of the surface bend around and over the bumps on the other surface rather than having to bounce over them.

Consider pushing a heavy box across a wooden floor. The box bounces along awkwardly with plenty of frictional resistance. If we took a piece of carpet, turned it upside down and put the box on top, now the flexible hairs on the carpet would fit into the gaps between the bumps, smoothing the ride and making the box easier to push.

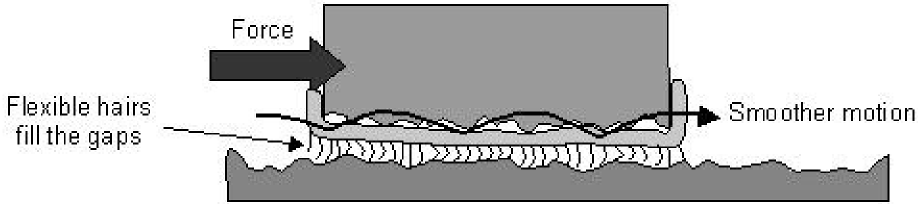


Fig. 3.2 Using elasticity to smooth the ride

Now consider what would happen if we now had to push the box (with the carpet attached) across a carpet. The two sets of hair in the carpet would now entangle, actually increasing the friction. The algebra of this is as follows:

Bumps + Bumps = Friction
Bumps + Elasticity = Less friction
Elasticity + Elasticity = More friction!

To increase or decrease friction, consider the elasticity in both surfaces. Think about how easy or not it is to move a vacuum cleaner around the house. Over carpet, a smooth metal plate would be the best bottom surface, over a smooth floor a bristle surround would be better. The whole picture is complicated by the fact that you have air flowing between the surfaces, but the principles are clear. (Note: This an example of a contradiction, as will be described in Chapter 5. You sometimes want smooth and you sometimes want fibrous/rough surfaces.)

Fracturing

For some surfaces, the problem with lack of smoothness is overcome by the fact that molecules or even lumps of molecules will crack and break off as you move objects against each other. If you start sanding a piece of wood the first push may be hard but it soon gets easier as the surfaces are broken down to become smoother. The bits that are broken off also fill the holes, serving as an added lubricant; it is only when you blow the sanded wood particles away that you find out how truly smooth the wood has become.

Thus another way to increase or decrease friction is to find ways in which you can increase or decrease the ease of breaking off small pieces of surface.

Making things colder or hotter is one way, as this will change the brittleness of the materials. A special example would be ice, as this is complicated by the fact that the ice will melt in places to give you a liquid lubricant.

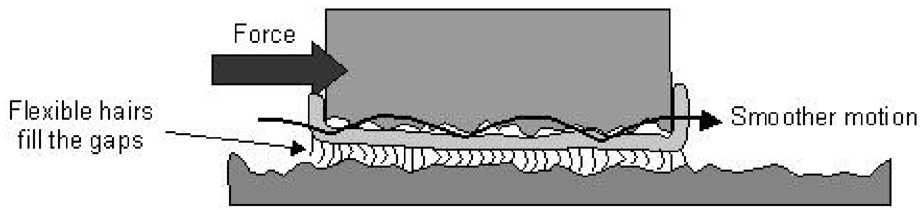


Fig. 3.3 Fracturing pieces to smooth and reduce bounce

The first three features of friction we have discussed (bounce, elasticity and fracturing) are to do with larger mechanical forces. These can be understood simply by drawing rough surfaces on a large scale and asking yourself what happens to objects moving past each other. For the next three features we are going to move closer in to the molecular level.

Electrostatic action

When molecules of two objects are in contact then some of the forces between them will be electrostatic. Electrons will be held in position and have a force between them and other positive charges in the molecules (protons) of the other object. There are technical names for the different ways this happens (Covalent bonds, Metallic bonds, Hydrogen bonds and van der Waal forces). What is happening depends on whether the electrons are held specifically between two molecules or are held generally in the electrical field created by many molecules. An easy way to think of this is by imagining a crowded party. You may have difficulty moving between people because of the general need to push people around to make space for yourself or you may need to break apart hands which are holding onto each other. So molecules may just occupy a crowded electrical space or they may be holding tight and the bonds need breaking.

What is really going on is very complicated but for inventions we might be able to simply think about what we might do to a surface to increase or decrease the friction from electrostatic forces.

For example, we could deliberately charge up the surfaces, placing electrons on or near the surface. We can alter the field reaction between the objects if they can carry a charge, we can even make the force a magnetic attraction. We can also change how much hand holding there is by changing the properties of the materials (with additives or new materials).

We should be aware that if we make our surface smoother then more molecules are getting close to other molecules, which could increase the forces of attraction between them, hence making friction greater. So we can see that although making surfaces smoother reduces friction by reducing bounce, shearing and elastic bending it increases friction through greater electrostatic forces.

Viscosity

Imagine pushing a brick across a treacle-covered kitchen table. It would not be an easy slide. But what if you replaced the treacle with engine oil? The brick's journey would now be much smoother. So what is going on? How does a lubricant act to reduce the work of brick-pushing?

One thing a lubricant does is to keep apart by a small distance the surface molecules of the brick and the table. By keeping them apart we can reduce the bounce needed (they ride smoothly on the wave of liquid), reduce the need to fracture on the surface, reduce the elastic bending of bits that protrude, and reduce the electrostatic forces.

The difference between the oil and the treacle is how easily the molecules *within* the lubricant move relative to one another (because the electrostatic forces are really weak). This kind of 'internal friction' is viscosity of the liquid. In a really good lubricant, the molecules bond better to the brick and the table than they do to one another.

Now imagine something that has *really* weak attraction between the molecules (they could even be repel one another). This sounds very much like a gas. If you can keep the bodies apart, gas is an excellent lubricator, as Sir Christopher Cockerell, the inventor of the hovercraft, well knew.

Think about a jar of jam. Inside you have a wide blade and you want to stir the jam. If the opening in the pot of jam is much larger than the size of the blade when you stir, it is easy for the molecules to move as they have lots of places to go. They can move to the biggest gaps. When the space available is limited they are harder to push around. The same is true if you want to move people around in a crowded room! So when you have a very smooth surface against another very smooth surface the viscosity can go up a lot because the molecules do not have much room to move around. Thinking creatively means using principles of friction and viscosity in situations where others would not, but which will lead to real insights.

The slippery case of ice

Most substances behave in predictable ways so we can have some good guesses and see what ideas arise. But exceptions occur, and a simple one is water.

For most liquids, as you cool them down, the molecules move closer together as they jiggle around less. When they have calmed down and are close enough, they can then bind with other molecules, forming the solid. Because the molecules are closer together the solid is denser than the liquid and will sink in it.

But water is funny. Icebergs are funny because they float. They float because when water freezes it takes up more space (volume) not less as most things do. It is just the way the molecules bind together!

Now if you squeeze a solid, you will raise the temperature and it will eventually liquefy as the molecular bonds are broken. So it would seem that squeezing ice will turn it back into water, and perhaps this is how ice skates work.

Wrong again. You need lots of pressure to liquefy a solid and the pressure of ice skates is not enough to melt the ice. So what is happening? It appears that at the surface of ice there is a very thin layer of liquid molecules that form an excellent lubricator. Along with a slight bow wave and the physical cutting into the ice by the corners of the skates, this is how ice skating works!

Gravity

Gravity would seem to be a significant factor in friction, as this is what makes the block heavy, but thinking differently about this shows that is it not that important.

First of all, there will be some gravitational attraction between two objects which will have a small part to play in how you can separate them. But it is so small that it is usually not worth considering.

But surely gravity plays big part in how difficult it is to move one object against another? This may seem to be true, but is only indirectly so. The weight of an object does not make it difficult to move, but it does change how the other forces above are working. For a heavy object the surfaces are pressed together more, requiring more fracturing to get things started and more bounce to keep it going.

Gravity is a contributor to the effects of friction, but it is not the real culprit and we need to be careful about how we treat this weighty subject.

Invention so-what

The ideas we have discussed above are not presented as the high science of friction, but a surprising number of things you can make will require some thinking about how well parts hold on to, or let go of, other parts. Whether you bolt, screw, glue, weld or fasten pieces together, you should think about the potential of changing how you do this using the considerations above.

Think of it as a ‘what if?’ checklist. Can you invent better ways of connecting parts? If so you may be able to produce a much better design. Many things we use do not have good friction properties. Things stick when we want them to glide and slip when we want them to stick. Things break apart and they should stay together, or refuse to come apart when we want to separate them. Invention opportunities abound for the observant.

Just for fun, have a look around the supermarket and look at how produce is sealed into bags, boxes and tubs. Look at how many devices there are and think bout how well they work. Do you buy things in bags and then have trouble getting them to open? Bottles for pills are a good example of good and bad design as they are specifically designed to so that children cannot open them (but they often can) and adults can (but often cannot). Can you think of better designs using the ideas about friction above?

Look at the various devices and objects Fig. 3.4. What are the points at which friction occurs in them? What are the effects of friction? Where is friction most troublesome? How could you reduce or even eliminate friction? Could you use some form of lubrication? How would you contain it? Could you use less moving parts? Could you have less area of contact? Or more? How would this change things?

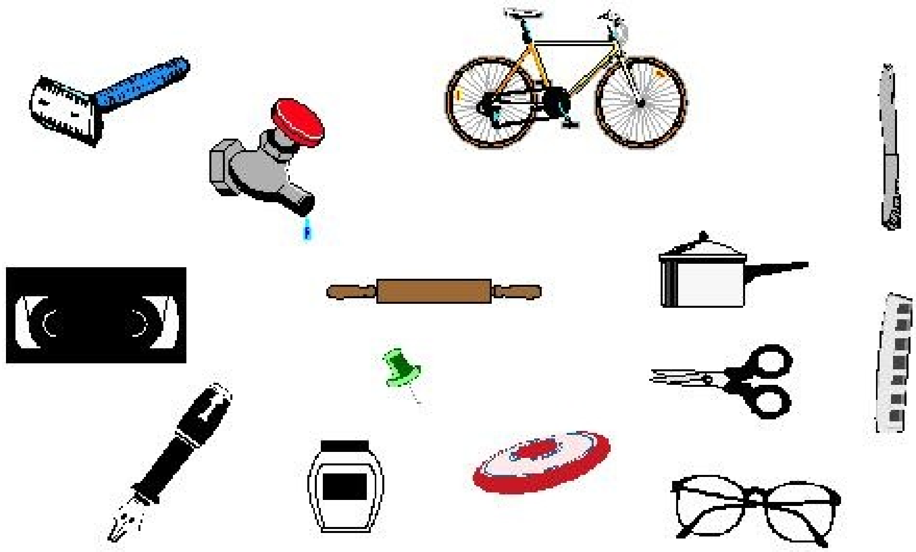


Fig. 3.4 What are the friction effects? How can they be improved?

4 Applied Simple Science

Now that we have taken a look at some simple science and how to look through the simple science lens at scientific principles, let us now investigate how this may be use in the ‘real world’ to invent useful devices. Note that we are using the word ‘device’ for the things around which we will be inventing. A hinge, for example, is a device for assisting the holding and moving of the door, whether it is a car door or a flap on a mousetrap or a door in our house. Our device stories help us look at different elements of the design process.

Devices deliver functionality, which means that they have a function or purpose which adds value in given situations. In being inventive we can question the purpose of the device, what functionality we want and how it is delivered. When we know what the device is supposed to do we can start inventing new ways of doing this. We can also look at the broader circumstances of its use and invent new ways of using it. But enough of abstract talk, let us look at some everyday objects and how we can invent around them.

Hinges

We pass through many doors every day but seldom, if ever, pause to look at that wonderful little device that holds the door onto the doorframe. There are many varieties of hinge, using different materials and with many surprising functions.

Let us consider the function or purpose or the hinge. A function of ‘enabling the door to open’ is not really enough to stimulate inventive thought, so if we chunk down into the detail we can separate out the main functions of the hinge.

First, the door is closed, and so one function of the hinge is to hold it closed, and in a security-conscious situation (such as your front door), we may want it to withstand a ferocious physical assault. The door is a seal between two environments and you do not want the wind whistling around the hinges, so these must be a part of the seal.

When the door is being opened, it should not be stiff and the hinges should allow the door to start moving without having to give it an initial shove. The door should not collapse at any stage, so the hinge must support both its weight plus any additional forced placed on it (such as children swinging on the door handle).

As the door moves, it should move smoothly, neither racing away from the person opening it, nor being hard to push. It should also avoid any obstacles such as a carpet. At the end of its travel, we do not want the door to hit anything, like the wall or a table behind it, and it should slow down and stop as easily as it started on its journey.

Opening the door too far should also not result in the hinges being torn from their mounting point. When the door is open, it may be desirable for it to stay where it is put or it may be preferable for it to automatically close. Closing should be as smooth as the opening, and the door should fit snugly into its frame with the catch hitting the strike-plate in exactly the right position so the door fully closes to an exact fit.

And if that is not enough material for invention, an exposed hinge may also have an aesthetic function such that it is pleasing to the eye and matches well with the handle, catch and surrounding furniture.

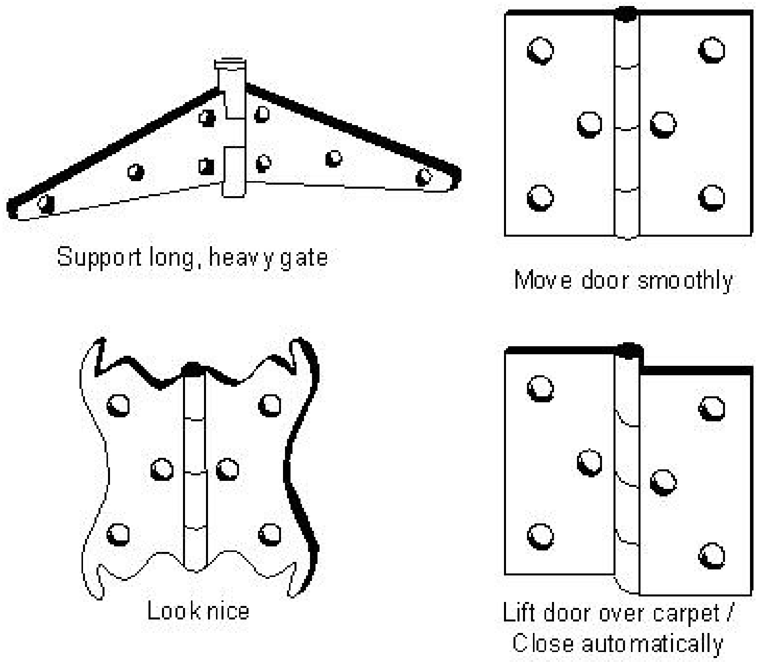


Fig. 4.1 Some functions of hinges

Having identified what it is supposed to do, we now start the design stage, asking how it should be done. If you want a really radical design then you forget about how you do it now and explore the most abstract level of wish. You might start from the concept of a seal for the doorway which avoids obstacles and consequently invent a rail for the door to run along, with a concertina-type door, or nested sliding doors.

We can think about the hinges in terms of the forces involved. In hanging the door, there is a shear force across the hinges. The door will try to pull out the top hinge, which must hence be well attached to the door frame, and push in the bottom hinge, which thus might be a lighter attachment. Other factors that involve forces were found in the discussion about function. These include the additional weight on the door, security implications and the forces of opening, closing, starting and stopping the door.

The reality for most doors is that you have a lot of compromises. You find that someone fitting the door cannot get the hinges lined up perfectly as they are screwed maybe into wood and the wood gives way a bit so as the door is fitted it sags a bit. In practice, it works best if only one hinge carries the weight of the door. If two or more carry weight then the forces as the door swings tend to work against each other and it is difficult to open. The function of carrying weight tends to be best for the lowest hinge, with other hinges just holding the door neatly away from the frame.

We can also consider the friction involved. As well as the friction in the hinge, we can consider the what is happening in the catch, or even the rubbing of the door against the carpet. Rising-butt hinges that lift as they open have already been invented. How about using electromagnetism in some way? How about creating charges on the carpet and the bottom of the door that repel one another, so the carpet flattens itself as the door opens? Or perhaps a similar charge on the leading edge of the door and an opposite charge on the trailing edge that lifts the pile of the carpet back up again (Wow: we have just invented a device for restoring old and tired carpets! This is how inventions sometimes happen–whilst you are inventing for one purpose, you discover something better for another domain).

Notice how we are looking at the overall problem, not just the actual hinges. Let us return to the hinges themselves. The lower, weight-carrying hinge could use a small type of ball-race or ball and socket joint to carry the weight smoothly, reducing friction. The upper hinges can be of lighter construction as they are just holding the door in place. They may also have some vertical play in them as we do not want the hinges to fight one another.

We can take inspiration from other places, including our good friend, Mother Nature. Nature does not use metal (it requires too high a temperature to create) but it is full of hinges. Natural hinges are made of flexible substances, often fibrous to give them extra strength. But a small bendable hinge would not hold the weight of the door very well. So how about having one long flexible hinge the length of the door? You could even include it in the design of the door, moulding it as a single unit.

We can also look at the fastening method. With a combined door and hinge we could have a long plate that screws to the wooden frame (although we could reinvent this too). There could be then be a simple hook-and-snap mechanism that pulls the door exactly in to fit the frame, as in Fig. 4.2.

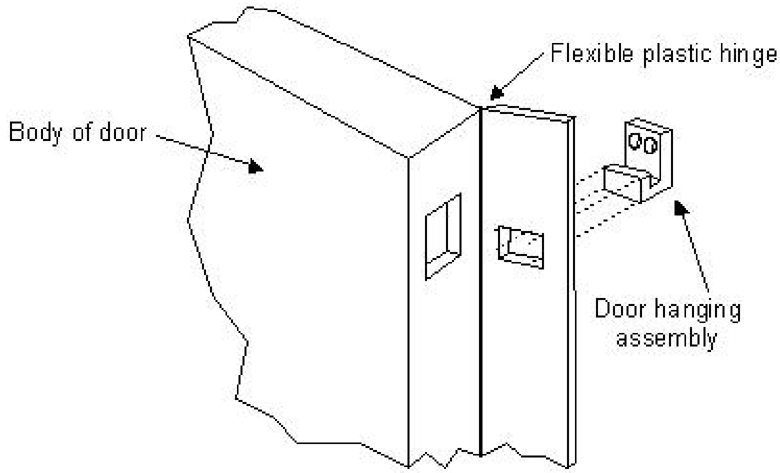


Fig. 4.2 A new door hinge?

These ideas are unproven! We have been illustrating ways of thinking here and not designing a finished product. Beyond this thinking process there is often a long process of try-outs and finding ways of economically manufacturing the product, let alone marketing and selling it to the sceptical public.

We can see, however, that it is not too difficult to generate good ideas by simply asking ourselves what *functions* we want the hinges to carry out, what *forces* are working for and against us and what type of *friction* is involved in different places.

Bottle-tops

What could be simpler than bottle tops and other food containers? Next time you are in the supermarket, look around: you will see many different bottles and containers with a wide range of tops. The numbers of designs suggest that the functions vary quite a lot, which they do. This is a simple but interesting invention subject which we will explore now in terms of issues of *shape* and *time*.

So what is the function of the bottle top. Is it to keep the contents, such as a liquid, in the bottle? But this is not quite enough because the liquid could be kept in by sealing the bottle completely. This, however is still wrong because we want to get the contents out. So the function is really about access: I want the liquid to come out when I want it to and stay in the bottle when I do not.

There are several other factors which have led to the different bottle-top designs. Preservation of food is enhanced if there is little or no air which may react with the contents, and what air there is has been sterilised to remove airborne bacteria. Thus, once the bottle has been opened, the contents may well have a limited shelf life. The life may be extended by keeping the bottle in the refrigerator, in which there may be little space or headroom which, in turn, will affect the design of the bottle and thus the top.

In today's world of terrorism I also need to have a way for the customer to know that they are the first to open the bottle, that it has not been accessed after sealing at the factory with something put in it that I do not want there. So designs now take into account the difference between first access and later access. There are many designs which have "locks" which break on first access. These locks might also be used to increase the sealing while in storage.

There are thus several time elements to bottle-tops, from initial preservative and security sealing, to subsequent sealing after use. Even when the 'use by' date is passed, the top is still useful to keep the remnants in to prevent mess and keep in any decomposed food.

As many frustrated people will attest to, despite the attention of a huge industry, bottle and other container tops are far from satisfactory. Friction effects are familiar to those who know the ritual of passing around a jar or bottle with a reluctant lid, often exacerbated by the forces of a partial vacuum in the jar. All are grist to the mill of the determined inventor. So think: how could you improve the situation? How could you reinvent the bottle-top such that it preserves food before opening, is easy to open, easy to reseal, and is also very cheap to manufacture?

Fig. 4.3 Can you improve these container tops and seals?

Gillette's razor

King Camp Gillette was a moderately successful salesman of ‘Crown Cork Seal’ bottle tops, but his real driving ambition was to invent something that would make his fortune. He was a part-time inventor, and even had several patents to his name. One day, when discussing his big dream with a friend, the friend suggested that he should invent something like the Crown Cork Seals he sold: a device that was used once and then thrown away. The idea took him and he started his desperate search.

His favourite creative triggering system was what he called the ‘Alphabet system’, where he took each letter of the alphabet and listed every product he could think of starting with that letter. But despite repeated use, this did not work this time. Finally, in 1899 when he was half-asleep and shaving, the idea of a disposable razor blade suddenly came to him. He immediately sat down and sketched out the idea.

That same day he stopped at a hardware store in Boston and bought brass and steel strips and started on his first prototype. Unfortunately, a truly sharp blade was more difficult to create than he at first had thought. He consulted many experts, even people at MIT, who all said it could not be done, yet still he did not give up. He formed a company and after five years of research including some brilliant work by a young engineer by the name of Nickerson, the first Gillette razor was sold.

When the first razor blades were sold in 1904, they cost one dollar for twenty blades. It is a testament to Gillette’s constant innovation that in 1960, despite 56 years of economic inflation, the price was still unchanged.

Levers

Levers are simple devices that are used in many situations. We think that we understand them well, which makes them an excellent subject for invention: many inventors will ignore the ‘well-understood,’ preferring the choppier waters of new technology, leaving the simple and once over-fished territory for those who prefer profit to glamour.

At its most basic level, a lever is a trade-off between force and distance. Increase the length of the lever and less force is needed to move the target. As Archimedes said, ‘Give me a lever long enough and a prop strong enough and I can single-handedly move the world.’ But we can invent further beyond this basic variable.

Let us look closer at the humble door handle, round or flat lever, it does not matter. With some initial consideration, we can see that its function is to turn. All levers are carrying out a turning function. We use the handle to move a small part in the door: a lock or catch. To prevent the door rattling, the catch is pushed against the door frame parts. To hold the door firmly closed, we have friction, and the lever action is needed to overcome this friction.

So most of the time we want the friction between the catch and the frame, but when we open the door we want that friction to go away. When we have a door which is stuck we often push the door to reduce the friction between these parts. Here is an opportunity! Can you redesign the catch system so that less leverage is required?

For some levers it is not the friction which is the problem but the weight or mass of the object being moved. We are then using a lever to enable us to use a small force to move a large mass. A car jack operates like this, either with a long arm or using a screw action.

If you have ever used a poor quality jack you may have noticed that it bends near the connection point. This is because the greatest force is near the point of the fulcrum. Consider the shape of the arm/lever: usually they are of uniform shape and material along their length. As we are only applying a small force at the end we need only a light small section to our arm at this end. We need more and stronger material near the fulcrum.

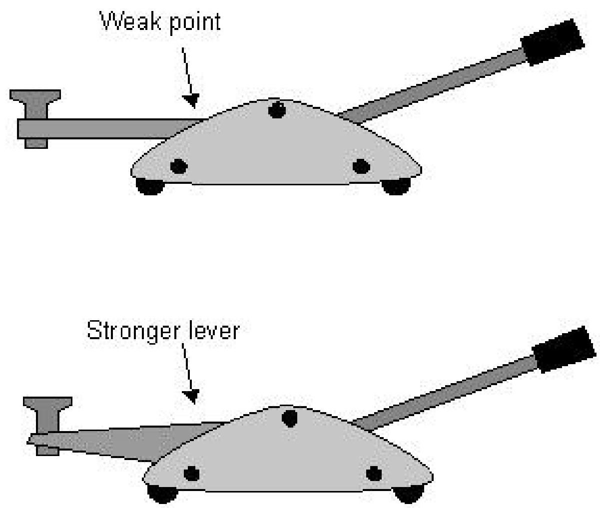


Fig. 4.4 Improving the vehicle jack

Look around at lever systems–you may see these in the kitchen (grinders and graters will have some leverage somewhere) or in the garage (the door may have a lever system for operation) or anywhere. Now invent!

Nuts and bolts

Nuts and bolts are such simple and well-understood things that the term is often used to mean ‘the normal little bits and pieces of the problem.’ And yet, by thinking differently about them, we can challenge our normal mental model of nuts and bolts and rebuild it with more useful detail.

Firstly, when we consider the purpose or function of nuts, bolts or any other type of fastener, we will find that it varies from job to job. Engineers may talk about the purpose of nuts and bolts as being to hold, retain or contain things, a language which suggests keeping things the same. When we examine the situations in more detail we find that the world is a much more dynamic place and that we want our designs to make things do things not keep them the same.

How is this so? If you bolt two parts together so that a liquid or gas cannot escape, then the function is to seal. If you are keeping things together, then you have a joining function. And when the overall structure is solid, you have a strength-creating function. Let us consider each of these in more detail.

Sealing

Like the screw thread on the bottle, the screw thread between a nut and bolt is a way of delivering pressure, although you might reasonably be asking now, ‘Why do I want the pressure?’

Suppose you want to seal in a gas. So you put two metal plates on to each other and think about how to create a pressure between the plates so that the gas does not leak. If one plate starts off sitting cleanly on the other place, the pressure is evenly spread. You then put in lots of bolts and start to turn them, and suddenly the pressure is not even! Even if you put in a million bolts, as you tighten them up, the pressure will be uneven.

But why are you creating uneven pressure when you wanted even pressure? With a bolt and nut we are pushing locally in one place so we get a reaction in another. To create a better design we should think about what is happening everywhere across the surfaces.

In an injection-moulding machine (Fig. 4.5) a liquid is injected which then hardens. But before it hardens it might leak between the plates. What is needed is to create pressure around the joints so that the liquid is sealed in while hardening takes places. You may well have come across many plastic parts where some leakage still exists despite the attempt to cut it away after manufacture.

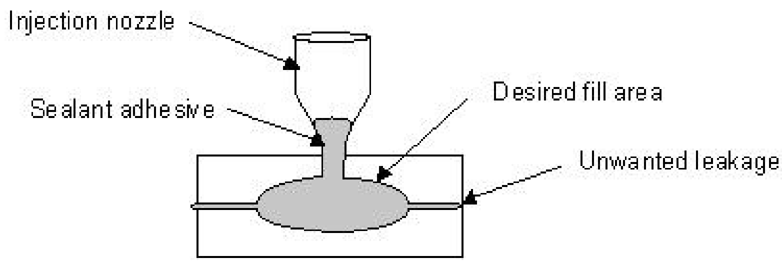


Fig. 4.5 Injection sealant leakage

So where do you want the pressure? This is where thinking about molecules comes in useful. The metal molecules around the edge of the shape you are making need to come together at high pressure so that the liquid does not leak. But in many injection-moulding machine the plates are flat. Molecules along the flat plates mostly push other molecules apart. You want pressure only where the plates need to seal. Not at other points. To deliver this you need to consider the shape of the plates and how pushing them together creates the pressure profile you need, as in Fig. 4.6.

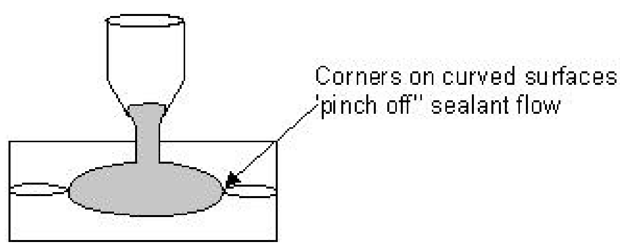


Fig. 4.6 Preventing unwanted sealant leakage

Joining

Consider the simple problem of bolting a road wheel to a car. The first question again is to ask the question ‘Why?’ to discover the function of this attachment. Most people will first answer that this is to hold the wheel on, but if this were all that were necessary, then we could weld or rivet the wheel on, although this would be a problem when we want to change the tyre.

Going back to basics and thinking about energy, force, matter, space and time, we can reframe the problem as one of time. Sometimes I want the wheel and car to stay together, sometimes to come apart. Time is particularly important for racing cars doing a pit stop, so they use a single nut that allows a wheel to be changed in a few seconds. Thinking about force, a tapered fit and single nut also overcomes the problem of distortion that came up in the previous section on sealing, although it also increases the risk that if the one nut fails, the wheel falls off with potentially fatal consequences. To try and balance these two problems, some manufacturers use three or five nuts.

Thinking differently again, what happens when the car is going around a corner? The forces will tend to slide the car, distort the tyre and apply a shearing force to the wheel connection. The problem now could be viewed as one of preventing the car from sliding sideways. Perhaps we could use the method of joining the wheel to the car to supplement the steering geometry, maybe tilting the wheel to compensate for the lateral forces.

A different view is of how the car is joined to the road, enabling the energy in the engine to be transformed into forward motion. This is prevented sometimes when the wheel lifts from the road. So perhaps we could also combine the joining of the wheel to the car with a suspension function. We might thus design a nut and bolt system which does not transfer small movements only big movements. Can you think of ways to do this?

A nutty problem

Imagine you are an aircraft engine designer. One of the problems you face is screwing together the various parts of the engine casing in such a way that the whole engine can withstand the enormous forces that it is subject to while flying at 30,000 feet.

A standard approach to the compression problem is to use many nuts and bolts around the two parts of the casing to be joined. This leads to subsequent problems in that you need a lot of nuts and as you tighten them, it creates uneven pressures around the casing, which can lead to unwanted distortion.

Darrell Mann, at Rolls-Royce, came up with the idea in Fig 4.7, where a tapered gap between the two parts leads to the parts being pulled steadily together as the bolt is tightened. This invention also allows the number of bolts needed to join the two engine parts together to be reduced from an average of about 100 to around half that number, while still giving the same sealing capability as the old design.

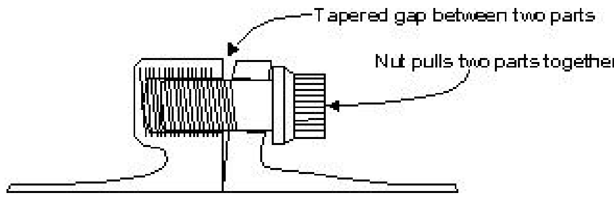


Fig. 4.7 US Patent: 5,230,540 'Fluid Tight Joint'

Knives

Let us try an example of thinking at the molecular level. If you want to divide something cleanly into smaller parts, then you might use a knife.

So what happens when we cut, when a blade is pressed against another material? If we zoom into the molecular level we can see that the blade is designed to get between the first layer of molecules of the thing being cut and *push* them apart. Because it is difficult to push lots of molecules apart in one go we tend to slide the knife back and fore, helping the knife to push the molecules apart over a period of time.

But why is the surface so important? Because if we can start a fracture, then it is very easy to propagate it. When we are wiggling or rocking the knife sideways, we are trying to extend the fracture we started at the surface of the thing we are cutting, so that it cracks *beyond* where the knife blade is sitting.

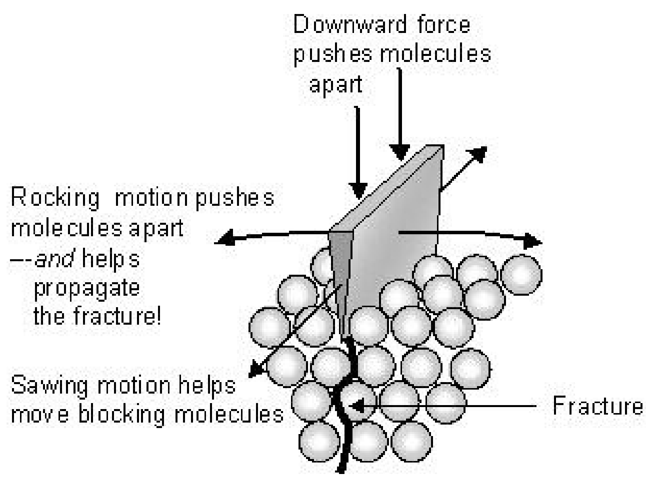


Fig. 4.8 Cutting action

Think about how different vegetables cut on a wooden or glass cutting board. A carrot will cut well on glass as it fractures. Lettuce needs a wooden board as it is fibrous and the knife needs to slice through all the fibres and hence sink a little way into the board below.

Now that we have recognised the fracturing effect we can think about how we can do this *pulling* the molecules apart. For example, we can also think about the material if we need to cut. Can we make it softer? Can we make it more fragile? How would using an elastic substance change things? We can also create a pulling force at the edge of the fracture through bending or shearing. By breaking the problem into two parts, starting the fracture and propagating the fracture, we can use a blade to do the starting and bending to do the propagating, as in Fig. 4.9, which is exactly what is done when cutting tiles and glass (where the fracture can also be extended simply by tapping).

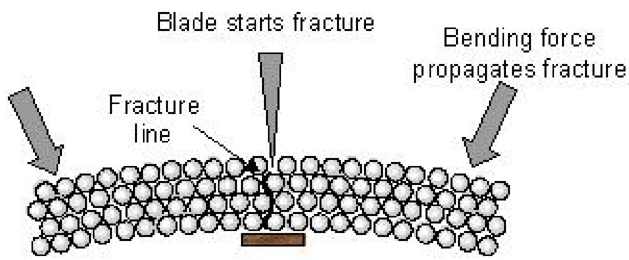


Fig. 4.9 Cutting by bending

Let us try a train of thought about cutting with energy. Heat changes the way materials respond to cutting forces. More heat increases the excitation of the molecules, making them push each other away, thus enabling the initial cut, whilst more cold makes fracturing easier. Perhaps, then, if we could heat the surface and cool the interior, it would make the material easier to cut. How could we do this? Maybe by cooling the entire thing, then applying heat through the knife. How could we heat the knife? Friction in the sawing effect happens naturally, but with a different viewpoint, how about eliminating the knife and using only heat, such as from a laser. Lasers heat the molecules so much, they turn them into gas so they are removed completely. If we now think about *removing* a complete column of molecules, we can look at other methods, such as a water jet or even a simple saw.

How does a pair of scissors work? A few minutes ago it may have been a difficult question, but having just thought about shearing and fractures, it is now easier to understand. Scissors work like a combination of cutting and tearing, with some molecules being moved upwards and some down. Tearing works by a pulling action and scissor cutting by a pushing action, but the direction of forces for both is the same.

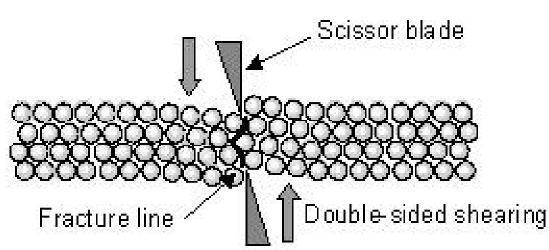


Fig. 4.10 Scissor action

Overall, we can think of cutting as ‘fracture management’, where we can think of separating and removing molecules by pushing, pulling, bending and heating different materials. We can also combine some of these, for example if the cutting and separating action is difficult.

What can you think of for inventing which might lead to better ways of separating substances? If you are not sure where to start, begin in the kitchen and work out a better way to crack open an egg!

Invention so-what

All mechanical devices are designed to manage the movement of molecules. The molecules may be solid as in hinges, nuts and bolts, levers, and knives, which simply manage the speed and direction of movement of parts relative to each other, keeping them together or separating them.

For liquids and gases we manage their movement usually with solids, so we have pumps, valves, channels and seals, although if the molecules or atoms have an electric charge, we could also use fields.

We hope that in this chapter you have found new ways of looking at common devices, using basic science to help challenge assumptions and do things in different ways. By understanding the true fundamentals of what is happening and then using basic psychology to prompt your thoughts into action, you can invent not only in the mechanical world of this chapter, but in any other world you face.

Toolbox 2: Scientific

Many people over many years have filed millions of patents and you might wonder whether some of them were reinventing the wheel, or at least had something in common with other patents. And you would be right. In fact, many inventions unwittingly use the same principles.

Russian Genrich Altshuller (with a few colleagues) spent over 50 years poring over more than 200,000 patents, extracting the common scientific principles that they used and the way in which these were used to overcome various problems (or ‘contradictions’).

Scientific invention = parameters + principles + contradictions

TRIZ, the Russian acronym for ‘The Theory of Inventive Problem Solving’ contains quite a lot of detail. The following chapter extracts the key points that will allow you to use these invent for yourself.

5 Basic TRIZ

In 1946, a Russian Naval Patent officer, Genrich Altshuller, noticed similarities in invented solutions from different fields. He had the temerity to suggest to Stalin that he could improve inventing and was sent to a Siberian Gulag for thinking too much. Fortunately for him, the labour camp was also home to many other thinkers, including physicists, chemists, engineers and mathematicians, who helped him continue the development of his theories. After Stalin's death and his subsequent release, he continued his research via an 'underground University' of like-minded scientists. Anyone could join, provided they analysed a few thousand patents!

After some 1500 person-years of research, including analysis of over 200,000 patents, Altshuller developed and refined the Theory of Inventive Problem Solving, or 'Teoriya Resheniya Izobretatelskikh Zadatch' in Russian, which gives the acronym TRIZ (pronounced 'trees'). What Altshuller discovered is that most patented ideas use a relatively small number of objective principles and are based on a finite number of physical, chemical and geometric effects. TRIZ is the condensation of this knowledge. He also found that 90% of problems had already been solved, often in another scientific field where the inventor lacked knowledge of these existing solutions. Another finding was that only 1% of the real inventions came from real scientific discovery (32% of inventions are from personal knowledge of the inventor, 77% are from within the company and 95% are from within the industry).

At a recent conference it was stated that it might take 5 to 7 years for someone to get to be an expert in TRIZ. We are not going to try to make you an expert in this chapter, but by the end of the chapter you will understand some of the key principles and be able to use the basic TRIZ tables and lists.

TRIZ principles

In its simplest form TRIZ may be seen to represent some easy questions. These are represented in this book in various ways.

As TRIZ contains generalisations of many principles, the first step is to create a standardised abstract model of your problem that fits into one of the TRIZ models for which it can offer a generalised solution which you can then interpret for an answer to your particular problem, as Fig. 5.1

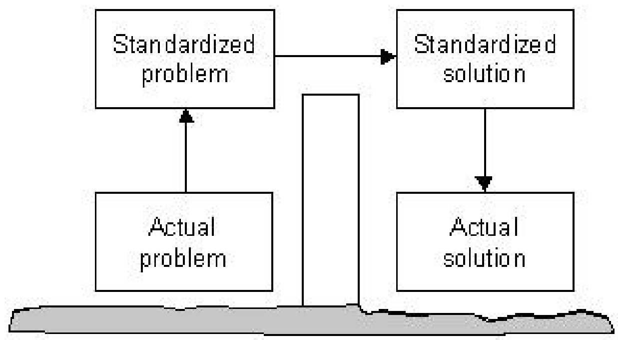


Fig. 5.1 Getting over the invention wall

This is not too difficult as it is similar to how people normally approach many situations: first understanding the problem in terms of their own internal interpretations, then musing on approaches that they know about, then trying them out in practice.

Function

All parts of a device perform functions. Whenever something happens, a function has been performed. There are *primary functions*, which perform the main desired effects, and *secondary functions*, which support the primary functions (note the similarity with primary and secondary functions of Value Analysis in Chapter 1).

To find out what is happening, you can use chunking (as in Chapter 1) to either zoom in to the detail (even to the molecular level) or out far enough to see the big picture.

To identify functions, look at what is being done and the results of those actions. Results of an action produce change of some sort, which hopefully is what is required. To assess the change, it should be measurable, which means it will have a value and units, such as of heat, shape, motion, energy, *etc*.

Harm

In TRIZ, functions are either useful and hence desirable, or they are *harmful*. This is a slightly different use of the word ‘harm’ to normal English usage as it does not imply that anyone is hurt, simply that net value is adversely affected and that the harm should be eliminated as far as is possible. All financial costs are considered as harmful, as are things which cost in different ways, such as taking up time or causing people anxiety of any form.

Just as there are primary useful functions, there are also primary harmful functions, which are the main undesirable factors and hence become the first targets for removal.

Harmful functions are often unintentionally caused as a side effect of useful functions, and may be identified by looking at causal relationships, as described in Chapter 1.

The ideal solution

TRIZ asks you to think about what an ideal solution would be like. For example, if you have a hall where you want people at the back to hear you clearly, then an ideal solution might be where the hall itself becomes the amplifier, eliminating the need for a microphone. Although this may be considered silly, such consideration of *ideality* leads to useful attention to how the shape and surfaces of the room affect the transmission of sound.

A critical effect of considering an ideal is that it focuses thinking on functions, both useful and harmful, and how these might be enhanced or eliminated.

The ideal solution does zero harm and provides maximum desirable functionality.

Trimming

TRIZ invites you to trim away unnecessary devices by thinking about how some parts of the system may deliver the functions that currently other parts deliver. We tend to add a device every time we need another function. Many systems can be trimmed if we think carefully about how to deliver the functions we want.

A trimmed system not only costs less, it also has less scope for uninvited harmful functions to appear, and is thus doubly desirable.

A simple example would be an assembly where instead of screwing one part to another the shape of the parts allows them to be clipped together. Screw, glue or other fasteners have been trimmed away by changing the shape of the parts.

Substances and Fields

In all devices there are two basic elements: parts of the system, or *substances*, and the medium through which they interact, or *fields*. The substances can include parts of the system, such as wheels and cutting edges, and also external elements such as the atmosphere and a rock that is being drilled. The field may be mechanical connection, electromagnetic, hydraulic, chemical, acoustic, *etc*.

Problems often occur because either the parts interact inefficiently or they interact when they should not. By identifying these ‘substances’ that interact and the field through which they interact, you can discover where improvements are required and hence a focus for invention.

Evolution

TRIZ invites you to think about how devices and systems evolve. There are a predictable patterns of evolution that can be used as a focus for attention, as follows:

- *Increasing ideality*. The ideality of a system is defined as the sum of its useful effects divided by the sum of its harmful effects. The system can thus be evolved through increasing its benefits or by decreasing factors that either cause problems or add no significant value.
- *Improving interfaces*. Parts of the system work together better through improvements in the substance-field relationships.
- *Harmonization*. Where the system involves multiple vibrations or oscillations of any kind, unless they are harmonized, they will interfere with one another. This can include such as drills that vibrate at the harmonic frequencies of the target materials.
- *Completing the system*. All systems have a source of energy, parts that

use the energy to deliver the function of the system, a way of channelling the energy to the delivery function and a control system. A weakness in any of these may limit the whole system. The energy delivery system in particular can be problematic and is the subject of many patents.

- *Increasing dynamism*. Things that were fixed tend to become movable, to eliminate problems of them being fixed or to increase flexibility. For example, in aircraft, undercarriage became retractable and wings movable.
- *Inward focus*. As the larger systems problems are resolved, remaining problems tend to be at increasingly levels of detail. With physical problems, you thus tend to end up at the atomic level (which you can, of course, go directly to with simple science of Chapter 2).
- *Extending the system*. When a system has reached its ideality limit, further improvement can be achieved by combining it with other systems or adding new parts.

Contradictions

The heart of invention with TRIZ is the identification and resolution of contradictions. Indeed, Altshuller said that all inventive problems contain at least one contradiction. This changes inventing from ‘dreaming up ideas’ to finding and resolving contradictions, which is a far more structured approach.

There are two types of contradiction: technical and physical. Fig. 5.2 shows the structure of a technical contradiction. A desirable function A uses a second function B which has undesirable effects, either causing a third function C which is harmful or harming an existing function D. For example, you can evenly spread light over a large car park by having a tall lamp post but this requires a high strength post to hold the large light far above the ground. A, (distant light source) needs B (tall strong post) which leads to C (high cost) and D (difficult maintenance).

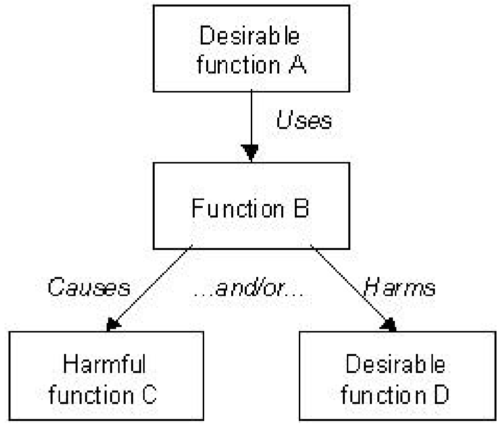


Fig. 5.2 Technical contradiction

Physical contradictions occur where the two opposing physical states are required, for example a blacksmith wants the horseshoe to be hot enough so the metal is workable, but he would also like it to be cool enough to hold. The 'harmful' solution is to use tongs, which are not as easy to use as fingers.

To address a contradiction, we can change the functions that cause harm or we can add functions that prevent or reduce the harm. Questions to resolve contradictions take the form of 'How else can I…?' or 'How can I reduce or eliminate…?'

So with the lamp post I can solve my problem of a heavy light source high above ground by placing a light mirror at the top of the post and beaming light from a source on the ground which is then reflected all over the car park! This solution also enables light bulbs to be changed more easily.

For physical contractions in particular, separation in time, space or scale often works. The blacksmith's tongs use separation in space, which could be reduced with protective gloves. You could also change the 'scale' of the working hands by using a large machine which can form the horseshoe quickly and easily.

When we do change the solution, it is a good idea to check that we have not created more harmful contractions (for example, 'How is the desirable function of 'being able to withstand rough treatment' affected?').

Using contradictions and principles

Appendices A, B and C detail Altshuller's key discoveries about inventions and can be used as a set of tools that can be used for scientific inventing. The approach to use is as follows.

1. Critical parameters

Use the table of 39 Parameters (in Appendix A) to identify critical parameters of your problem.

For example my lamp post problem had weight of a stationary object (parameter number 2) and length (parameter number 4) as critical parameters. I might also think about No 34, repairability (maintenance).

2. Contradictions

Identify contradictions between these parameters, where one parameter causes problems with another problem. In our example, contradictions include (a) that the weight of the light source combined with the distance from the ground causes undesirable force on the post, and (b) the distance from the ground makes it difficult to repair.

3. Find numbers of resolution principles

Use the Contradictions Matrix (in Appendix B) to find the numbers for the Principles that can be used to resolve the contradictions. For contradiction (a) in step 2, the feature to change is 'weight of stationary object' and undesirable result is 'force'. Looking this up in the matrix gives Principles 8, 10, 19 and 35.
For contradiction (b), weight against repairability, this gives Principles Nos. 2, 27, 28 and 11

4. Investigate the resolution principles

Use the numbers from the Contradiction Matrix to look up resolution in the list of 40 Principles (in Appendix C).

In contradiction (a), Principle 8 is 'counterweight', which might be achieved with a tension wires on the side of the post. Principle 10 is 'prior action' maybe we shield the lamp from the wind so it is less likely to be bent at an angle where its weight it too great a force on the post.

For (b) we have Principle 2, Extraction, extract the disturbing part of the system and place it elsewhere, so we have solved the problem by placing the light source on the ground. See if you can get other ideas from the Principles.

Simplifying the principles

We can reconstruct the 40 Principles of TRIZ to fit into a small number of groups and in doing so help you think about how they work. However, be aware that any grouping of this kind potentially simplifies to the point where something may be missing. If our grouping does not work well on a problem then go back to the original list.

Some Principles look like they may fall into two groups. Where this is true we have chosen what we found to be the most obvious group. For example, one might argue that use of composite material is about changing the physical structure rather than the chemical structure.

Try to see how these principles work together to solve problems. What you are doing is solving the problem by managing the action as it occurs, managing the time that things occur, designing how parts work together (as place or shape or structure) and how much action you get for your money (chemical action). If you can see these generalities then you can put them together in combinations which should lead to novel solutions.

Any of the groups may yield a solution to a problem as there are many ways to crack an egg. To crack an egg you can use Time (quickly) Shape (thin blade), Chemical Action (Phase Transition with lasers.), Place (slice off the top) and Physical structure (Porosity/Local Quality: suck the egg out).

Generic principles

Let us start with the group of Principles which are so generic that they apply to any situation, not just technology.

The Generic Principles are: Combination, Universality, Counterweight, Prior counteraction, Inversion, Partial, overdone or excessive action, Convert harm to benefit, Feedback, Selfservice, Copying, Inexpensive short life, Inert environment (5, 6, 8, 9, 13, 16, 22, 23, 25, 26, 27, 39).

These portray how we manage the action we have. If we wanted to manage the work of a football team all these could come into play. They suggest we consider ways of managing the interaction of the parts and the whole. They therefore can be used for any problem you want to solve. They are about protecting, controlling, and managing the environment.

Time principles

The principles for time are: Extraction, Prior action, Cushion in advance, Dynamicity, Mechanical vibration, Periodic action, Continuity of useful action, Rushing through, Rejecting and regenerating parts (2, 10, 11, 15, 18, 19, 20, 21, 34). These all suggest you consider when something is going to happen and how fast.

They are also fairly generic in that they can be applied to business or even planning a holiday. But they are placed in this group to help you think through all your time options.

Shape principles

There are three shape principles: Asymmetry, Spheroidality and Thermal expansion (4, 14, 37).

Take any parameter or feature of your device and think about how you can change its shape to a more complex shape along one two or three dimensions, and you can do this as it operates by thermal expansion.

These are more technological in nature but with a bit of imagination you can see parallels with more general problems. For example, what would an asymmetric policy for answering customer calls be?

Place principles

The two Place Principles are: Equipotentiality and Move to a New Dimension. (12 and 17). These suggest doing something where it is already or doing it in a different direction.

Physical Structure principles

The Physical Structure Principles areare: Segmentation, Local quality, Nesting, Mediator, Replacement of a mechanical system, Use pneumatic or hydraulic systems, Flexible film or thin membranes, Use of porous materials, Changing the colour, Homogeneity (1, 3, 7, 24, 28, 29, 30, 31, 32, 33).

These are all about how the various parts interact themselves (as opposed to how we manage their interaction in the Generic Group). They interact according to their properties (including colour) and the way they are connected.

Chemical Structure principles

The Chemical Structure Principles areare: Transforming physical or chemical states, Phase transition, Use strong oxidisers, Composite materials (35, 36, 38, 40).

They suggest changing how something is working by changing their chemical activity (what is happening via the bonds they form).

TRIZ Thinking

After working with TRIZ for a while, you will find its principles invading your approaches to solving problems. Here are a few examples of how TRIZ thinking can be used, starting with some problems from around the house.

The blocked sink

Recently, Graham's kitchen sink was blocked, so he went for the standard solution, a sink plunger, but it did not work. Solution number two was to use chemicals and hot water. After a long time spent emptying the sink, pouring hot water and dissolving stuff down the plug hole, the sink was still blocked.

So now Graham started using TRIZ thinking. He defined the problem as 'how to move solid substance in a tube'. The constraint was that he could access the substance only from the sink end or the outside pipe.

What was needed was to create a pressure wave in the fluid sitting over the blockage. The plunger did not create a good pressure wave precisely because it was flexible. Why is it flexible? To create a good seal at the sink. So here is our contradiction. The plunger must be flexible to create the seal which is needed to create the pressure but it also must be solid so it transmits a high-impact the pressure wave.

The next question was how to get a good seal without flexibility. This could be achieved with something which fitted the plughole perfectly. Looking around, a coffee mug was found (it had been there all along). It fitted beautifully and with a single sharp pull, the blockage was removed.

Mowing the grass

I have a bit of a problem mowing my grass. Not the cutting bit but the tidying up and putting things away. To run the electric mower I need power. I run the extension lead from inside the house to the outside. Fine. I cut the front lawn and need to move the mower round the back.

The problem now is that I have grass on my trousers and shoes and I need to take out the extension lead and move it to the back. So I brush down my trousers, take off my shoes, go into the house and remove the lead only to have to put my shoes on again and walk round the back with the mower. It takes such a lot of time and I never manage to get all the grass off me!

What does TRIZ suggest? My contradiction could be stated as Speed against Harmful factors acting on an object outside (9 goes up and 30 goes up too). As my speed goes up more grass gets inside the house, which is outside the garden (You have to think laterally sometimes!)

One Principle suggested from the table is number 1, Segmentation – or divide an object into independent parts, which could lead to my extension cable being divided into two parts. One runs from the house to the window and the second from that point up to my mower. Now I can disconnect the mower while out in the garden. And I have a second extension cable already set up for the back of the house (Principles number 10, Prior action and 26, Copying – cheap of course!).

So I can pack all away just once and take a bit more time getting rid of the grass before coming back inside.

An engine hatch

Here is an example of a problem we solved using TRIZ when building a large (six-foot wingspan) radio controlled model plane.

We had a fuel tank which had to sit at the front of the plane. It had three pipes to be connected to it. We could only place the pipes onto the fuel tank if they were long enough to extend into the middle of the plane where we had access from the top. But if they were this long we knew that they would risk being crushed as we pushed the fuel tank into the front of the plane.

This is a contradiction between the parameters of Length of moving object and Reliability. According to the Contradiction Matrix it can be solved by Principles 10, 14, 29 or 40, that is: Prior action, Spheroidality, Use pneumatic or hydraulic systems or Composite materials.

The last two give us ideas but involve changing the pipe more than we want to. Spheroidality is interesting in that we could think or how we might get the pipes to be rolled into a ball as they are placed inside the front of the plane.

We chose Prior action: we would build a hatch which means we can get to where we want to fit the pipes. But we then had a problem of how to secure the hatch without ugly and complex devices. We saw this as a Reliability vs. Waste of time contradiction. TRIZ suggests Principles 10, 30 and 4 (Prior action, Flexibility and Asymmetry).

We had thought of a hatch with simple straight sides across the nose of the plane. Asymmetry made us think of cuts at an angle in the thick balsa wood.

This also fitted with the Principle of Selfservice, how to get the plane to hold the hatch down. The hatch would now only slide across and could not pull out vertically.

But we had another contradiction. If we made the hatch so well that there was not an ugly gap it might bind to the plane through too much friction (Accuracy of manufacturing vs. Harmful side effects). Again TRIZ suggests Asymmetry and New dimension. So we extended our asymmetry so that the cuts across the balsa were such that we had a wedge-shaped hatch, as in Figure 5.3. Now the hatch binds only when it buts up against the body. We had one final problem to solve. How to stop the hatch sliding out? (as it is wedge shaped it has no friction once slightly away from the body). We felt we needed a 90 HOW TO INVENT (ALMOST) ANYTHING Mediator, something between the body and the hatch. We did not want it on the outside so we chose New Dimension (on the inside of the plane body).

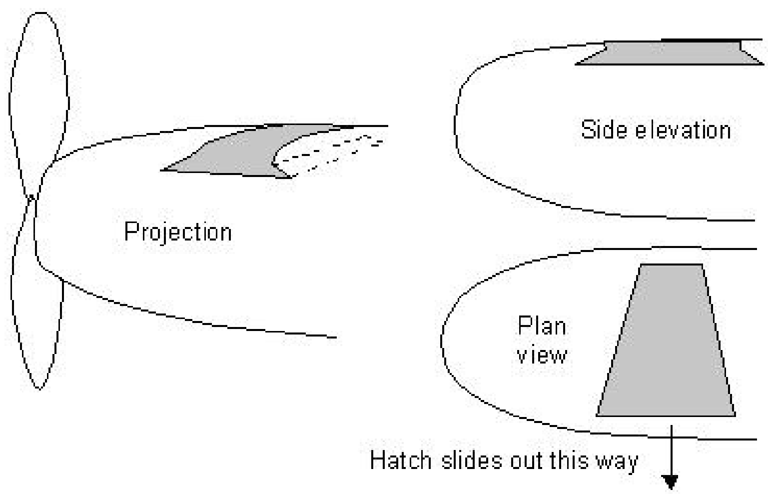


Fig. 5.3 Plane hatch example

How were we to fit a rod through the body into the hatch so the body and the hatch would be held together? We did not have a drill long enough for such a small hole, however. So we chose another TRIZ Principle: Selfservice..

We made the end of our rod slightly flat and put it into the drill and used the rod to drill its own and perfect hole!

Printing

Our printer would not print properly as the pages were not pulling through.

On looking at the situation, it was clear that the problem was the paper. It was a set of sheets of labels and the sheets were binding to each other.

Putting a single sheet in the tray did not work either, as the printer wheel could not grip the paper. So–we needed several sheets, but the friction was too great when we had sheets next to each other. The question was how to solve the friction problem.

One TRIZ Principle is to inset an intermediary object. Maybe if we inserted low friction sheets between the label sheets it would feed through OK. But then it would print on sheets we do not want to print on.

So we add a page of printing nothing to every other sheet. It worked perfectly!

Cleaning with TRIZ

For most people the task of washing dishes, if not done by machine, is a chore and one which you either resign yourself to or argue about who is going to do it.

We can improve the situation if we look in detail at the task, just as if we were thinking it through as a manufacturing process. We have to look for ways to change the unpleasant portions of the task, so that the "operator" is happy to execute the entire process.

The first step is to break the task down into stages as follows:

- Remove the leftover food from the plates (Not pleasant).
- Stack dishes and fill a bowl with water and dish soap.
- Begin dipping and wiping, maybe with gloves on and maybe not, depending on operator preference.
- Rinse.
- Drain and leave to dry, or wipe and dry, depending on operator preference and available space.

If we look at the whole operation, we can see that how it begins is nicer than how it finishes, except for the scraping of food off plates. The first plates are dipped in nice, warm, soapy water, which we can enjoy. Toward the end, the water gets pretty mucky and not so nice to use.

To overcome these "harmful" effects, we can use the principles of

Preliminary Action and Segmentation. Can we change something that will allow us to end up with almost clean water so the task is still pleasant? Can we break down this part of the task so that we complete the stages in a different way?

Our current process takes a plate and has a cleaning operation applied to it thoroughly removing all the dirty substances. For each plate this takes a given amount of time. Typically most of the substance is removed early on and the remaining time is spent to ensure that the entire plate is clean.

When we break this process down into two stages, we can see alternatives. Instead of thoroughly cleaning each plate, what if we partially clean the plate (one second at most) and dip a second plate into the clean water to soak? This option quickly and 'mostly' cleans all of the dishes, and leaves us with a set of plates that we can now enjoy fully cleaning.

An analogous situation is cleaning the car. The unpleasant job is getting rid of all that stuck on dirt. The nice part is taking time to carefully restore the pristine finish and to play with clean water while doing so.

Now we can see that there is an opportunity to enjoy washing dishes or the car by making the time spent mostly playing with the water and only partially doing the less enjoyable parts.

The dishwashing process can be further improved, by introducing a new stage. If we place a large paper bag in the sink and have a tap slowly running water into the bag, we can quickly remove most of the food from the plate with a quick wipe under the tap. The food is being stored in the bag and when all plates have been quick wiped under the tap, simply squash the bag down hard to remove excess water and place in a plastic bin for emptying out in the compost pile.

This combines the TRIZ principles of Preliminary Action again and Substitution (placing a bag in the sink so that the material can be removed easily). You may need to experiment a bit with the type of paper bag.

It may seem silly changing how we do the dishes, but surely it is even more so to continue doing something in a way that you do not enjoy, when you can inventively do it in a way that you can enjoy. This process really does work for most people who have tried it. And, when you have proven that the process of washing dishes can be improved, you can tackle other tasks like cutting the grass, hedges, weeding, *etc.*

The point is that TRIZ can impact everyday life. Mundane and difficult tasks can be improved if we can convince individuals to get out of the habit of doing things the way they've always done them, and look for ways to do them differently. Nearly every job can be improved and made more enjoyable if it's approached the right way, even something as simple as washing the dinner dishes.

The ‘no board’ whiteboard

Graham helped a company called Intralon, that makes whiteboards, to design and develop a future generation product using our inventive processes, including TRIZ. The whole process was completed in less than 8 months, from idea to manufactured product.

What do we have now?

Whiteboards are a very common device in businesses for writing and sharing ideas. A problem with this is that you cannot take what you write with you. A fairly common solution to this is the electronic whiteboard, which will record and print off what you write on it. The downside of this innovation is that the board is fairly heavy and big to carry around and costs a lot to produce and buy, which means it is limited to professional markets where the cost can be justified by time savings from the board’s use. The results also need to be photocopied for others to receive copies.

What do we want?

The first thing for us to consider is *ideality*. The question to ask is what we *really* want from such as device, keeping *only* what gives us a benefit. The answer is that we want to see where the pen has been, as soon as it has been there, and to be able to capture and share the resulting lines.

So we need a pen, a display device and a recording device. The goal is to get the pen to tell the recording device directly where the pen is. We can say that the pen ‘knows’ where it is (this may need some thinking about but is essentially true). An ideal solution is to get the thing that knows things to do the work, not some other device.

Solutions and contradictions

When we considered this, we saw that the pen is always visible although our brains are not good enough to track its movements to see what has been written over any period of time. So we asked, ‘Why don’t we just watch the pen and record where it goes?’ We could thus watch the pen with a camera of some sort.

A Contradiction here is the person with the pen may get in the way of any device watching the pen. A TRIZ principle to resolve this might be use of ‘Another Dimension’. So we could watch the pen from one side or up high, where the writer does not block the field of view of the watching device.

Another Contradiction is visibility of the pen to the tracking device. How well does the pen stand out in any environment? We could ask people to write in the dark and use a luminescent pen but the customers may not like this. The simple TRIZ Principle of ‘Changing the Colour’ works here, although by ‘Colour’ we mean change to Infra-red. So now we put a little infra-red transmitter in the pen so that is the only thing we watch and record!

The eventual solution, after a number of further sessions of identifying and resolving contradictions, is that Intralon have replaced a big heavy board with a simple inexpensive camera which detects only the Infra-red signals from the pen and (with a smart bit of software) passes this to a computer which records where the pen is.

The computer can now print off everywhere the pen has been (so recording any writing) or if used with a projector can display in light what the person is writing. So now, any wall becomes a whiteboard of any size and you even can choose whatever colour you want with the same pen!

So we have reduced cost, reduced weight (to a small, very portable box), made a system which will work any where, with almost any size of ‘whiteboard’, with electronic results that can immediately be emailed to anyone else. Not bad for just a few hours TRIZ-ing!

6 The 7-Step TRIZ Process

TRIZ can seem very complex with many new words and ideas which, when you are not fully comfortable with it, can make the development of new ideas somewhat more difficult. When building TRIZ, the Soviet TRIZ scientists had technology very much in mind, so most TRIZ examples strongly feature machines and mechanics. Sometimes it is not easy to see the process ideas embedded in the solutions for the devices being reinvented.

We have been asked again and again to simplify TRIZ and to make it applicable to non-technological areas such as services, marketing, software programming, and systems design rather than hardware design. So we applied the methods in this book to TRIZ itself, taking out the technical elements to leave the core process intact.

You can use this simple matrix approach as a start to learning and using TRIZ and then move onto the more traditional TRIZ approach. You can also, of course, use it for technical as well as non-technical inventing.

To make the process simple, a short list of steps is used. Practise Steps 1 to 3 on many different everyday things from the design of your kettle, to planning a holiday, to using your time at work. Then as you get to use these steps easily you will find the others get easier to use, too.

When you are familiar with the steps you can vary and extend the approach by jumping around inside these steps or go on to a more detailed approach.

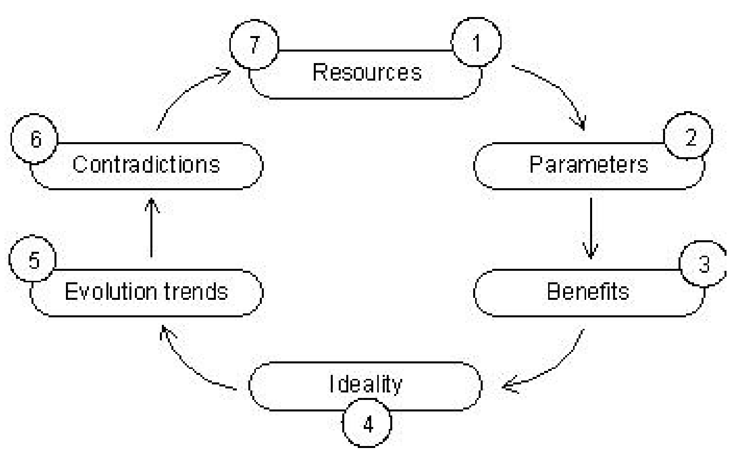


Fig. 6.1 The TRIZ 7-step process

Step 1: Resources

Step one is simply to list all the *resources* in the system as you see it at present. These are not just the physical items of the device (say, motor, wires, case) but also all other things that can carry out some function (that may change one or more parameters) of other things in the system. So the air may be a resource, or someone's shoes, or their hair which may fall out, or the dust, or the sunshine coming in from the window.

Current resources may currently exist in the system or things you can introduce other *optional resources* to it. You can also creatively identify *fantasy resources*. For example, to invent a different table current resources could include legs, feet, top surface, inner structure, edges, coffee stains, the floor, the walls and people's hands. Optional resources could include ropes, chains, electricity cables, mouse pads, ash trays. Fantasy resources could be ghosts, socks, garden gnomes and butterflies. The fantasy resources may not be immediately useful as they are but they may stimulate an idea which you can work on and make practical.

Put the identified resources as a list in the first column of a table, such as Table 6.1.

Step 2: Parameters

Now, for each of the resources you have identified, list all the *parameters* that are being changed or you might like to consider changing for each of the resources. These can include shape, temperature, texture, speed, rigidity, and so on. Note those which are helpful or useful, those which are harmful and those which reduce any harmful effect.

Try to include as many as you can although, if the list gets too long, you may choose just those that, after some careful thought, seem to be the essential ones. A way of organizing this is in a table, as in Table 6.1.

Resource	**Parameters**			
Leg	*Rigidity*	*Temperature*	*Curvature*	*Length*
Table Top Surface	*Texture*	*Porosity*	*Colour*	*Flexibility*
Feet	*Surface area*	*Rigidity*	*Asymmetry*	

Corners	*Curvature*	*Rigidity*	*Asymmetry*	
Edges	*Curvature*	*Texture*	*Colour*	*Heat transfer*
Top surface main body	*Rigidity*	*Heat transfer*	*Weight*	*Porosity*
Table Under Surface	*Texture*	*Asymmetry*	*Rigidity*	

Table. 6.1 Resources and Parameters for inventing a new table

Step 3: Benefits

Now carefully evaluate the *benefits* of changing each of the parameters. How does it improve or worsen the functioning of the device? If changing a parameter in one direction makes it worse, would changing it in the other direction make it better?

If you have a lot of parameters and resources the list can get very long, so think about the *primary benefit* you are seeking. A *primary technical benefit* might be durability or longevity, strength or speed, whereas a *primary non-technical benefit* might be customer loyalty, brand image, or simply profit or market share.

Go through the parameters of the resources you have and simply ask how they might improve or worsen the primary benefits you are seeking.

For example, a benefit changing the rigidity of a table leg is that you could change its height, although this might worsen its stability. This could lead to ideas of curved compressible legs with a locking bar to achieve stability, as in Fig. 6.2.

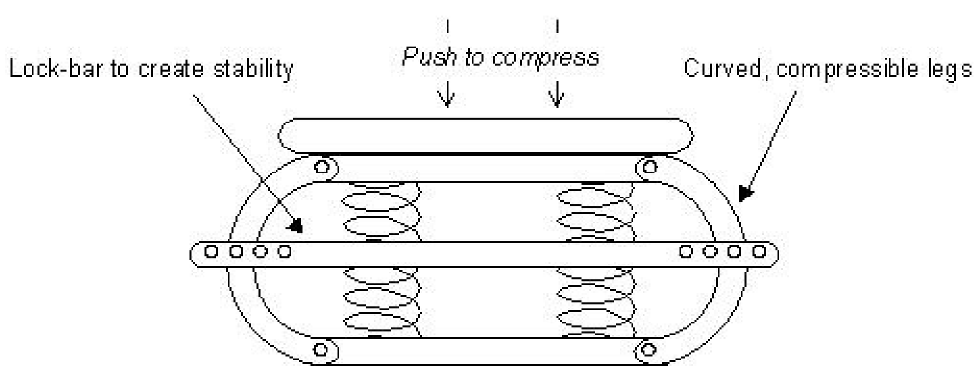


Fig. 6.2 Compressible table

You can use a range of scoring systems to decide how good potential solutions are. The NAF method is to score out of ten for each of Novelty, Appeal and Feasibility of real-world solution (although what seems infeasible is often just another inventive challenge). The VICE system scores on each of Value-added, Impossibility, Can-do-ability and Energy-for.

Step 4: Ideality gap

Along with considering benefits, consider how far from the *ideal device or wish* you are. Are there some changes you can make which lead to increasing benefit and reducing harm/cost? If you are a long way away from an Ideal device consider changing the device drastically in design so that it would function as the Ideal device. Consider doing this by trimming (i.e. removing or simplifying) the secondary functions that do not deliver the primary value.

A major goal in using Ideality is to simplify a system so that future innovations can be introduced with less things to consider. In a technical device the fewer parts there are the easier it is to add something later without so many variables to consider (everything has some kind of affect on everything else, especially in manufacturing).

In a non-technical system reducing the number of elements in the system gives you a faster potential change in the future. How close can you get to a virtual marketing campaign, one which delivers the function of the marketing without any actions needed by the marketing team?

For example, the ideal number of legs are zero, as the real value in the table is in the top. So what if there were no legs? How about a suspended table on a pulley system? When you were done with it, you could push it right up to the ceiling!

Step 5: Evolution trends

Examine your system in terms of the *trends of evolution* of your device. Any parameter which is simple or uniform along any physical dimension can be made to be more complex. Consider making it more complex in successively more complex ways. Straight can be changed to angled, to curved, to wave formed, to complex wave formed, to matching wave formed to mismatching wave formed.

Also think about how the time dimension has changed and might change. What if you make things shorter or faster, more frequent or occasional?

Consider making it more complex in more than one dimension, if necessary playing with ideas for all four dimensions. The *trend for trends* is to slowly, step by step, make each parameter one stage more complex, from uniform to linear change to curvilinear change to complex change.

A common evolution trend is for one parameter to change, then a second and then a third and so on. And the final trend for trends is to change your parameter in just one dimension, then two, then three and finally in all four dimensions, including time!

A technical trend might be where chocolate which was solid when sold, then segmented, then has voids (holes in it) then has things in the holes. A non-technical trend could be the shift from role based teams ("solid" single functional units) to complex teams which may then change to segmented, nested, flexible and asymmetrical. Software design has followed some of these trends, with the change from sequential to parallel processing.

Step 6: Contradictions

Consider the *contradictions* in the system. As you improve one function, does another get worse? If you are not sure, then imagine magnifying the 'improvement' many times. For example, rather than making it 10 times faster, make it 10,000 times faster! This method can help to make the contradiction really stand out.

Now try to solve that contradiction by imagining you really have to make it go that fast. Use the 40 Principles (Appendix C) and the evolution trends to guide you and give you ideas for solving this contradiction. Do not accept compromises!

You can use the 40 Principles simply as a creativity list or you can use the Contradictions Matrix (Appendix B) to find principles used by other inventions in this circumstance.

The most powerful use of contradictions is to create them in your imagination. If you thought about how your device might change if something was changed by 5 or 10%, it might well be difficult to imagine what would happen. But if you magnified the change to 1000%, the effect should really stand out.

You can also think about how you might vary the *conditions* in which your device will operates in order to challenge how you could improve it further still.

For example, a contradiction with a suspended table is that to wind up the table you need a flexible suspension, yet for stability you want rigid suspension. Perhaps you could use a hydraulic system which becomes rigid when it stops? What if the table-top was liquid-filled?

Using the Contradiction Matrix, we can change 3 (length of moving object) with the undesirable 13 (stability of object). This offers the following principles:

1: segmentation (telescopic system?)

8: counterweight (balanced folding system?)

15: dynamicity (use the potential energy of raised table to propel in a rigidity device?)

34: reject/regenerate (use wires to lower and add snap-in stabilizers?)

Step 7: Resources again

Now consider all your resources again. Zoom in and Zoom out again and again to see how you can move your design towards the ideal solution and solve all of your problems.

You may find yourself with another problem at a more detailed level. No problem! Just swish around the loop to step 1 again.

For example, zooming into the suspended table, we might look at a seal in the hydraulic lowering system, as in Fig. 6.3.

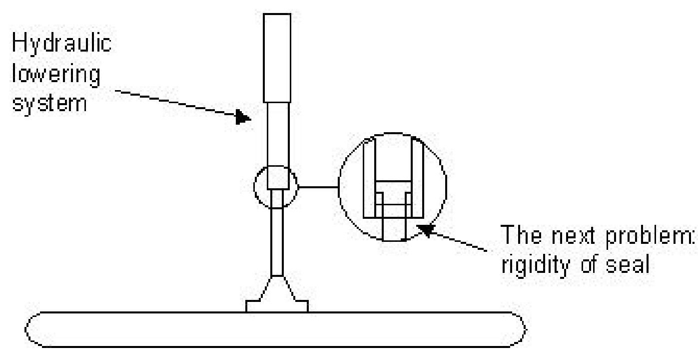


Fig. 6.3 Around the loop to the next level of problem

Part B: Psychobabble

Quick: What is the second most difficult thing in the world to understand? Other people, of course, because the most difficult thing to understand is ourselves. Using our brains to understand our brains is a reflexive twist that sometimes threatens to turn us inside out, but it is worth the effort, as our brains are the only real tool with which we can invent.

Part of the problem is that our minds are remarkably good at self-defence, throwing out potential new ideas with a deft dodge or even a more terminal twist of the knife. We constantly babble away to ourselves, whispering dire consequences that deny our creative possibilities. We thus need to learn to use the internal arts on ourselves, smoothing past the inner critic to rediscover the creative potential that has become dormant in so many of us.

The first step on this path is to throw back the covers and take a peek at what lies (in all senses of the word) beneath. As with our playing with simple science, the imperfect view that we gain sure beats no view and offers us a whole raft of tools with which to prise out the seeds of ideas that we can turn into the great inventions of tomorrow.

7 How the Brain Works

If we are to really understand how to invent anything, we need to go back to basics in thinking as well as in science—and that means understanding something about how the brain works. Thinking about that blob of grey matter inside your skull can be rather disconcerting, but we will not be side-tracked by metaphysical debate; if you have private views on spirituality, we will not be challenging them. Suffice it to say that if there is a human spirit that inhabits or constitutes our minds, it is way beyond the simple science of synaptic connections.

If we were to present our descriptions of the brain to experts, whether they were brain surgeons or psychologists, there would be many challenges, particularly of the kind “but it is much more complex than that!” But we are not trying to get you to be brain surgeons or psychologists. We are describing the brain in a simple way so that you can hopefully understand enough about how it works to use is in different ways for different purposes. Even if all you do is realise that you can change how you are thinking and move from focusing-in to crazily-creative and back again, and do this with a sense of purpose then we will have achieved our purpose. It is your machine so use it!

A quick history of brain science

The brain is, in many ways, the last frontier of modern medicine and despite many years of research much of its functioning is still something of a mystery.

Beginning our history with the ancient Egyptians, the brain was not thought to be very significant for the journey after mummified death, and their embalmers scooped it out down the nostrils and threw it away. The Greeks had a greater regard for the brain, knowing that this was the place where thinking occurred, although they concluded that the mind and spirit existed in the internal cavities of the head. This inextricable mixing of body and soul continued until Descartes, the 17th century philosopher and mathematician (founder of Cartesian logic), concluded that the physical body and the metaphysical mind/soul were separate things.

The brain started to get more attention in the renaissance from such notaries as da Vinci, who mapped much of the human body, and in the 18th century, along with the discovery of electricity and Galvani’s experiments with frog’s legs, the nerves were identified as ‘wires in the body’.

By the mid 19th century, the functions of various parts of the brain were beginning to be identified, often through observing the location of brain injuries and the resultant impairment. Other discoveries came through gruesome experiments, such as the removal of a dog’s cortex to show that as it could still walk, the motor parts of the brain were lower down.

Even in the modern day, brain surgeons still find their way around by prodding bits of the brain and asking the conscious patients what they feel. Although they know approximately where many functions lie, they do not know *exactly* where, and a short distance can separate very different motor or cognitive areas.

The real parts of the brain

The brain is made up of three main parts. The bit that we usually envisage when we hear the word ‘brain’ is the cortex. This is the crinkly big walnut at the top that often features in biology lessons and science fiction films.

The cortex does a great deal of processing, most of which we are entirely unaware. It is a curious paradox that although it seems like this is the part that makes we humans very intelligent, but if it gets damaged it often seems not to have much effect! It is highly connected to all the other parts of the brain and interacts frequently with them.

You might think that if it does all this processing of information then what it does reflects mostly the input from our senses. But the latest research suggests that in fact what it processes is as much influenced by what the other parts of the brain suggest should be there as what is there. In other words if you so strongly believe you will see a ghost (or your partner when out on an illicit date!) then that is what you will see. In fact, in order to deal with the complexity we have to deal with, it seems likely that the brain is constantly predicting what you see and processing what it thinks you will see before you see it. We live mostly in the world of our imagination and only when the real data coming in hits us very hard will we take that much notice of it. This helps to explain why creativity can be difficult without help: you do not even see the creative idea because you are not expecting it.

The rest of the brain is made up of a number of individual parts, some quite small, although size is not an indicator of importance. These parts are smaller than the cortex but are much more susceptible to damage. You can think of these as the main process managers. If they go wrong you are in trouble.

The limbic system or ‘leopard brain’ contains emotional controls and basic reactions such as the fight or flight response.

Below the leopard brain is the more primitive ‘lizard brain’ which controls basic functions such as breathing, digestion and circulation. To make a nice set of three ‘Ls’ the upper cortex gets called the ‘learning brain,’ reflecting that this is where we consciously think, learn and create.

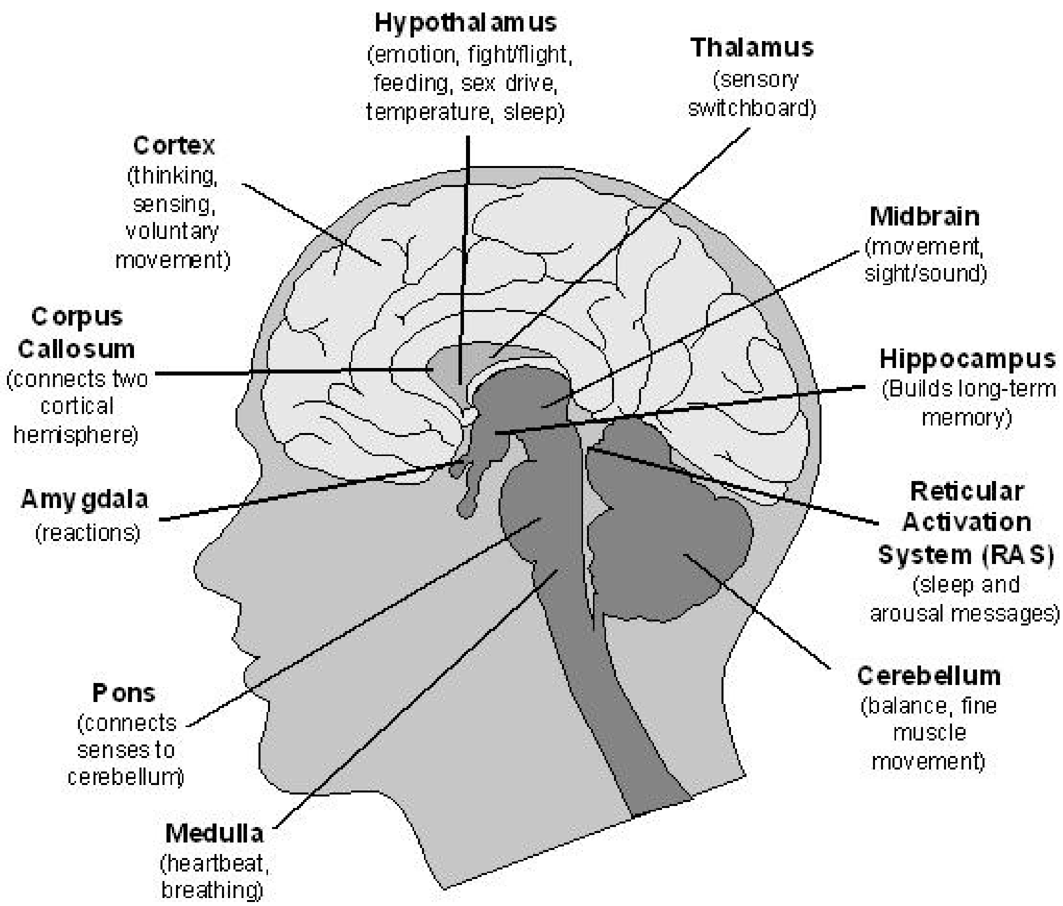


Fig. 7.1 Bits of the Brain

Some, but not all, of the more interesting parts of the mid and lower brain are as follows:

Hypothalamus

This is a little powerhouse in the middle of the brain which houses many of the basic animal drives, including the ‘four Fs’ of feeding, fighting, fleeing and fornication. It is also affects temperature control, sleep and emotions.

Being outside the cortex means that all of these potential inhibitors of creativity are outside of our direct conscious control, and can (and do) interrupt us at the most inconvenient moments.

Thalamus

All senses except the sense of smell, which goes straight into the brain, pass via the thalamus, which acts as a communications centre, passing information to various parts of the cortex. The route from the outside world to our conscious perceptions of them is by no means direct.

Hippocampus

Long-term memories do not go directly to the cortex, but are laid down by the hippocampus. It does this by replaying experiences to the cortex, including in dreams.

Amygdala

This little button-like system acts as a bypass to the conscious mind, causing us to react unthinkingly to such situations as a falling branch or child tumbling into a river. When people say, “I just didn’t think about it,” they are probably right. It also drives many of our fears, causing primitive and phobic reactions.

How we think: Patterns of the mind

The basic cells of the brain are called neurons, of which we start life with about 100 billion, which is quite a lot. This is just as well, because we then proceed to lose about 100,000 of these each day for the rest of our lives. That adds up to about 37 million per year and around 3 billion over a lifetime. Older readers will be delighted to hear that this is a long way from being the main cause of any senile decay. In fact our creativity and intelligence is not so much connected with the number of neurons we have at any one time but, as we shall see, *what we do with them*.

Reaching out to communicate

Although they come in many shapes and sizes, a magnified single neuron (Fig 6.2) looks like an alien from another planet. From its central cell body, an *axon* stretches out as a long-distance nerve fibre, communicating with other neurons, muscles or glands through its set of *terminal buttons*. Other protuberances are called *dendrites*, reaching out to listen to other neurons, ready to connect up in the vast Internet of the mind.

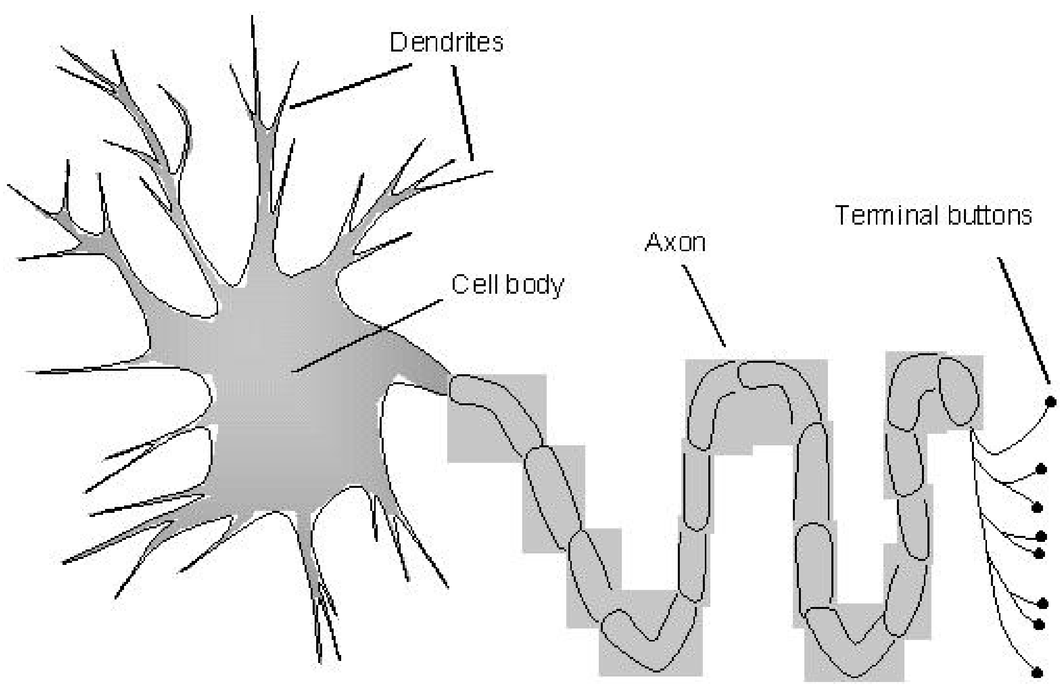


Fig. 7.2 A neuron

Neurons communicate with one another through a combination of electricity and chemistry. A neuron at rest has a net negative charge. This attracts the (mostly) sodium ions outside the neuron into it. This causes another change which results, about one millisecond later, with the ions being pumped back outside. The voltage on the cell thus swings up and down and is the ‘firing’ that is the basis of communication between neurons.

When a terminal button of a neuron gets close to the receptor areas on a dendrite of a second neuron, it does not quite touch, but leaves a gap known as a *synapse*. When the first neuron fires, the electrical charge causes little containers in the terminal button called *synaptic vesticules* to expel the chemical they contain across the synapse and into receptor cells on the second neuron, as in Fig. 7.3.

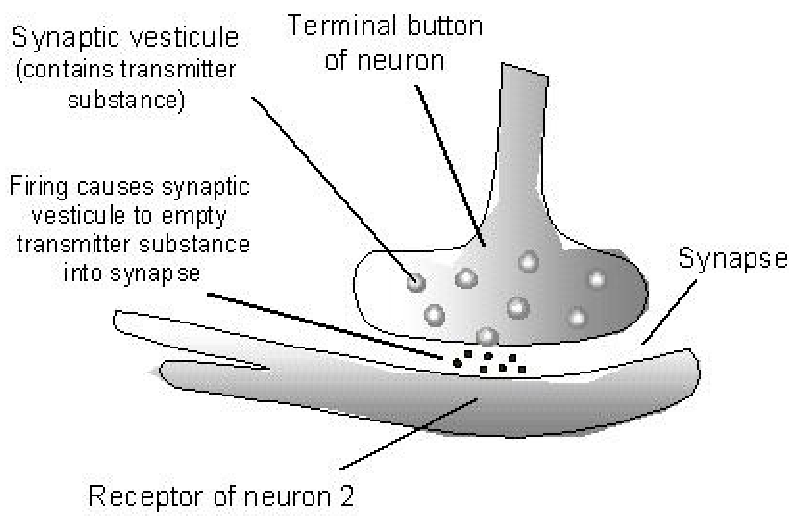


Fig. 7.3 Neurons connecting

There are two types of chemical that can be transmitted across the synapse: exciters and inhibitors. Exciters stimulate the second neuron, increasing the chance of it firing and inhibitors decrease the chance of it firing. If the second neuron fires, then it will stimulate a further chain of neurons to fire, creating a thought pattern in the brain.

There are various chemicals that are used as transmitter substances, such as acetylcholine and norepinephrine. Just to complicate matters a little, a single chemical can be either an exciter *or* an inhibitor, depending on where it is being used.

Just for interest: mind altering drugs often work by playing around with this synaptic connection. Cocaine and amphetamines, for example, prevent the reabsorption of norepinephrine, resulting in an extended period of stimulation as the brain fills up with incomplete synaptic transmissions.

Thought patterns

Thoughts, then, are simply long sequences of synaptic connection across chains of neurons, as each firing either excites or inhibits further connections. If you could attach little light bulbs to each neuron, you would see a non-stop thunderstorm of lightning flashing and flickering across the surface of the brain.

So with all this connecting, how do we learn? How do we remember things? Very simply because once a terminal button has fired against a second neuron, it becomes more likely that it will fire next time. Think of it like hot ink sloshing over a gently tilted waxen surface. The first time the ink runs, it takes a random course, leaving a little bit of a depression behind from the path that it took. Next time, different routes may be taken, but maybe a little more of the ink runs down the shallow path that has been eroded. When you repeatedly think about the same thing, the channel gets deeper and deeper each time it is used.

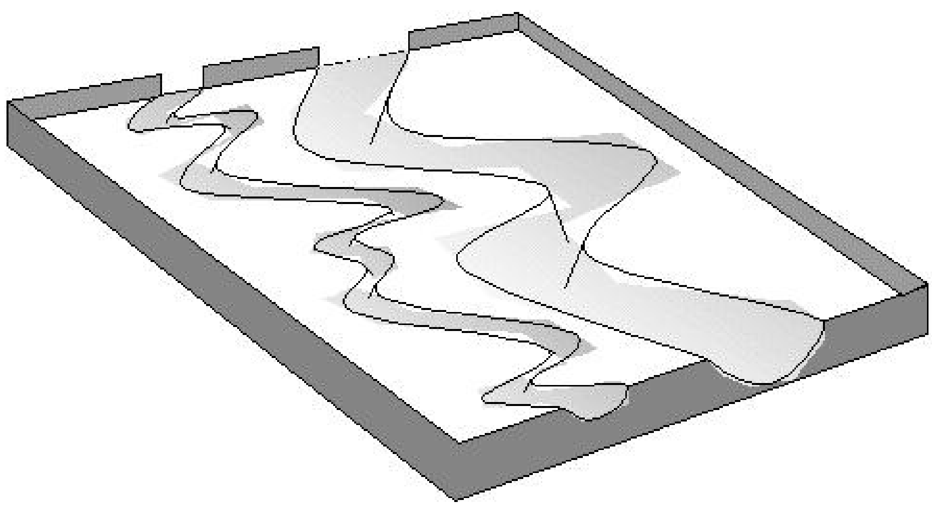


Fig. 7.4 Repeated thoughts are like channels in the mind

Before long you have a repeatable thought that is easier and easier to make. This is what learning and memory is. Virtual grooves in the brain from patterns of thought and perception are what enables us to repeat experiences, using the things that have worked best for us in the past.

In practice, the landscape of the brain is more complex than the wax example as multiple pathways can pass through a single neuron and one neuron can fire more than one subsequent neurons. A single neuron can thus take part in many thoughts, resulting in an almost infinite number of possible thoughts and memories.

A new thought, then, is quite a significant event, as it is too easy to fall into pre-formed mental patterns. Being creative and inventing things is about thinking differently, of forging patterns where there was none before. As biochemist Albert von Szent-Gyorgy put it, "Discovery consists in seeing what everyone else has seen and thinking what no-one else has thought."

An important point to remember from this is that the brain works by *patterns*. Whether it is patterns of recognition or patterns of behaviour, the past pathways tend to lead future responses, which is a critically important reason why creativity and innovation can be so difficult.

Memory patterns

When we commit something to memory, it is held as a potential pattern, a burning of a pathway across the brain. This is basically how we learned our multiplication tables: as we repeat “two times two is four” the pattern gets burned deeper and deeper each time until all we need to hear is “two times two..” for the start of the pattern to be found and “..is four” is simply a continuation to completion.

Things get a little more complex when we visually recognise a friend. When remember a person’s face or any other object, we do not remember it just as a fixed block of colours, but as a pattern. Seeing Jane with our stereoscopic vision, from multiple viewpoints, we remember the pattern formed by the relative sizes and positions of her major features. We can then still recognise her when her face is distorted into different expressions, when viewed from different angles and even when she is partially obscured, such as when she is standing behind a lamp post.

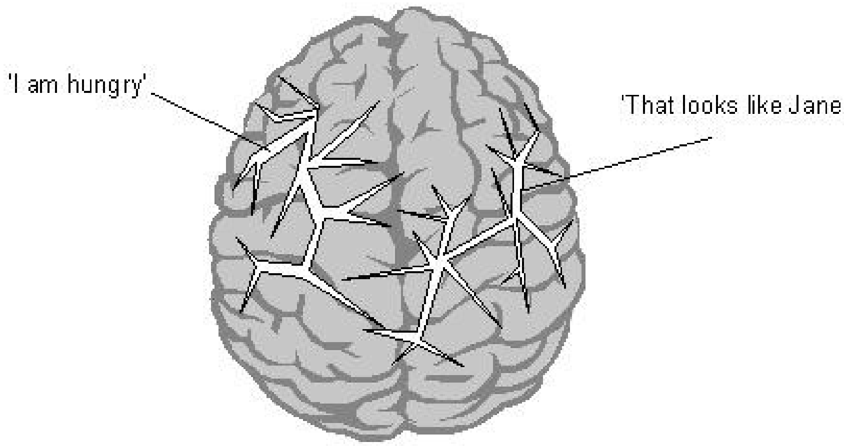


Fig. 7.5 Thought patterns

You can easily test this. Think of someone you know well. Now try to recall the detailed shape of their mouth or nose. Then go and look at them to test your memory: the chances are that you will not be entirely accurate, even though you may have known them for many years.

This is also why children draw people with large eyes and stick bodies: they are drawing the pattern they are perceiving, rather than the actual visual image. Even as adults, our pattern memories prevent us from drawing what is really there unless we are taught to look beyond our clever, but limiting system of mental patterns to the real patterns of hue, contrast and light.

The ability to remember facts is often associated with intelligence, but such activity simply involves saving and recalling patterns. Creativity is a different kettle of fish, as this requires us to create new patterns, new and original thoughts. Although creativity increases with intelligence (possibly due to increasing ability to use our brain), it is not unknown for it to drop off at higher levels of intelligence as experts become trapped by predefined systems of knowledge and reasoning.

In the end, we only have two things we can use to innovate: the mental patterns, the grooves of thought and experience, stored in our memories and the way in which we manipulate them. Manipulation also requires mental patterns of thought, and this book aims to give you those thoughts so you can use what you already know to invent what you really want.

Left-brain, Right-brain

The 'learning brain' cortex of the brain is not uniform in its use and different parts get used for different functions, such as speech and motor control (which is why brain damage can have different debilitating effects). This is accentuated by the way the cortex is divided into two halves, connected only by the bundle of nerve cells called the *corpus callosum*. Roger Sperry received a Nobel Prize in 1983 for his work that showed how these perform different functions. Where the left hemisphere deals more with language, logic and detail, the right hemisphere deals more with patterns and wholes.

The work of Sperry and his colleagues has led to the useful notion of 'left-brained thinking' as cold and logical and right-brained thinking as emotional and creative. Thus the Analytic invention methods of Chapter 1 can be seen as left-brained and the 'creative' methods of Chapter 10 as right-brained. A caveat to this: this is a tendency and the divide is not as clear as some would have you believe. Nevertheless, there is some truth to it and it can be a useful thinking model.

Classification: making sense of the world

To understand the workings of memory better, particularly in regard to innovative thinking, let us go up a level or two, shifting gear in order better understand how we make sense of the world around us.

Chunking the world

When a baby opens its eyes, its brain is swamped by the riot of colour in the world around it. To understand this complexity, it gradually learns to break the world down, encoding it into separate chunks of information. Mother, father, food: each gradually comes to be recognised as a distinct and individual chunk of information.

We continue to manage the world's complexities by creating hierarchies of chunks. A leaf is on a branch, which is on tree. Thus we can focus in on our mother's finger-tip or hand, or chunk out to see the whole person as a single entity.

We can make deliberate use of this ability in innovation, for example by chunking down into the detail of the problem or chunking up to see the big picture. By changing our perspective, we see different things about the situation.

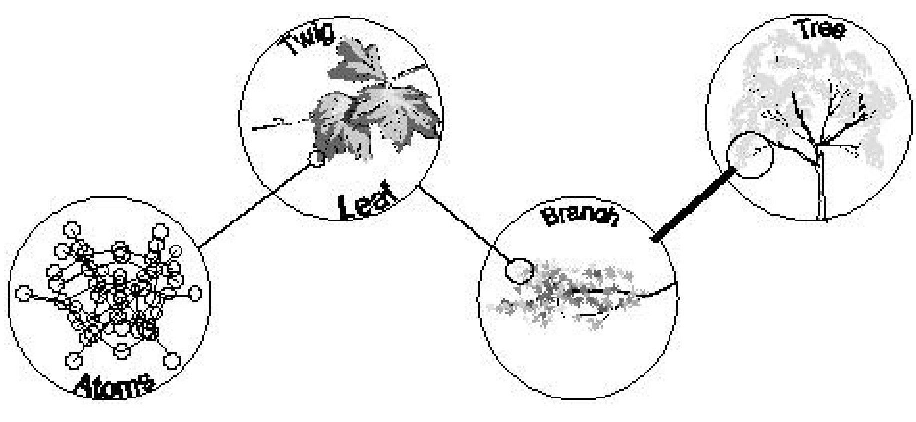


Fig. 7.6 Chunking levels

Languaging chunks

Words are perhaps the ultimate chunk, with each word *representing* a predefined chunk of experience. Words set us free but they also ultimately constrain our ability to communicate and describe the world around us.

Words helps us differentiate, sometimes in subtle ways, between chunks of information, and the language we use is indicative of our experience. For example, Eskimos have a number of different words to describe snow. There is also a native American tribe who have a single word for both ‘blue’ and ‘green’, and as a result of this is that they cannot distinguish between these two colours: they simply are seen as shades of the same colour.

When we experience something new, if we cannot describe it with words then we will have difficulty in making sense of it. Creating a new word is a significant event that effectively says, ‘This is so different and important, we need to mark its existence with a new symbol.’

Words are so important for describing, we even think with them. Our self-talk and dreams contain endless inner conversations as we ruminate about the world around us and plot how we might better cope with the outer confusion.

If our vocabulary is small or our ability to use words is limited, then this can also limit our ability to manipulate the verbal chunks that describe our experiences and hence constrain our ability to use them to create new combinations and concepts.

Short-term memory

Our short-term memory contains about seven ‘slots’ each of which can contain one chunk of understanding. Items in these slots have very low lifespan: have you ever been introduced to a person and then forgotten their name moments later?

Short-term memory is primarily verbal and phonological, where each chunk is represented by a sounded word. This has been shown by experiments where short-term tasks have resulted in confusion, for example between ‘pear’ and ‘fair,’ but not between ‘pear’ and ‘peach.’

When we are dealing with new or complex concepts, short-term memory very quickly becomes overloaded with details that we have not yet learned to combine into larger chunks. We often do not realise this when we are describing new ideas to others: these people cannot yet handle the ideas as single chunks and so must break them down into more fundamental components, only a few of which can be processed at one time.

Long-term memory

By the time things get put into long-term memory, they have often received a significant amount of processing to extract patterns and create meaning. A key type of long-term memory is thus sometimes called *semantic* memory to reflect the fact that it contains our interpretation of the real world, not what is really there. We also have *procedural* memory for ‘how to’ skills, *fear* memory for phobias (stored in the amygdala) and *episodic* memory of the films of direct experience.

It is worth keeping this in mind when we recall things from memory, that the chunks we recall are not necessarily what is true, even though we treat them as being complete and absolutely correct.

An effective long-term memory for creativity is one from which we can recall thoughts with reasonable ease. By learning to remember well we can build a greater resource which we can use to stimulate new thought, although a too-tidy mind can be detrimental when it will not entertain thoughts that do not fit into its predefined classification system.

Classification

When I see a pattern of a long, irregular vertical stem with smaller stems off it, I easily interpret it as a tree. This is very useful as it saves me from having to remember a separate chunk for every tree I see. Now I can recognise an *instance* of the *class* I call ‘tree.’ I can also create a hierarchy of classes, recognising oaks, beeches and sycamores each as a *sub-class* of the class of ‘tree’ and ‘plants’ as a *super-class* of tree.

This ability to see the basic patterns in similar items and consequently create generalised descriptions enables us to significantly reduce the chunks we would otherwise need to understand and manage our world.

When we do not have an appropriate classification box, then we have to either create a new box or approximate to the closest match. Creating a new box is a big thing as it disturbs the pattern of boxes we already have and admits that our previous system of knowledge was less than perfect. Too many boxes can also undermine the basic advantage of classification in the way that it simplifies our world. How, then, do we handle situations which do not fit into one of our existing boxes? Fortunately, we are pretty good at ‘fuzzy’ matching, fitting our experiences into a ‘good enough’ box, finding patterns that do not match exactly, but are sufficiently close to be acceptable.

Much of learning is about creating new classification boxes, along with appropriate rules for recognising and dealing with their contents. As our learning slows, we create fewer new classifications and we eventually may even forget *how* to create them. Creative people tend to have a large and expanding number of classifications, primarily because they never stop learning and finding new ways of viewing the world, out of which they can derive even more new ideas.

Rapid classification

We tend to have a desperate need to classify everything we experience. When I meet you, one of the first tasks I set myself is to push you into one of the boxes I keep for classifying people. Within seconds you will be in a box marked something like 'arrogant-and-aloof' or 'mother-earth-type'. Once you are in the box, ininif you try to get out, I will work hard to push you back in.

Although such classification systems enable us to simplify the massive level of complexity that we face in the world, our need to classify everything we experience can prevent us from seeing things in different ways. As Einstein said, "A great thought begins by seeing something differently."

The speed with which we classify our experiences will depend to some extend on our needs for control and certainty, as discussed in Chapter 7. When something is unclassified, it is uncertain and potentially threatening, so we move away from the uncertainty and into the nearest classification. If this is wrong, our deep need not to appear wrong (another block to creativity) makes us reluctant to change the classification, dooming us to a lifetime of misunderstanding.

Creative people tend to be slow to classify and are relatively comfortable with uncertainty. When they stand at the junction of such a decision, they look carefully down each classification road or even out into the undergrowth, exploring possibilities of descriptions off the beaten path. They may also put off the decision, exploring each path in turn or coming back later to peer and ponder.

Big patterns: mental models

The way we create internal patterns of the outer world stretches to complex models of behaviour and the whys and wherefores of how things work. A *schema* (plural *schemata*) is an internal pattern, a large-scale classification that contains many generalisations and assumptions. A friendlier term that we will adopt, first used by Scottish psychologist Kenneth Craik, is *mental models*.

For example, we have a mental model for each different nationality: the French may be assumed to be, amongst other things, self-absorbed, romantic connoisseurs of good food and wine, whilst the Germans are taken to be arrogant and bombastic, but with a great eye for detail. This makes it much easier to for us to decide how to deal with different peoples, even though the biases embedded in our schema may make this interaction inevitably unfair.

A mental model is a larger-scale pattern of understanding of the world, and may contain other models, classes and objects. These big pictures guide much of our interpretation of the world around us and can enhance our creative ability, but more often act to constrain our thinking.

Mental models are where we hold our learning. We experience the world, spot the patterns and then slot them into our mental models. A particular trick that we do after the 'aha' we experience when we learn something is called *closure*, where we effectively close the door on the mental model. After this, when we see something that will fit that model, we just say 'oh, it's just one of those'—that is, we *stop learning*. Because we can approximately fit an experience to the model and this is sufficient to enable us to predict what will happen, we ignore any further detail. It then often requires an unpleasant surprise for us to reopen the door to improving the model.

A simple technique for creative and inventive thinking is to stand back and recognise that we are using these imperfect mental patterns. When we realise what we are doing, we can then challenge the assumptions and generalisations held within the mental models.

This is summed up well in the poem by psychiatrist R. D. Laing :

Knots

"The Range of what we think and do
is limited by what we fail to notice.
And because we fail to notice
that we fail to notice
there is little we can do
to change
until we notice
how failing to notice
shapes our thoughts and deeds"

Association: Just like that

Classification helps up break things up into recognisable chunks, but we also benefit from stitching these chunks back together again, for example stringing words together into a sentence or remembering that flashing lights are often found on police vehicles. As we have discussed, our brains are a network of connections, not a set of pigeon-holes, and as such we have a powerful ability to think in highly connected ways.

Neural networks

Think of elephants. Then watch where your mind goes, through other associations you have with the word. Do you recall trips as a child to the zoo? Or Walt Disney’s ‘Dumbo’ or various jokes? Memories can be related in many ways often from experiences, or through secondary links, such as when elephants remind me of tigers, because a tiger scared me soon after I saw my first elephant at a zoo.

Fig. 7.7, where the thicker arrows represent more likely thought associations in the mental landscape, illustrates some of the effects of such networks. Likely thoughts may come from repetition, but these deep valleys can also be cut in a single slice by traumatic experience, such as the ‘elephant–zoo–tiger’ link. Thoughts may be deep hollows in which we can arrive from many directions, such as ‘Africa’. They may also be mountains, from which we can easily roll downhill in many directions, such as ‘grey’ (they can even be both at once!). Associations can be one-way or two-way, with a different thickness of arrow in each direction. The associations we have recently made may affect our choice of the next association, so ‘elephant–musty smell–horses’ may be likely but ‘zoo–musty smell–horses’ may be unlikely.

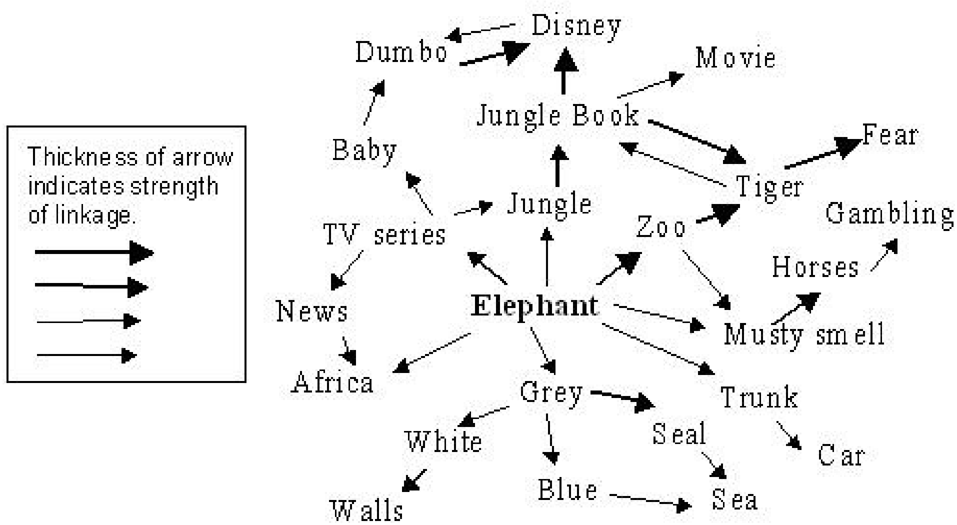


Fig. 7.7 Linked memories

One of the traps of creativity is that we start digging for gold, looking for an idea, and then get stuck in the hole as each new idea is constrained to be closely associated with the problem. Association keeps us in the hole and it can also lift us out, if only we loosened the bonds a little. This naturally jumbled linkage of thoughts is a gold-mine of stimulation that we can deliberately use to leap and link to more distantly connected thoughts and hence to new ideas.

Just like that

If I see a plant I have not seen before, to create a new classification I typically start with plants I know which are similar to the new plant. New classifications are often held as ‘like A but with differences X, Y and Z.’ A zebra is like a horse with stripes. An eel is a cross between a fish and a snake. Jane looks like Susan, but with black hair. This makes classification easier, although this connectivity can cause problems: if I change my understanding of horses, should that also change my understanding of zebras?

When we understand things in terms of other things, we are using analogies and metaphors. The use of metaphors is so common, we often do not realise we are using them, for example when we say an experience was ‘brilliant’, we do not mean it gave off light. At its most extreme, every word is a metaphor, as the word is a representation, not the actual thing.

The question, ‘What’s it *like*?’ is a powerful tool for bouncing ourselves out of uncreative holes. If I were trying to come up with ideas for a home security business, I might think start with, “A person’s home is their castle” and then link to “It’s like building an impenetrable wall around the house,” which could lead me to thoughts of toughened glass or a secondary toughened door (the ‘portcullis’) that comes down behind the normal door.

Associated emotions

When we commit something to long-term memory, the associations of the context in which we experienced it often get saved alongside it. If we remember a concert we went to, we may also remember details of the people around us, the sound of the music, the smells in the theatre along with the emotions we felt. If I saw a friend just after witnessing an accident, then thinking of the friend is likely to drag along the memories and traumatic feelings about the accident.

One of the unfortunate effects that this has on innovation is that we may well associate having creative new ideas with being told off as children (or even as adults) as we are taught to conform to strict social norms. As a result of this, creative thoughts can be associated with feelings of guilt and repression, resulting in rejection not only of our own ideas but also those of others. We seldom do this consciously or even remember the original incident.

If we do not take steps to understand and release the trauma of our past, it will follow us around like a trail of tin cans, clanking inconveniently and tripping us up when we least need such disturbance. These bad feelings are very good at protecting themselves: consider how the notion of psychotherapy or counselling of some sort is alien and frightening to many people, despite the fact that taking time to look inside yourself can be a powerful creative tool. The first steps on this path is to gain a greater understanding of how we work and how our inner mental systems can help or hinder inventive thought. This section of the book, although not a definitive tome on psychology is intended to help you along the way.

Invention so-what

So what have we learned in this chapter that will help us invent? Here are some of the key points to remember:

- If the primitive parts of your brain are in control, you cannot invent. Fear is a big creative block. Even desire may get you only what you want to see.
- If you have thought about something a lot, you are likely get stuck. Inventing often means breaking out of thinking ruts to make new thought patterns.
- Thoughts link together. The more thoughts you have had, the more thoughts you can have. *Any* thinking exercises or new experience is good for developing the ability to invent.
- Breaking things down into smaller chunks is a simple and natural principle for seeing things in different lights. Great inventions can come from changing just small parts of things. You can also chunk up to change concepts and purposes.
- We think in words. A larger vocabulary will enable you to understand more things and hence use them in invention.
- Do not try to take in too much at once: your short-term memory is a bottleneck. Creating concepts and models in larger chunks is a good way of handling bigger things.
- Avoid generalising what you see: find many ways to classify things. When things do not fit easily into one of you little classification boxes, neither push it harder nor ignore it. Just hold it and wonder about it.
- Find ways of understanding things: build lots of mental models. Each model is a lens which can be used to examine the world either from a different viewpoint or in greater detail.
- Build links between your thoughts, making unlikely associations that can lead to good ideas from many places. Ask ‘What’s it *like*?’ to get off the beaten path and find those weak associations.
- Watch out for emotions! They come attached to many memories and thoughts, and can lead to the lower brain taking over our better judgement.

8 The Motivating Fire

In the last chapter, we discussed the basic functioning the brain and how this is relevant in creative and inventive thinking. Now we are going to move up another gear to explore what motivates us, how we derive meaning, and consequently how we interact with the world.

An evolutionary background

A general theme of this book is that to gain a good understanding of how things work and hence how to make them work for you, it is very helpful to go back to first principles. Much of what drives us can be understood by taking the view from the evolutionary corner.

The basic thesis of evolutionary science, as Darwin described in his ‘Origin of the Species,’ is survival of the species. Quite simply, those species that are unable to survive the changing climates and competition for food will die out. More recently, Richard Dawkins elaborated upon this idea in ‘The Selfish Gene’ where he shows us to be little more than ‘gene machines,’ driven by their need for reproduction.

In evolutionary terms, the human species has not been around for very long at all. At four million years, we have still a long way to go to outlast the dinosaurs, who managed to survive around 135 million years. Although we may consider ourselves to be highly evolved, we may yet prove to be one of nature’s less successful experiments.

The deceptive brain

For most of our evolutionary history, our brains were relatively small, with a cortex that was much smaller than our current sizeable piece of grey matter. The reason for the fairly sudden growth of this complex and higher part of the brain where our conscious thoughts happen has been an area of debate for evolutionary scientists for some time.

One intriguing theory for this enlarged thinking brain is that a pre-historic human with a larger brain was more capable of tricking other humans and consequently gaining better access to food and mates. This successful principle was then continued, leading to people who could perceive the deception and create traps of their own. This spiral of deception and counter-deception is believed to be what led to us to develop our current massive brains.

Deceiving someone means thinking differently, being creative. It means finding new ideas that fall outside the repetitive pattern of habitual thoughts. This implies that our brains developed solely to enhance our creative potential, a principle that is certainly evidenced in the diversity and complexity of our spread across the planet.

The evolutionary rule-set

Neurophysiologist William Calvin has described the basics of evolutionary creativity in a set of 'Six Darwinian Essentials'. He also shows how the principles of human evolution can also be applied to other areas, such as ideas.

1. There is a pattern

In animals and people, this is the DNA patterns, held in the genes. This principle was taken further by Richard Dawkins when he described the 'meme,' which is a single idea or thought.

2. The pattern gets copied

With animals, this means reproduction. Your children contain copies of your genes. With ideas (or memes), copying occurs when other people learn of the idea.

3. Variations occur in the patterns

Your children are not exact photocopies of you. They may look similar, but they not only are made up of a combination of their parents' characteristics, but the genes do experiments along the way, mutating into different forms.

This happens with ideas too. When you tell them to other people, or even recall past thoughts, the received thought may be subtly or somewhat different from the original idea.

4. There is competition

A given area of land will support only a limited number of animals, plants and people. We compete both within our own species and between species for access to those things that are needed to survive and procreate.

Ideas also fight both one another and established concepts for the prize of development and use. Good ideas spread more rapidly as they are told and retold. Ideas which are weak or difficult to understand are given less consideration. When an inventor chews over ways of cooling down a room, established concepts (such as fans) compete with new ideas, for example using thermal materials for heat transfer.

5. There is a complex environment

The environment in which the species live will tend to favour some animals over others. For example, mountainous conditions will help scrubby plants which can survive in rocky outcrops and animals like goats which can get to these plants to eat them.

Different business cultures will also help different types of ideas. In an R&D environment, product ideas will thrive, whilst in a marketing group, new ways of communicating will be given more space for experimentation and trial.

6. Successful variants get varied more

When an animal mutates successfully, evolution seems to pay particular attention to it, performing additional experiments. Perhaps unsurprisingly, humans are the most rapidly evolving species. Out of interest, the second most evolved group are birds: the dominion of the air has given them a huge advantage in reaching food and travelling distances with which other species can not compete.

We can use the same principle in our inventions. If a line of agricultural thought on turning over soil leads to a new form of plough, further exploration along the same line could lead to an even better plough.

Basic drivers

As humans and animals, then, we have a deep and abiding need to survive and procreate. But we know there is more to our lives than that. Psychologist Abraham Maslow described his now-famous ‘Hierarchy of Needs’ in 1943, where he showed how we have prioritised layers of needs. Once we are reasonably healthy and safe, we start to pay more attention to what other people think about us, but if we fall sick, then all thought of achievements at work are forgotten; all we want is to get well again.

If we look again at Maslow's hierarchy, we can see two more fundamental drivers that underlie his five categories. As Fig. 8.1 shows, the lower-level needs are connected with our need for a sense of control and the higher needs are increasingly about our sense of identity.

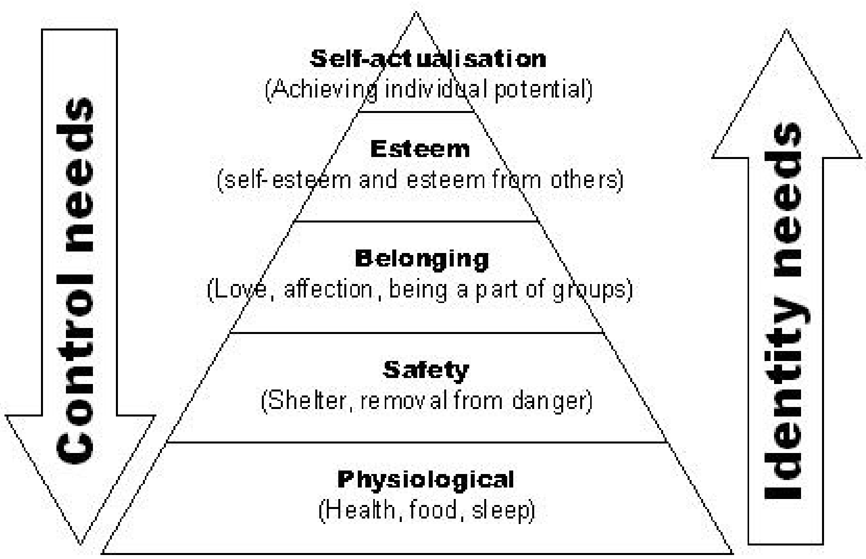


Fig. 8.1 Maslow's hierarchy

To make evolutionary sense, these needs should lead to the evolutionary goal of survival of the species. This is shown in Fig. 8.2, where a linked set of needs shows how achieving needs as described by Maslow and others leads to this ultimate goal.

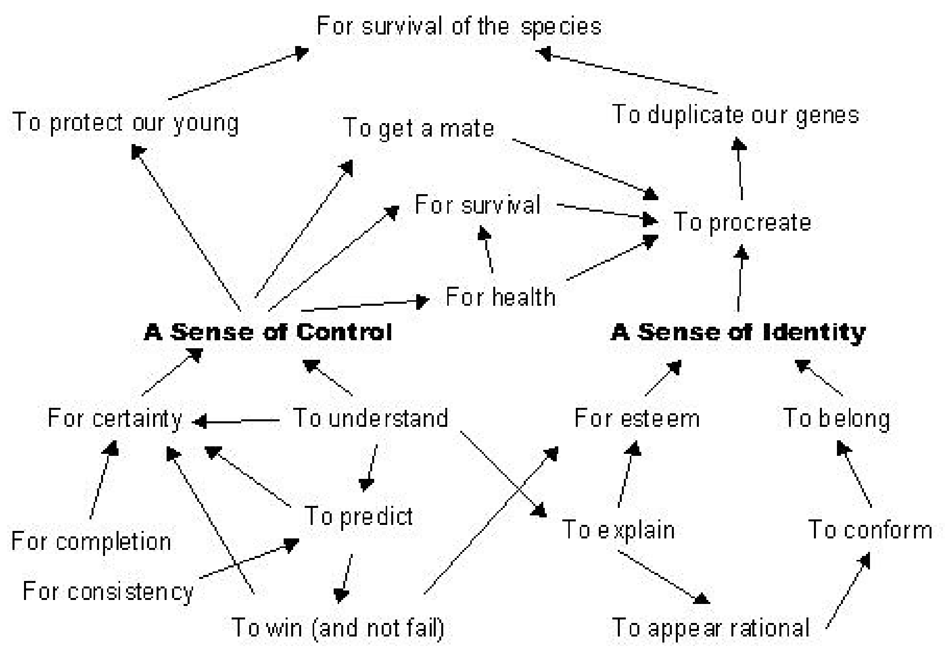


Fig. 8.2 Causal linkages of deep drivers

A sense of control

One of the most disturbing things about having a terminal illness, as those who unfortunately suffer from such afflictions will tell you, is the feeling of powerlessness, of being unable to do anything about it. Being unable to control the illness can be even more painful than impending death.

From an evolutionary standpoint, if we are in control of our environment, then we have a far better chance of survival. Our deep subconscious mind thus gives us strong biochemical prods when we face some kind of danger (see the side box ‘General Adaptation Syndrome’).

Let us look at some of the factors that affect our sense of control and how they also affect our creative ability.

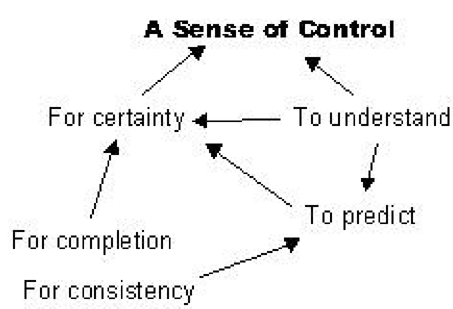


Fig. 8.3 Factors leading to a sense of control

The need for certainty

When we are certain about the world around us, we are in control; a reduced sense of control is highlighted by our feeling uncertain. Unfortunately, as John F. Kennedy said, 'There is nothing as certain and unchanging as uncertainty and change.' Despite this, many people spend their lives in search of certainty. Many psychiatric illnesses, from anorexia to compulsive-obsessive disorder, stem from the deep need for control and certainty.

New ideas, by their very nature, are uncertain. Unless we are a Mozart or Tesla, ideas do not come to us complete and certain. To think creatively requires that we tolerate ambiguity and keep an open mind. If we try to control our environment too much then we will also be reducing the chances of serendipitous discovery that has been the source of many great inventions. Deliberately creating uncertainty is a valuable creative technique.

The need for completion of

Does the above title bother you? Something which is incomplete is not certain and leaves us unsatisfied and seeking to resolve the incompletion. Writer of soap-operas and other instalment-based entertainment know this well. All stories can be viewed as nothing but a series of tension-creating incomplete scenarios, followed by satisfying completion, tying up the loose ends and giving a sense of control and that all is now well in the world.

We can make use the principle of incompletion as a powerful tool to prod our subconscious mind into coming up with new ideas. By deliberately giving it unsolved problems and half-complete answers, the creative tension that results can catapult valuable new ideas into our conscious minds, where we can evaluate, reject or utilise the ideas as appropriate.

The need to understand

If we understand the world around us, then we have a far greater chance of controlling it. Even if we cannot control it, we can make informed choices about what we might do next. The brain helps us do this, by giving us a little squirt of dopamine whenever we learn something, creating that satisfying 'aha!' or ‘eureka!’ experience.

One of the natural benefits of inventing new things is in the way that it shows us how we understand the world and can control it to meet our needs.

The need to predict

One of the benefits of understanding the world is that it helps us to predict, and hence control, future events. In our ruminating and decision-making we are constantly looking forward, trying to decide the best course of action to achieve our goals and avoid potential discomforts.

Creative thinking is not an exact science, and this can negatively impact our need to be able to forecast the future. It can also be beneficial, in that imaginative thinking can help us to find possibilities that we might otherwise not have found. Unfortunately, some of those possibilities might be less than comfortable, resulting in discomfort and either denial or more creative thinking to get around these negative effects.

The need for consistency

In 1957 psychologist Leon Festinger described a very powerful motivator, which he called *cognitive dissonance*, where inconsistent attitudes, concepts or ideas makes us feel uncomfortable. This drives us to such actions as seeking confirmation of any decisions we make and avoiding anything that might prove those decisions to be anything less than perfect and wise. When we buy a new car, we will happily read articles that praise it, but we will feel bad and discard magazines that show our decision to be unwise.

This can drive us to remarkably unhelpful actions, for example, if I believe myself to be uncreative then I will avoid any creative activity, just in case I am proved to be wrong. I will also reject many of the ideas I have for the same reason that the pain of dissonance now overcomes any potential benefit from using or proposing my ideas.

The General Adaptation Syndrome

In 1952, psychologist Hans Selye described the General Adaptation Syndrome (GAS), more commonly known as the ‘fight or flight’ effect. When we perceive a significant threat to us, then our bodies get ready either for a fight to the death or a desperate flight from certain defeat by a clearly superior adversary. It all starts in the back of the hypothalamus and results in:

- Our senses sharpening. Pupils dilate (open out) so we can see more clearly, even in darkness. Our hairs stand on end, making us more sensitive to our environment (and also making us appear larger, hopefully intimidating our opponent).
- The cardio-vascular system leaping into action, with the heart pump rate going from one up to five gallons per minutes and our arteries constricting to maximise pressure around the system whilst the veins open out to ease return of blood to the heart.
- The respiratory system joining in as the lungs, throat and nostrils open up and breathing speeding up to get more air in the system so the increased blood flow can be reoxygenated. The blood carries oxygen to the muscles, allowing them to work harder. Deeper breathing also helps us to scream more loudly!
- Fat from fatty cells and glucose from the liver being metabolised to create instant energy.
- Blood vessels to the kidney and digestive system being constricted, effectively shutting down systems that are not essential. A part of this effect is reduction of saliva in the mouth. The bowels and bladder may also open out to reduce the need for other internal actions (this might also dissuade our attackers!).
- Blood vessels to the skin being constricted reducing any potential blood loss. Sweat glands also open, providing an external cooling liquid to our over-worked system. (this makes the skin look pale and clammy).
- Endorphins, which are the body's natural pain killers, are released (when you are fighting, you do not want be bothered with pain–that can be put off until later.) The natural judgement system is also turned down and more primitive responses take over–this is a time for action rather than deep thought.

Unfortunately, we are historically too close to the original value of this primitive response for our systems to have evolved to a more appropriate use of it, and many of life's stresses trigger this response. This includes when a creative new idea makes us feel uncertain about things of which we previously were sure. The biochemical changes in our brain make us aggressive, fighting the new idea, or make us timid, fleeing from it.

In a creative situation, if people start to argue or clam up, this could be a sign of the General Adaptive Syndrome taking effect. Watch out for angry red faces, cold and clammy skin, signs of a dry mouth, increased breathing rates and jitteriness from activated muscles (in yourself, as well as others). If this happens, take a break or otherwise give up the creative efforts until things have calmed down.

If you see people suddenly, uncontrollably laughing at an idea it might just be this response and if so it could just be the idea you are looking for. So go for the ideas that are laughed at! Their brains are telling you that there is something to be scared of!

A sense of identity

Beyond the sense of control, we are deeply driven by our sense of identity, of who we *are*. 'I' is a capital letter, denoting the importance we place on our sense of individual self. As Descartes said, 'I think, therefore I am.'

The sense of identity appears early on in life during the 'terrible two's, when toddlers start to discover and assert their individuality. At this time, they typically cling to a single teddy bear or doll, through which they know their own identity (I am not my teddy). When this 'transition object,' as psychoanalyst Donald Winnicott called it, is removed, a part of their identity is lost, causing distress and tears. This pattern continues through our lives as we identify with our possessions and the things around us and feel bad when they are changed or lost.

Fig. 8.4 shows basic factors that affect our sense of identity and which are discussed below.

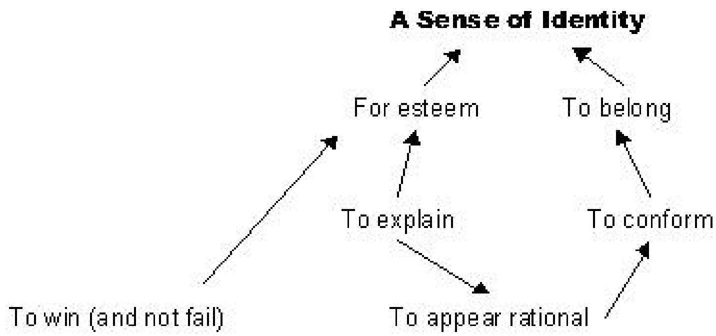


Fig. 8.4 Factors leading to a sense of identity

The need to belong

We categorise ourselves in terms of other people and groups. Evolution has taught us that it is beneficial to live in tribes, where we can share out the work of daily survival. When asked about yourself, you may well describe yourself in terms of your work and family relationships: ‘I work for AB Corporation.’ or ‘I am married to Steve and have three children.’

If we lost our job, it would not just be the loss of money (affecting our sense of control) that hurt us, but also the loss of relationships and feelings of being outside the company with which we have identified ourselves for so long.

The fear of rejection from the groups with which we identify is a powerful force and just the thought of this is enough to dissuade many people from ever taking their creative ability out of the cupboard where they have locked it for fear of its potential social effects.

The need to conform

One way in which we retain approval by other group members is by preserving *their* sense of control, which translates into conforming to group norms. This may include dressing similarly (from jeans to suits), using jargon (from street slang to professional terminology) and behaving within and outside the group in specific ways.

Loneliness can be a terrible feeling and the threat of rejection or even simple disapproval by group members is a powerful incentive to conform. Even the stereotyped image of the ‘lone inventor’ (remember how we categorise people) who is shunned and laughed at for his or her social ineptitude is enough to dissuade many people from taking any actions that might get them thought of as inventive.

We also conform to our own self-image; ‘I am not creative’ or ‘I cannot invent things’ are powerful affirmations that can effective prevent us from even trying to disprove them.

The need for esteem

Once we are established within a group, our next step is to climb the ladder of popularity, seeking the esteem of other members of the group. Esteem can be a slippery slope, and any form of behaviour that threatens the group can result in a loss of social position. We are so driven by the need for approval of others, we tend to avoid activities such as making creative suggestions that might cause discord of any kind.

It is critical if you require approval or agreement when being creative around other people, whether it is coming up with new ideas or showing them your inventions, to get social permission, for example by explicitly stating that this is an new and uncertain situation.

The need to appear rational

If I am not rational, then this means that I will upset the need for predictability of the people around me. Where the creative process is not understood, then anyone speculating about ideas may appear to be irrational, leading us to avoid such situations. As with most creative situations, the social effects require very careful management.

The need to win (and not fail)

If I succeed at what I do, then I will not only increase my sense of control, but should also increase the esteem I receive from other people. This need is illustrated when our favourite football team wins and we say ‘We won!’, bringing closer our identity with the team, but when the team loses, we say, ‘They lost,’ now distancing ourselves from the failure of team.

Inventing and being creative is, by necessity, a numbers game. You must expect failure on the road to success. Thomas Edison, who held over 1300 patents, failed many times when inventing the electric light bulb. When criticised for not producing early results, he replied, ‘Results! Why man, I have gotten a lot of results. I know several thousand things that won’t work.’

The need to explain

If I can explain my own actions, then I can appear rational. If I can explain other things, then I can appear to be an expert and thus increase my standing with other people. Coupled with the needs to appear rational and to win, this often appears in the form of blaming. When something happens, the first response of many children (and adults, in more subtle forms) is, ‘It wasn’t me,’ followed by an instant theory of what happened, attributing the cause to other people and events.

Creative thinking can, at times, be vague and unclear, for example when we are following a hunch, which is just an unexplained idea from the subconscious (which, unfortunately, does not always help us with our personal needs). Good ideas have been likened to jokes, whereby you are in the dark until the punch line arrives; until the idea is proven, you cannot be sure how good it really is.

The need for novelty

If you were very rich and admired by many, would you be happy? The evidence seems that this is not so. Rock stars and movie moguls who achieve fame and fortune tend not to sit on their backsides for long. They keep working, even to the point of spending away their fortune and achieving disrepute rather than more fame. So what is going on?

Viewing this situation through the lens of evolution, if we stood still when we had achieved our goals, we would be overtaken. Evolutionary biologists call this the ‘Red Queen Effect,’ after a situation in Lewis Carroll’s ‘Through the Looking Glass,’ where the red queen admonishes Alice, ‘It takes all the running you can do to stay in the same place. If you want to get somewhere else, you must run at least twice as fast as that.’ Evolution is a race: if the competition evolves faster than you, you are as good as dead.

The need for novelty is the fuel of creativity and innovation. We are impelled to create and change, even if we are otherwise comfortable, and nature has provided us with several drivers to ensure that we do not stand still.

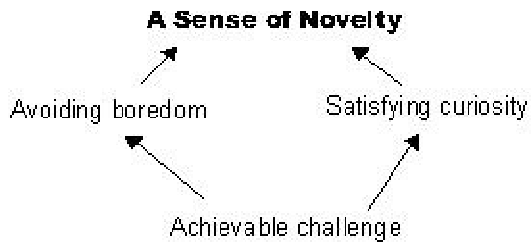


Fig. 8.5 Factors affecting our need for a sense of novelty

Boredom

Repeating the same action time after time, as many factory workers know, can be deadly dull. Even when we go on holiday and are sunning ourselves by the swimming pool, many of us can only do this for a limited period before we have to get up and do *something*.

In a world-wide study of happiness, Chicago professor Mihaly Csikszentmihalyi discovered the work-leisure paradox, where when we are at work, we dream of being at leisure, but when we are at leisure, we are not as happy as when we are embroiled in some stimulating work.

Curiosity

If boredom pushes us away from doing nothing, it is curiosity that pulls us towards investigating new things. Children are born curious and constantly explore and test the world around them. Lewis Carroll's stories of Alice's adventures are all about curiosity (the word and it variants appears 52 times in his books). As Alice said, 'curiouser and curiouser.'

Unfortunately, the forces of curiosity are often overcome by the forces of control. The need that adults have for control and conformity lead them to suppress the sometimes destructive explorations of young children. This suppression then carries over into adult life and we learn to be very cautious about how and where we allow our inner child to express itself (see the side panel 'Transactional Analysis').

Achievable challenge

Mihaly Csikszentmihalyi, through his work on happiness, discovered the simple secret of success. The trick is to take on challenges which stretch you, but where you have sufficient capability, time and other resources to complete the challenge. He also describes the 'autotelic' personality, where people of all classes and positions have discovered the secret and set their own short-and long-term achievable challenges.

Creative and inventive situations are full of challenge, which can be made far more achievable when you understand the basics of how people and science work. This book, then, could hold the key to greater happiness and fulfilment in your life!

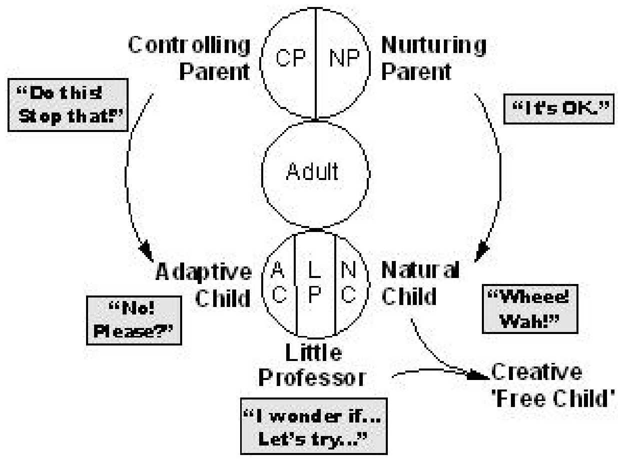
Transactional Analysis

Transactional Analysis is a branch of psychology, originated by Eric Berne in the 1960's, where the way we work is viewed through the lens of us having three main elements to our psyche.

The 'parent' part of us provides control, directing (through the 'controlling parent') and giving permission (through the 'nurturing parent') to our actions. Our internal parental models often come from our own parents and others in authority, such as teachers and managers. In particular, the parent gives or denies us permission to be creative.

Our 'adult' side is the assertive, mature persona who can understandingly tolerate the ambiguous and uncertain periods of creative activity and then even-handedly evaluate the new ideas and concepts.

Although we sometimes prefer not to acknowledge it, we also have an internal child which, which can operate in three different modes. The 'adaptive child' learns to live in the outer world, complying with or rebelling against the controlling parent. The quaintly-named 'little professor' is where our curiosity comes alive, investigating the world around us. And finally, the 'natural child' is driven by raw emotion and represents some of our deeper animalistic elements.



Transactional Analysis model

Together, the little professor and the natural child make up our creative persona. The problem is that this persona is very sensitive and is easily repressed by not only our own controlling adult, but also by the adult of anyone else around us (including complete strangers). It is thus critical when creating individually or in groups to mobilise the nurturing parent to protect and give the free child permission to explore and experiment.

Aesthetic needs

Perhaps most perplexing from the evolutionary viewpoint is our needs for aesthetic satisfaction. Shapes, pictures, colours, sounds, textures, patterns, all make us feel more or less good, but it is not easy to explain the value of these in the primitive sense. Nature uses a number of sensory signals in courtship rituals and other forms of communication to other animals–perhaps, having mastered all other species and with time on his hands, ancient man abstracted from these to create forms of pure pleasure to fill the duller moments (which he also did with sex).

Creativity is sometimes all about aesthetics, as in art and creative writing, sometimes purely technical, as when devising new propulsion systems, but is often some combination of the two. Engineers may look down on artists and artists ignore engineers, but both can learn from one another. The greatest inventors, such as Leonardo da Vinci were often both scientists and artists.

How the brain does it

At a fundamental level, the brain has a simple carrot-and-stick biochemical system of forcing us into action, as illustrated in Fig. 8.6.

Brain motivation starts with the subconscious limbic 'leopard brain' system, where incoming stimuli such as low blood glucose levels leads to a basic urge being passed to the cortex. The cortex then translates this urge into a desire for something specific, which gives us a conscious motivation towards a particular goal. When the limbic system detects that we are satisfying the urge, it rewards in two stages: first we get to feel satisfaction that eating is the right thing ('That's right! Keep doing that!') and then, when we have eaten enough, we feel fulfilled ('Well done! That's enough for now.').

Urges tend to have a feeling of 'emptiness', whether it be an empty stomach, the empty feeling of loneliness ('Get protection from others! Find a mate!') or the urge to create ('Prove yourself worthy!' 'Meet your goals!'). The limbic system needs to see *action*, such as eating, before it rewards the conscious mind (so the act of eating is satisfying, but intravenous feeding is not). The cortex is rewarded with internal opiates, such as dopamine, that literally *make* us feel good (yes, we are all junkies from birth!). The final reward of 'fulfilment' is the serene feeling that the emptiness has literally being 'filled until full'.

This urge-desire-action-reward loop also works for more complex drives, such as control and identity needs. We can utilize this effect in creative situations by consciously avoiding unproductive distractions and setting up desired goals that lead to urges and rewards for the actions we really want.

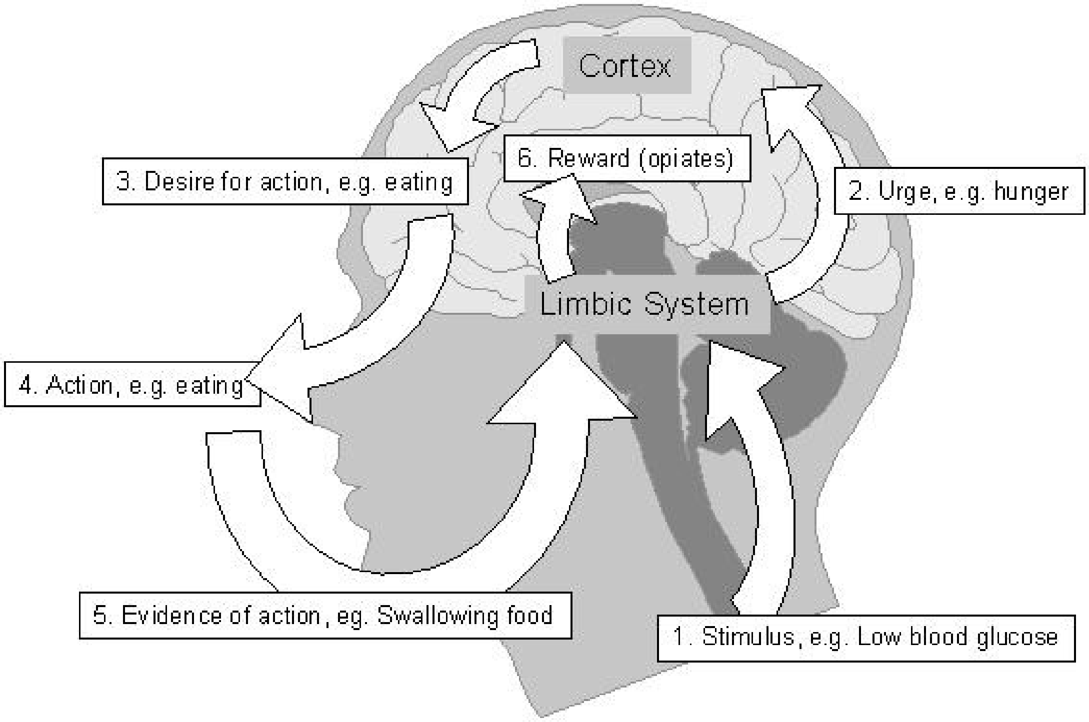


Fig. 8.6 The neurological carrot and stick

Emotions

Why do we have emotions? What is their evolutionary value? From a creativity viewpoint, emotions can cause significant blocks, making us shy away from activities that might gain disapproval from others or which have a high degree of uncertainty.

Emotions are emotions, moving and motivating us, forcing us into action. Fear, anger, love and desire, all impel us to get off our backsides and get on with our lives. The limbic urges propel us into action. We are not alone in having emotions, as many pet owners will readily agree. Many animals, although not self-aware, feel fear and affection, and also are affected by the General Adaptation Syndrome.

The problem with emotions is that we have very little control over them. They come from the deeper and subconscious parts of the brain, and lead to biochemical changes that literally force us to act in different ways. Alcohol and narcotics are simply chemicals that act on the brain, and their effect on our emotions are well known.

So what does this mean for creativity and invention? The uncontrollable nature means that it is difficult to 'turn creativity on' whilst the delicate nature of the creative state makes it easy for 'negative' emotions to knock us off course, effectively blocking creative thinking.

How to get into a creative mental state

Think of a time when you were being really creative, when ideas were just popping out of the top of your head so fast you hardly had time to explore them, write them down or tell other people. Remember the circumstances, the room you were in, who else was there (if anyone), what you were doing, and anything else that seems interesting, so you can see the full period of creativity like a section of a movie.

Now go back in that memory to just before you started getting creative: notice the detail of what was happening around you, what happened to start you down the track to that idea-full state. Was it something someone said? Was it something you thought? Was it a steady build-up or did the creative state arrive suddenly?

Remember what position you were in. Were you sitting or standing? How was your weight distributed? Were you moving or stationary? What were you doing with your hands? Step into that picture and put you body into the same position.

Notice what you felt in your body as you began to feel creative. Where did the feelings start? How did they feel? Was it a tingling, a buzzing, a numbness, or what? Slow the movie down so you can see, hear and feel every detail.

Now notice how the feeling changed and moved to other parts of your body. Sometimes people start with a feeling in their chest and it moves to their head or hands, or moving from their nose to their ears, or maybe something else. There is no right or wrong: it is simply how you felt.

Follow the progression of sensations through your body and notice the change in your emotional state, how you felt more and more creative, how the stream of ideas or even just one really big idea came unbidden to mind.

After you have that movie mapped out in full detail, play it again, noticing where the feelings start and where they end. Now add the amplifier: loop back the feeling from the end point to the start, so it begins again with an already-powered-up energy level. And as you tingle up to the creative peak, create a physical trigger by doing something like pressing a finger and thumb together or squeezing a fist. And keep repeating this, time after time, looping around and firing the trigger until you are *really* buzzing.

Then start generating ideas, and watch them flow…

And in the future, when you want to get more creative, just fire off the trigger, pressing together the finger and thumb or squeezing the fist to stimulate the response of how you felt so creative.

Emotional states

At any one time, we are in a mental and emotional ‘state’, being angry, happy, disconnected or attentive. We can also be in a creative state, where ideas flow easily to mind, where we are engaged and productive.

Can we change our own mental state, or are we at the mercy of subconsciously-driven emotion? The fact is that we can turn the tables, and with careful conscious thought we can affect our subconscious. The side-panel ‘how to get into a creative mental state’ uses the way that we store feelings alongside memories of events to re-access the creative state. It also adds a couple of other mental tricks to amplify the state and to create a trigger to help get into a creative state even faster by using the basic Pavlovian stimulus-and-response mechanism.

You can find many triggers which might work for you–consider the triggers used by these famous artists:

- Rudyard Kipling only wrote in black ink.
- Immanuel Kant wrote in bed, at the same time each day, staring at a tower outside his window.
- Schiller kept rotten apples in his desk and put his feet in ice-cold water.
- Ben Johnson drank lots of tea while listening to a cat purring and smelling orange peel.
- Wagner composed while stroking velvet while Mahler preferred fur.
- Beethoven poured cold water over his head.
- Brahms polished his shoes.

Goals

Despite having deep drivers, we do not go around the place saying ‘How can I satisfy my need for a sense of control?’ or ‘How can I gain the approval of my peers?' but we nevertheless act to address these fundamental needs. We do this through setting ourselves goals, through wanting specific things, whether it is to become a rock star or to scale more geographic peaks, or simply to find shelter from a storm.

So how do we create these goals? Beyond the more basic short-term goals such as not being run-over as we cross the road or finding a satisfying meal, the larger goals in our lives often only appear after deep musings and pondering about the world, as in Fig. 8.7. We sometimes try goals on like a suit of clothes, and even wear them around for a while to see if they feel comfortable. A child may want to be a fireman one day and a rocket scientist a week later, whilst adults think long and hard, seeking deeper goals such as building their own business to make themselves financially secure (and thus achieve a greater sense of control!).

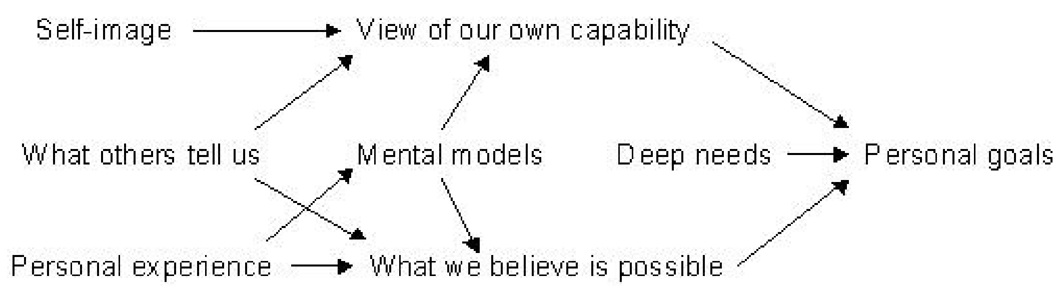


Fig. 8.7 Factors leading to personal goals

Goal-setting start with a consideration of possibilities. When planning a garden, we might consider creating a splendid riot of ever-changing colour throughout the summer, or we may accept that we are not *that* green-fingered and just settle for a bit of greenery. We first think, 'what is possible', then sort out the best option for us.

A problem here is that we can tend to eliminate a number of the options with self-limiting talk like 'I'm not good enough do that,' which we then rapidly support and confirm with excuses such as 'I haven't got the time, anyway.' The alternative is to take Mihaly Csikszentmihalyi's advice and seek an 'achievable challenge,' stretching the boundaries of what we believe we can do. Achieving goals that we thought almost impossible gives us the buzz, the 'eureka moment' in which all inventors revel.

A simple way of realising that challenging goals really are achievable is to consider how many inventors were actually ordinary people, and not brilliant geniuses. All they did was dare to dream.

Necessity is the mother of invention, as Plato said, and one of the simplest ways of making ourselves more creative is to want. If we can convince ourselves that we really need something and that it is essential to our future happiness, then the internal tension that is created can become a powerful lever to goad our subconscious idea engine into action.

If you want to work in India then the first step is to put a big map of India on the wall and just keep looking at it. Your mind will find the solution!

Invention so-what

Again, we ask ‘so what’. How does looking at motivation factors help us to invent space rockets? The bottom line answer to this question is that once we recognise what is happening, we can act to direct those things that drive our thinking towards solving our problems and away from how they often work, which is to block and divert our creative thinking. Some specific points include:

- Don’t fight evolution: use it. Do lots of experiments. Vary random things to see what happens. Most great inventions were unplanned accidents, so have some of your own.
- Create challenging environments which both stimulate and nurture ideas. Give space for uncertain ideas to develop, but at some stage, the fittest idea must survive.
- Your ideas are your children. Identify with and respect them. Also control them and expect things of them. Create tensions that draw them out.
- Suspend your need for certainty, consistency and control. Consider diametrically opposed ideas simultaneously. Build half-completed ideas. Revel in the creative tension.
- Gain a deep understanding of how things work, but never assume you fully understand anything.
- If you feel the fight-or-flight response, getting scared or annoyed, stop. Go for a walk, shout at the trees and sky. Do not take it out on your invention or yourself. The answer will come.
- If you are inventing with other people, watch yourself and them carefully. Are you truly synergising, or are you blocking one another, wanting to look good or fearing rejection? If you must work with others, make a pact to suspend such normal human behaviours.
- Challenge yourself constantly. Create a string of satisfying achievements stretching out into your future. Build internal goals that impel you in the direction to where you really want to go.
- Use planned boredom to stimulate yourself to do something different. Be curiouser and curiouser.
- Invent both in functional and aesthetic domains. Make things that help people do things better and just feel better about themselves.

- Give yourself permission to act as a child. Remember what is like to be fascinated and astonished by the wonders of the world, now and every day for the rest of your life.
- Find out what makes you tick, and what makes your clock go wrong. Leverage the ticks and get the emotional baggage that trails behind you fixed, once and for all.
- Build yourself powerful internal goals that stimulate the brain's urge-desire-action system.

9 Managing in a Complex World

If you are only creatively inventing a solution for the kitchen or garden then taking into account your deeper motives or those of others may not be important. But if you are really aim to invent something significant for others, then it is probably worth investing time to look deeply at all the kinds of human factors that may affect not only how you are deriving and developing your ideas, but also how you communicate with and convince others of the value of your inventiveness. If people are going to back you, work with you, support you or simply not resist you then you need to understand your ideas from the outside and the inside. This chapter should help you do this.

The world is a big and complex place and it is remarkable how much sense we are able to make of it. But with our deep needs to understand and explain, coupled with our marvellous patterning brain, we learn to encode the complexities of the outer world into a form by which we are able to understand and hence control our environment.

Fig. 9.1 gives a simple picture (the 'SIFT' model) of how we interact with the world that will be explained further in this chapter. The basic cycle is that we create meaning from what our senses tell us. From this, we build an understanding, however imperfect, of how the world works and from this create goals that will help us meet our deep needs that were described in Chapter 8. We then act in ways that we hope will get us closer to achieving our goals. The cycle then starts again, sensing and interpreting how effective our actions were, making corrections and trying again.

However, there is 'many a slip twixt cup and lip' and, as we shall see, we make many such slips during the contortions that we go through in order to create meaning out of the sensory bombardment we receive every moment of the day.

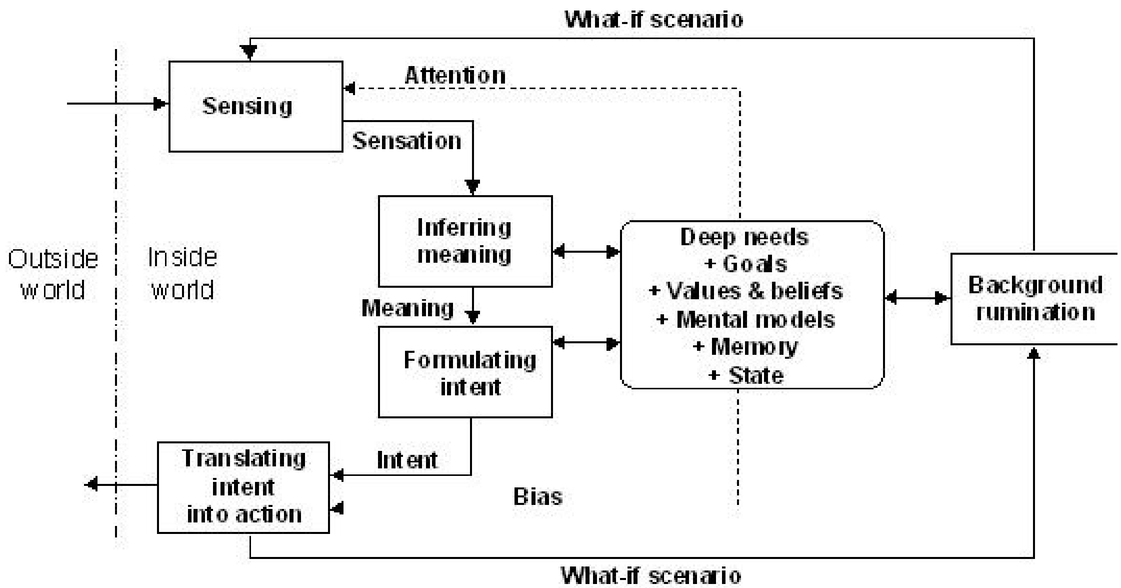


Fig. 9.1 The SIFT model of interacting with the world

Sensing

The first step in making sense of the world around us is to pay attention to it. Unfortunately, we can only pay attention to one piece at a time.

The first step in attending to our environment is in where we go, where we look and how we initially direct our senses, which is generally driven by the goals we have set ourselves. For example, if I wanted to be a rock musician, I would go to concerts, listen to CDs and read books on music. When we have found something of interest, we then continue to focus our attention, excluding all but the aspects of specific interest.

Uneven senses

We can get input into our brain via any or all of our five senses (taste, touch, smell, sight and hearing) although these are not all equal and are not equally balanced in all people. It is known, for example, that people with impaired vision often compensate with increased sensitivity of their other senses. What is not widely known, however, is that those of us lucky enough to have all senses functioning perfectly are also not equally balanced.

Imagine being young again; being very young. To a small child, the sense of smell is very important (can you remember how your parents smelled?). As they grow and start exploring their world, touch and taste join in (notice how toddlers put everything in their mouths). Sound becomes increasingly important as they learn language. And as they make sense and name the riot of colours in front of them, the visual abilities also develop.

As all of these senses are developing, one sense may be found to more effective, perhaps at an emotionally critical moment. If this happens, it is natural that the child pays more attention to it, and thus the senses develop unevenly. By the time we are adults, many people have a preference for visual data; they think more in pictures and even tend to use more visually-oriented words and phrases, such as ‘that looks like a good idea’ (as they actually *see* the idea in their heads). Others develop more with the balance tipping towards sounds and words (‘that sounds good’), whilst others again are more tactile (‘that feels good’). Very few have a preference for sensing with smell or taste, even though our noses are so sensitive, we can detect a single molecule of some substances.

Many creative approaches are based around words: in brainstorming, for example, ideas are spoken and written down. With an understanding of sense preferences, creative sessions can be made more fruitful by using techniques that stimulate the different senses, giving opportunity for stimulation that is more effective whatever your sensual preference.

The zoom lens

Try this: look at something. Take a page in this book and look at it. Can you read all of the words? As your attention goes from the page to words, you can actually only see a few words at a time. The same effect happens in a conversation when several people are talking at the same time and it is difficult to hear what everyone is saying.

Our attention is like a beam of light that we shine on the world around us, and like a trick torch, we can zoom our attention into detail or out to a more general view. Can you pronounce ‘llongyfarchiadau’ (which is Welsh for ‘congratulations’)? As you focus in on the word, notice how all other words, and even other parts of the same word, effectively disappear from your zone of attention. You can go even further, zooming in to a letter or even into a part of a letter. You can focus in your attention using any of your senses, listening more carefully or savouring the taste of a gourmet meal.

Martial artists surrounded by opponents use the reverse effect of zooming in as they spread their attention wide, not looking at anything, but being aware of the slightest movement around them. Bruce Lee said, ‘Observe what is, with undivided awareness.’

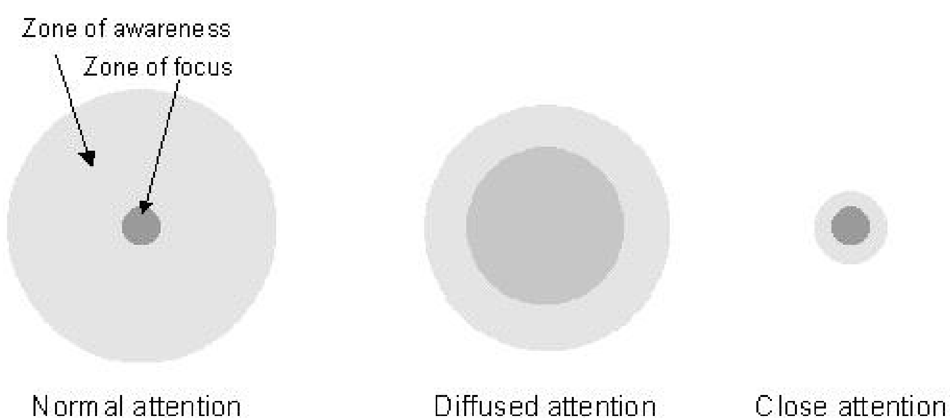


Fig. 9.2 Attention zoom

Attentive creativity

One of the tricks of being creative is to knowing *how* to pay attention. Artists and photographers learn to master their visual senses and when looking at a scene will see far more than the rest of us. They see texture, light, shadow and a myriad of hues that we barely begin to notice. Authors and storytellers pay greater attention to words and how they sound, both individually and in combination. In the same way, an inventor pays attention to the detail of a problem that other people pass by.

In 1819, Hans Christian Oersted was demonstrating electricity to some students, when he noticed the needle of a nearby compass flicker. Rather than ignore it, he investigated further and hence discovered electromagnetism.

Swiss inventor George de Mestral went hunting one day in the late 1940s and noticed how burrs from a plant stuck to his clothes, but could also be removed without damage to the clothes. Many people would just find this an annoyance, but de Mestral was so fascinated, both by how it happened and the potential for a clothes fastener, that he studied the plant closely and then spent several years perfecting what is now known as ‘Velcro.’

Another very important trick is where to pay attention. Defining the problem means defining where you are going to pay attention and consequently where you are not going to look. Ask questions like ‘What is the real problem?’ and look hard at the situation in different ways. In this way a completely new formulation can change your attention, for example if you changed ‘build a better staircase’ into ‘transport people to another floor’ or ‘make the hall look imposing’. You can also find a closer focus by considering detailed problems such as ‘how to cantilever into a thin wall’ or ‘how to create a sense of light solidity’. Zooming in and out of the problem and mentally flying around inside it can give you different perspectives that can lead to new and effective ideas.

Inferring meaning

Once perceptions have got past our basic attention and into the reasoning mind, the next step is derive meaning from those sensations, creating useful information from the raw data out of which we can then decide how to respond.

There are a number of overlapping 'lenses of perception' through which we rapidly filter this data (see Fig. 9.3), many of which can have a significant effect on the eventual meaning that we infer from the sensations we experience.

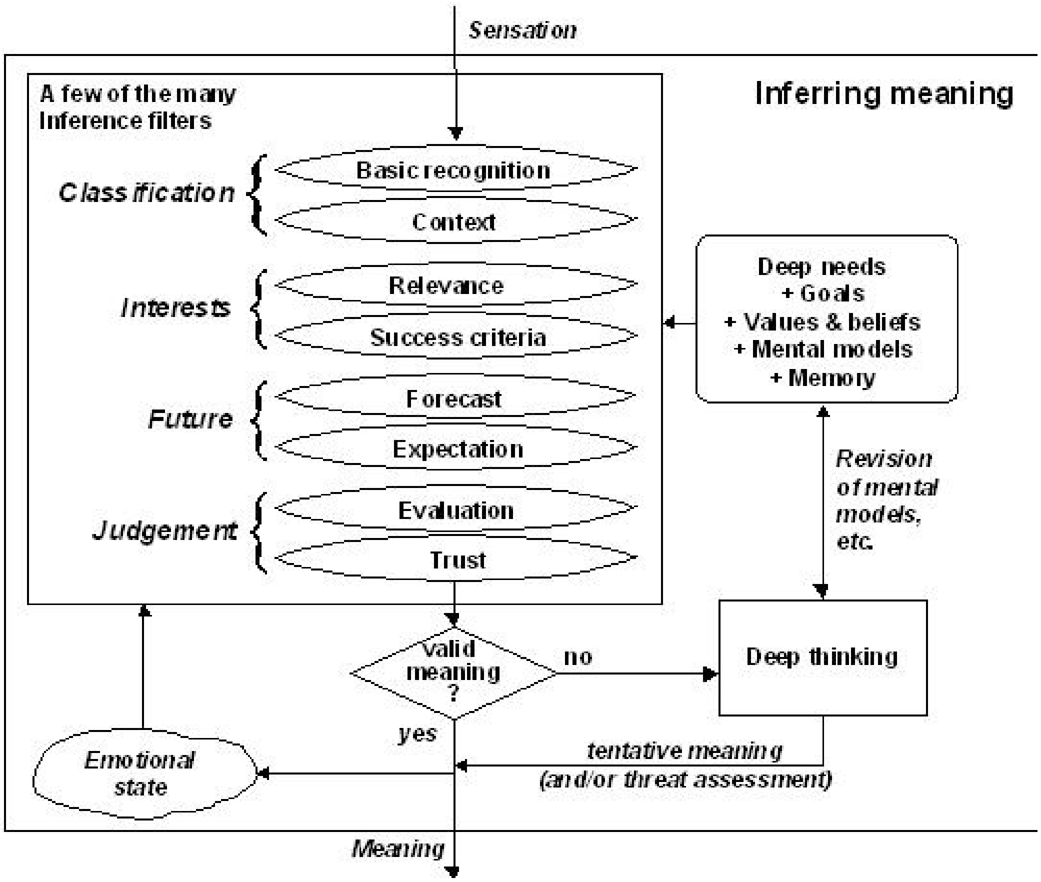


Fig. 9.3 Inferring meaning

Classification

Classification answers the basic question 'What am I perceiving?' and when compared with previous similar experiences may allow other information to be deduced.

Basic recognition

The first thing that we do when receiving an input from our senses is to break it up into pieces that we can classify according to the patterns we have stored in our memories, either by direct recognition (‘That is a hat’) or by taking an educated guess (‘That looks like a hat’).

In the rare occasions when we cannot even approximate a classification we might dismiss the perception (using the relevance filter), invent a new classification (for which we may need more data) or be worried by the threat that it might pose to us (using the forecasting filter -- see below).

The context filter

Imagine someone pointing a knife at you. How do you interpret that? If it’s a dark night and you are in a shady part of town, then it will have a different meaning from if you are in the kitchen and a member of the family is handing you the butter knife.

The surrounding context in which events happen has a significant effect on how we interpret those events. It is thus a good idea when you want to invent something to go somewhere where the surroundings make you feel creative.

The work context often puts people into a state of unquestioning compliance, which is not what you need when you want to be creative, so going off-site and wearing informal clothes can be surprisingly helpful.

Another way of being creative using context is to remove the item being investigated from its context and ask, ‘What if this was used elsewhere.’ Imagine taking a vehicle jack and putting it under a subsiding house: as the house leans, you could compensate with a simple adjustment of the jack. Take a razor away from your face and you have a new wood plane or potato peeler.

Comparing with interests

When I have identified what I am perceiving, I can then add further meaning in terms of those things that are important to me or in which I have some interest.

The relevance filter

If you wanted to invent a device for treating storm-damaged trees, and while surfing through television channels you came across a programme on rose-grafting, your ears might prick up at the thought of how it may help you understand how plants grow together. This is your relevance filter clicking in, saying ‘hang on a minute, out of all the irrelevant junk that has been passing before my eyes, this bit is actually of interest.’

The same effect happens when you have recently bought a new car and suddenly you seem to notice every car like yours on the road. Things at the top of your mind will act as filters on your perceptions.

If what we are perceiving is relevant to achieving our goals, then we will give it more time to understand its true meaning, especially as it relates to our goals. Creative people tend to have wider sensing in this area, spotting potential in many areas that other people miss.

Success criteria

When we are considering the meaning of something after we have taken some form of action to try and achieve our considered goals (and a large amount of what we do can be viewed in this way), then we view what has happened in comparison with those goals. For example, if you were doing an experiment with a new style of kite, if it flew well and was easy to control then you may well consider this a success and consequently be pleased.

Inventing is often an iterative process, and success means taking a step closer to your goals rather than coming up with the completed idea, Mozart-like, in one go. Inventors thus need a high tolerance of failure or at least need to define success in terms of learning, rather than achieving an immediate solution to a problem.

Comparing with the future

The future is all we have left, but it is uncertain and difficult to control. We thus pay close attention to the sequence of events through time and what the future might mean.

The forecast filter

Having a gun poked in your face can be very scary. But why–it is only a piece of metal. What happens is that we take our current experience and extrapolate it into the future, typically using our mental models (which are often wrong or limited) and then create meaning from the future we see.

Much of our forecasting is done in terms of how things might threaten us, rather than the creative opportunities that might exist. This is understandable when viewed in the evolutionary light, as there was much in the primitive jungles to threaten our forefathers, but it can be very unhelpful when we are looking to create new futures.

The expectation filter

If you buy a new computer and the salesperson tells you that it has studio-quality video graphics, then anything less than an excellent picture will probably disappoint you. Having had your expectations set, the meaning you create from your experience is now relative to those expectations.

Expectations may come from previous experience, forecast futures or from an external source, such as when we accept someone else's forecasts about what will happen. When we are heavily influenced by other people, many of our expectations are likely to come from them.

When what actually happens is not what we expected, we are surprised. If what happens is interpreted positively, then we are delighted. If we are surprised in a negative way, then we are disappointed. Surprise often leads to us changing behaviour or doing something different (such as not buying anything else from the computer shop).

If you are stuck in a rut when trying to invent something, do something to surprise your subconscious, jolting it out of the pattern of thinking in which it is stuck. For example, if you are designing a new writing instrument and are stuck around patterns of a barrel containing an ink cartridge, pick up the nearest object, say a stone, and try writing with that. You might then rethink the shape as something that could fit your hand better, and thoughts of 'blood from a stone' could lead to a porous body which contains the ink, rather than a separate cartridge.

Judging

Beyond recognition and success, I can also make judgements about what I am perceiving, to determine whether it is good or bad, trustworthy or not.

The evaluation filter

If you see someone shouting at a child, what do you thing about this behaviour? Do you feel that it is wrong? If so, you are evaluating it in terms of your own values, your individual system of right and wrong.

People with strong moral and ethical drivers will tend to be very evaluative in their interpretations of the world around them. Judgements are affected by established mental models such as when you show a new invention to other people, who seem to see its faults and how it will not work, rather than consider its possibilities.

Our education system is based on criticism, and we learn what is right very often by avoiding what is wrong. We thus cannot help but to adopt much of this critical attitude and consequently can filter out creative opportunity through our evaluation of our experiences.

Suspending judgement is one of the most important innovation skills that gets quoted in texts on creativity. If you can hold an idea in your hand, not thinking of it as good or bad, just ‘interesting’, you will be able to discover many more possibilities than if you rapidly boxed in into good or bad.

Finding ideas is a *divergent* activity, whilst evaluation is a *convergent* activity. If you try to mix the two, as often happens when people get together to discuss ideas, the judgmental convergence is likely to dominate and destroy the more delicate divergent creativity.

The trust filter

Consider what you would think if someone, who in the past had deliberately deceived you, came to you with an idea for increasing productivity in your workplace. Your first thought might, quite legitimately, be ‘what is this person trying to trick me into now?’ The same applies to inanimate objects, for example if a car keeps breaking down on you, you might never buy that make ever again.

Trust is essential for collaboration. In effect, we say, ‘If I help you today, I trust that you will help me in return in the future.’ Ongoing relationships are about delayed exchanges in value. When you have a final idea or product that you want to get manufactured, trust is also a very important factor, both around your fear that your ideas will be stolen and the trust that other people need that your idea will actually work and sell in the outside world.

Deep thinking

If we have difficulty in creating meaning, then we may have to reconsider our deeper needs, goals, values, beliefs, mental models and even recalled memories. You can see this effect when you tell other people about something that they do not understand (like your latest invention!). Their blank looks indicate that they have 'gone inside' to try and make sense of what you are saying.

When this happens, if we cannot quickly derive a satisfactory meaning, we may put it to one side and come back later when we have time to muse further about this new and confusing situation.

In creative situations, because they are necessarily new, we often meet these points of incomplete understanding. How we assess these as interesting possibilities or threats to be defended against will have a significant effect on any inventive outcomes, particularly with respect to what we decide to do about this new and potential meaning.

The inner world

Within each of us is a whole inner world, in which we sometimes spend an inordinate amount of time. It is populated with anything that our imagination can dream up, from replays of past events to fantastic dreamscapes.

In generating new ideas, creative people often spend much time working in our inner worlds and make much use of the powerful imagination that we all have. Nikola Tesla designed the electric motor entirely in his head; he could design and build complete machines and even mentally run them for days on end, then stop and disassemble them and examine the parts for wear!

We regularly flip our attention between the outer and inner worlds, living only in one place at a time. This can be a problem when brainstorming in a group when you go inside to think of your own ideas and miss ideas from other people which could trigger off even better ideas from you.

A constructed reality

We do not interact with the outside world. Well, not directly: what we actually work on is an internal representation that we construct out of the data we receive from our senses and the meaning we infer from that data.

We spend a fair proportion of our inner-world deeper thinking on building and adjusting our models of the outer world and how it works. A common question we ask ourselves when we ponder about what has happened in our lives, is ‘Why? What causes things to happen?’ If we can build a model of the world that enables us to determine cause and effect, we will be able to forecast more accurately and thus have greater control over our environment.

If we understand that reality is not necessarily exactly how we understand it (by including in our model of the world a part that recognises that it *is* only a model), then this allows us to question anything and everything around us, and especially our (and others’) perceptions. This opens out a whole world of creative opportunities, for example allowing me to step inside a reality which says ‘chocolate makes me fat,’ and rearranging the causal linkages to ‘eating chocolate that contains fats that my body does not need at the present gets stored as internal fat.’ Now chocolate need not be eaten, or may be reformulated to contain only essential nutrients.

The emotional state

Our mood and general emotional state strongly affects the meaning we infer from any situation. A person with a knife may be perceived as a potential murderer by the already-frightened person, whilst someone who has just been meditating or praying might see the other person as emotionally hurt and in need of friendly guidance.

It also works the other way, with inferred meaning triggering emotional changes. A situation interpreted as threatening will trigger fear or anger.

Multiple personalities

When we have conversations with ourselves, it sometimes seems as if there is a range of very different personalities inhabiting our minds. Most dangerous of these for creative situations is the critical voice that tells us we are worthless, our ideas are no good and that other people will ridicule or reject us if we voice our thoughts. Left unchecked, these inner voices can wreak havoc on any inventive thought, but with careful control they can be put to good use, for example imagining what other people will say about our ideas so we can devise effective responses.

Walt Disney made deliberate use of inner personalities when creating his cartoons to build a wide range of options and then filter them down to find the best ideas. He would first become the *dreamer*, imagining all sorts of unconstrained possibilities. He then changed hats to become the *realist*, taking into account the constraints of the real world. Finally, he became the *critic*, nit-picking at the details until all that was left was perfection.

Inner space

How do you see your ideas before you turn them into physical form? We typically use our imaginations to create inner pictures, borrowing the outer system of concrete space to literally see our ideas. We can invent something completely in our minds, giving it three-dimensional shape, rotating and moving it and changing it at will. This is just a small glimpse of the power of our imagination.

We also convert our concepts and abstract thoughts into shape to give them concrete form. When we think about time, we often ‘see’ it along a line. It may go from left to right or back to front or any other shape, but how we perceive this line can have a profound effect on how we live our lives. When you look along your time line, can you see your invention, complete and in use? If you cannot see it, or it is *always* in the dim distance, then you may be trapped by the joys of the initial idea, procrastinating the less pleasurable tasks of putting your thoughts into real action.

The best tool to counter the constraining effects of our mind is the same imagination that creates those same limiting inner pictures. Make inner pictures of yourself completing the invention and other people congratulating you and taking up your idea. Go forward in time to see this happening close-up. Then move back to the present, watching the events stack themselves up like a set of dominoes, with events happening each day that will lead you to your completed invention.

When you look at your timeline, are you standing in it our outside it? If you stand outside it, you probably feel detached from it, that time outside of you. Try moving to stand inside it. It may seem scary but it should also feel more real. You now are a part of time, moving in and with time, not passively watching it pass you by. Repeat the previous exercise of imagining your desired future and see how differently it makes you feel.

Assumptions and beliefs

Our need to understand the world around us can never be fully satisfied. Indeed, the more we learn, the more we realise how little we really know and how futile the task is. To complete our models of how things work, we thus have to start making assumptions about what is true and what causes what. Beliefs are thus about assumed truth.

Given a topic of interest, we have an area of true understanding, based on our verifiable experiences. Beyond that, there are three other ways of creating belief.

- We may accept a body of knowledge that is available from a highly credible source, such as mainstream physics or chemistry.
- We may accept a statement as true from somebody else. This can be quite insidious when people we trust, such as our parents, pass on their prejudices and biases as if they were unshakeable truths. This is also the basis of cults and groups where membership and advancement is based on unthinking acceptance of a predefined truth.
- We may autonomously decide that something is true, often because it fits with our own internal mental models or because it is simply convenient to do so (many beliefs are born of natural laziness).

Many of us have a strong need for certainty and will rapidly make assumptions and adopt beliefs about any new situation, which soon become cast in concrete within our internal models of the world. This can lead to a strategy for dealing with challenges to our beliefs that is more about denial and defence than curious exploration.

Creativity treads heavily in the area of belief, surfacing and challenging the assumptions and needs that puts things there. Inventors sometimes need large quantities of courage to question both unspoken assumptions and even those beliefs that they have long assumed to be unassailably true.

Values

Another internal system that has an effect on the way we interact with the world is our system of values. A value is a specific form of belief which helps us to make decisions and prioritise perceptions and actions. They tell us what is right and wrong, and, when things conflict, which is more important.

Values are particularly useful when we share them with others. If we all agree that it is wrong to kill people, then we are safe, at least from one another. Shared values thus improve our sense of control and become a significant part of our sense of shared identity.

When working in groups, the group values may have to be explicitly changed to legitimise the proposing of creative new ideas. Even if you are inventing alone, you will eventually have to take the idea to other people. When doing so, always be aware of the effect of what you say on their values, getting specific permission where necessary to ‘meet on neutral territory.

Attitudes

Beliefs and values often come from, or help us interact with, other people. We also develop and share attitudes to the world with our peers. We often share these three quite extensively with other people to the point where they become a large part of our common culture.

Attitudes appear in our actions as signals to other people. Young men in street gangs will swagger and stare directly at other people, signalling their readiness to fight. Senior managers may display an aloof attitude through their words and by not looking a person when they are talking to them.

We can hold creative and uncreative attitudes to the world, for example as seen in the way that we act in an interested or rejecting way towards problems. An inventor sees an unresolved situation as an opportunity to innovate, where others might only see the problems and hassle.

Formulating intent

Once we have created meaning and/or thought deeply about the external world, we have to take action. Fig. 9.4 shows that if the decision is more serious than can be handled with a simple short-cut, the main activities are to consider the possible different courses of action and to select the one you will undertake.

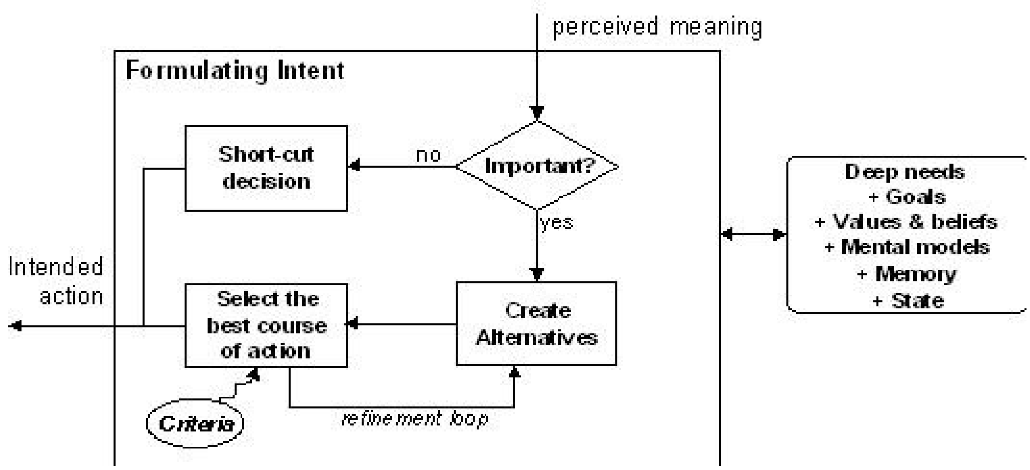


Fig. 9.4 Formulating Intent

The refinement loop

What also happens often within this situation is that rather than one simple decision, the final action is a result of a refining sequence of creating alternatives (*divergence*) and selecting the best course of action (*convergence*). For example as Fig. 9.5 shows, in a creative situation, typically the problem is first considered, then the idea is refined into a usable solution.

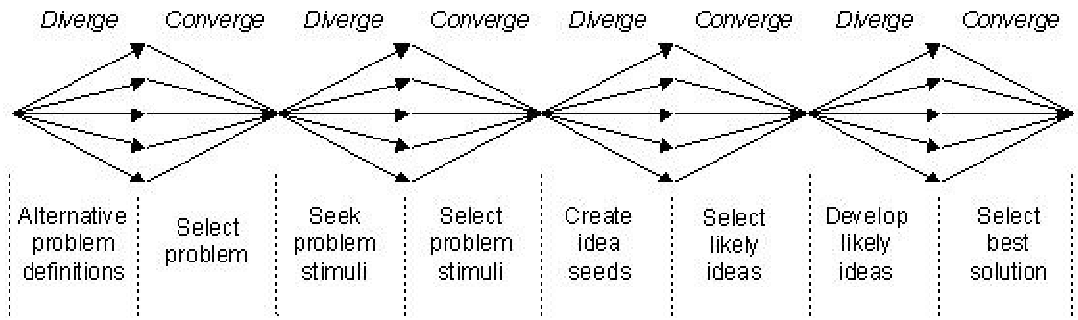


Fig. 9.5 Creative refinement

Short-cutting

We make a constant stream of decisions as we interact with the outer world and we do not have time to think long and hard about every decision. We thus need to make quick decisions about many of our actions, especially those we make when external events do not allow us to ponder for long on the best course of action. Unfortunately, the need for speed (or laziness) also tends to lead us into short-cutting past creative thinking.

Physical reaction

There are some events to which we react without even resorting to heuristics, such as when a branch falls from a tree above us, we quickly jump out of the way. When milliseconds count, there are specialised parts of the primitive brain that help us with these actions, literally bypassing the cortical decision centres.

Heuristics

A heuristic is a rule of thumb, a simple formula that says, ‘when this happens, do this.’ They are typically based on ‘what worked before will work again’ and we accumulate a vast array of heuristics to make our lives easier. For example a common parental heuristic is, ‘If the phone rings, it is probably for my teenage daughter, so there is no point in my answering it’ (the alternative is a race to see who gets to the phone first).

Heuristics are helpful, but they can also be too easy and consequently make us lazy. They can also misdirect us when we use them in inappropriate situations.

Habit

Do you usually buy one brand of coffee? The chances are that you do, and that the choice is more to do with simplifying your trip to the supermarket than whether it is the best taste or value.

Habits can have different strengths, ranging from simply repeating what worked last time to full physical addictions, where not following the ‘right’ decision results in significant discomfort. When smokers want a cigarette, they feel they have little choice.

Programmed responses

Like Pavlov’s dogs, we are programmed by the events around us, but unlike the dogs, we have many and complex programs. A person who is attacked once in a dark alley may have an aversion to them for the rest of their lives. Many of us have phobias of various kinds, ranging from a natural caution about high places to dark fears that constrain us at every turn.

We are also programmed by our parents, teachers and peers to act in ‘civilised’ ways that help people to live together in reasonable harmony. If someone offers you their hand, you shake it without much consideration of the alternatives.

Intuition

Intuition is not magic, although sometimes it can appear this way, such as when the answer to a question just pops unbidden into your mind. This is often just the subconscious at work, picking out a good match from previous experiences.

It has been proven that in situations where there is no time for conscious reasoning that experts, people who have a wealth of related experience, make much better choices than beginners. This can apply to creative situations too, although this is a double-edged sword, where the experience that filters out the inappropriate ideas also filters out creative new ideas.

Creating alternatives

If we get past decision short-cutting, then we start the conscious decision-making process by coming up with a number of possible alternative courses of action which may be taken in response to an external event or as an attempt to achieve an internal goal.

Same old way

We typically create alternatives by reaching into our memories and mental models to determine what has worked previously in similar circumstances. If we try something and it does not work, the most common response is to try it again, and then again and again until we realise that it is not going to work this time. Only after we are convinced that existing alternatives are inadequate do we typically start thinking creatively.

People can become so convinced that a strategy will be effective or be so blind to alternatives that they repeat unsuccessful actions, sometimes for years. Parents sometimes spend the entire time that their children are in their teenage years *telling* their teenagers what to do and what not to do, seemingly blind to the fact that their children are no longer compliant to commands (and in fact commands now causes serious revolution).

Creative creation

The creation of alternatives is a primary part of creativity and innovation, and the ability to ‘think outside the box’ is a key skill.

Studies of brainstorming and idea creation have shown that the quality of ideas tends to be fairly consistent as you generate more and more ideas. In fact, the more novel ideas often come out after you have gone through the ‘obvious’ solutions to the problem. This tends to go against a common tendency to cut directly to the chase and go with the first reasonable solution identified.

Selecting the best course of action

Given the possible courses of action, we now need to decide which will be carried forward for action. Creativity is often thought of as the divergent activity of coming up with good ideas, but equally important is converging back in as we select the ideas that will be used.

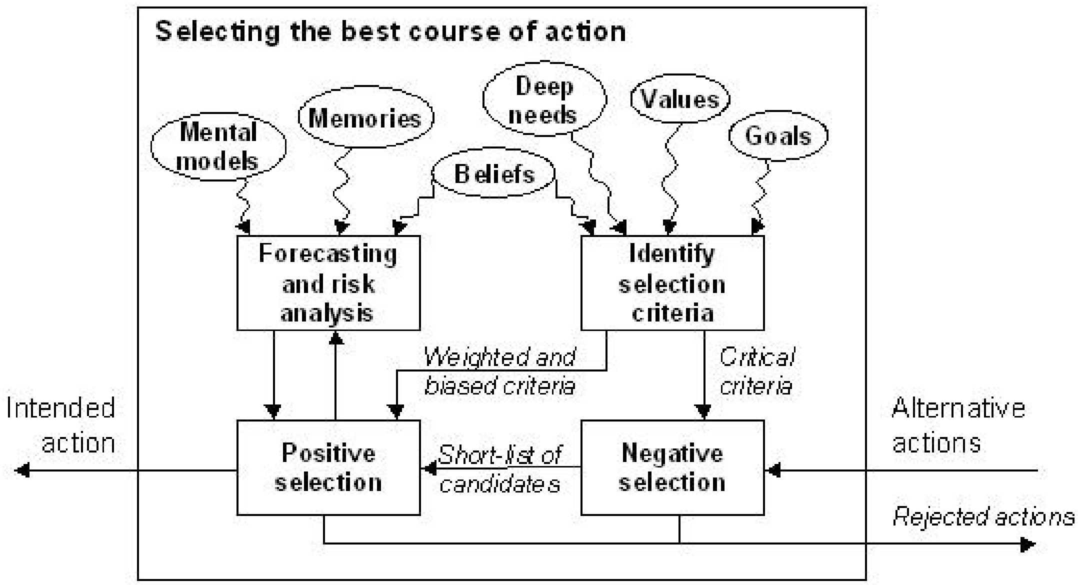


Fig. 9.6 Selecting the best course of action

Selection criteria

Selection is done through the application of some form of criteria, which may be consciously or subconsciously selected. These are reasons for or against taking the action, which will allow us to weigh up the pros and cons or the return on investment for each alternative.

Negative criteria, which give reasons not to select an alternative, may include costs, risks, difficulty, hassle and trouble. Positive criteria, which highlight the benefits that an alternative might offer, include whether goals will be met, how well they might be met, plus ease and speed of implementation.

We tend to use many criteria based on deep needs and personality factors, for example extraverts may seek attention and risk whilst introverts will seek safety.

Our values also lend key criteria that will help us decide what is right and wrong.

Criteria may also be prioritised, for example cost may be all-important whilst time is a more negotiable element. Although we do not do mathematical weighting in our heads, we will usually lean towards some criteria rather than others.

It is important to pay close attention to criteria when selecting creative alternatives, ensuring that personal biases do not lead to potentially useful ideas being rejected.

Initial negative selection

Remember when you last bought or rented a home. What you probably did was to go along to a number of housing agents and come away with piles of home details, then start your selection by sorting out the definite ‘no good,’ the ‘maybe’ and the ‘interesting’ homes.

The initial strategy that we commonly use when faced with a lot of choices is to ‘sort the wheat from the chaff,’ rapidly eliminating those items we do not want, rather than looking closely at those which we might select. The negative criteria that we use clearly define the boundary of the problem in terms of our primary constraints. We reject houses because we definitely do not want to live in *that* area or *cannot* afford that amount of money.

In creative situations, the danger here is of rejecting ideas that could be developed into useful solutions. We can use our creative skills to look carefully at these criteria, making them explicit and questioning why we chose them and how we might look at them in other ways. Thus we might consider alternative forms of finance, such as leasing options or sub-letting.

Forecasting

A key technique for selecting the best course of action is to project the alternatives we are considering into the future to see what might happen if we implement each of these ideas.

In forecasting we make much use of our mental models to help us grope forwards, weighing up the implications of each alternative, estimating both the possible outcomes and how likely each one is. We can then choose the most desirable future that will best move us towards achieving our goals. It is a testament to the power of human mind that we do this complex projection in the twinkling of an eye, whilst it still takes supercomputers many hours to calculate the weather.

Sometimes, when being creative and inventing things, it is our inability to see the possible futures that becomes the stumbling block that obstructs effective progress. The cause of this may well be our limited mental models about the world. It may also be due to the forecasting process, and in particular how we hurry through this stage, considering too few and too obvious futures.

Final positive selection

The final selection of the alternative that we will implement uses criteria in a more positive way, seeking to narrow down the short-list to the item we will actually implement.

This process is not always cool and rational, and even after a long and drawn-out selection process, we sometimes change our minds for no apparent purpose, probably because our subconscious either objects in some way to the selection or prefers another idea that has already been logically eliminated.

When you have generated a wide selection of ideas, selection of the few ideas to carry forward for further development often benefits from a deliberate balance of both rational and ‘gut-feel’ subconscious preference.

Translating intent into action

Once we have formulated our intent, all we have to do is do it. Although this seems quite simple, the translation from intent into action does not always go smoothly as our bodies are complex instruments over which we have limited conscious control.

If we are communicating with other people, then there is an additional step beyond our acting in which they sense and create meaning out of what we are saying and doing. Given these complexities, it is little wonder that there is so much misunderstanding in the world.

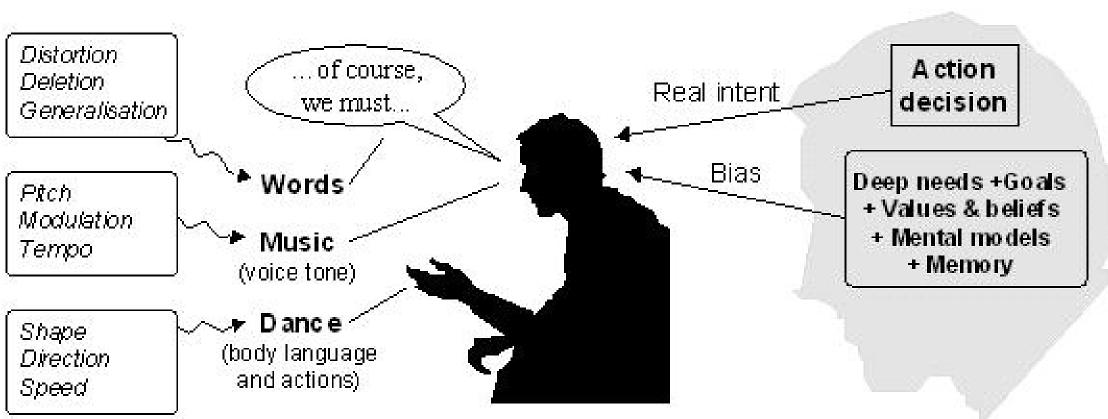


Fig. 9.7 Translating intent into action

Intent vs. bias

When we decide to do something, it is often held in the form of an intent to cause some external effect, such as performing an experiment or showing someone else how an idea works. That intent may be held in a number of forms, from an internal visual movie of exactly what is to happen, to a general desire to change someone else's point of view.

The problem with conscious decisions is that the subconscious is constantly looking on and can subtly interfere with the subsequent action, sabotaging what you really wanted to say or do in order to achieve deeper needs.

For example, if you were hammering out a car body, inner doubts about your own ability could lead you to miss-hit and cause damage. Also when talking to other people, your mental model about them will affect a lot of what you say. For example, a male engineer might have an internal model of women as being unable to understand technical things, and as a result unintentionally act in a patronising way. This would not be very helpful if the woman was a bank manager who could invest in his latest idea.

Particularly if we are unaware of them, our internal biases can wreak havoc on idea creation, experimentation and all parts of communication with, and persuasion of, other people. As well as controlling the world, inventors need to be able to control themselves.

Words, music and dance

Our input system of the five senses is complemented by our output system through which we interface with the world. For physical action we have a skeleton and muscles, whilst to communicate with others we not only have sounds and words but also the way we say them and the way we move our bodies whilst we are speaking.

Communication is not evenly balanced between these three systems: a 1970 study by psychologist Michael Argyle showed that only 7% of interpersonal communication comes from the words used. The voice tone accounts for a much larger 38%, whilst 55% of communication is made through body language.

Words

All animals communicate in some way, but humans are unique in the complexity of our linguistic system. Chimps can be taught a few words of sign language, but many humans have a vocabulary of tens of thousands of words.

Words, nevertheless, are limited and limiting chunks, they are individual building blocks through which we must interpret our deeper intent. Despite the words and syntax available to us, we can never fully express what we really mean. As such we have to start compromising in what we say.

Much of what we say is a *distortion*, for example when we say ‘I’m boiling hot’ it is not literally so, but is distorted using the metaphor of liquid-to-gas conversion in order to try and communicate the feeling of discomforting temperature.

Explaining the detail of what we mean would take a long time, so we also miss out a lot. For example, if I say ‘I am confused’ then there is a *deletion* in that I have not said what I am confused about or why I am confused.

A third factor is *generalisation*, where we extend a single or few experiences to the whole world. For example ‘I always make these mistakes’ or ‘They are all like that.’

Distortions, deletions and generalisations in what we are saying may well highlight limitations in our own internal thinking. We think, as well as speak, in words and if we can stand back to observe our self-talk, we can detect and correct these limiting effects and thus become more effective and open creative thinkers.

Music

When we speak, it is not in a monotone: the pitch of our voice goes up and down, we emphasise words, sometimes we speak faster and sometimes slower. These musical variations allow an enormous extra amount of information to be overlaid on the words themselves. We can say no and mean yes, and say yes and mean ‘maybe’ or simply ‘I understand.’

Dance

The final and largest part of our communication and interaction with the outer world is through our actions. When we are talking, our body language adds a great deal, and it also gives the game away if we are trying to deceive.

Generally, people deduce a great deal from our day-to-day actions. They will conclude that if we generate new ideas to solve difficult problems, we are creative and practical. If, however, we talk about ideas but do little, then they might reasonably assume that we are all talk and no action, and will treat us accordingly.

We also make deductions about ourselves from our actions, creating reinforcing spirals of negative or positive behaviour. If I think that I am not creative, then I will not create. Seeing myself not create, I conclude that I was right about my not being creative. The reverse is also true. If I am open and investigative in my experiments and persistent in my actions, then the creative success that results will reinforce a self-image of being innovative.

Invention so-what

We can see that that there are many ways in which our interactions with the world can cause problems. But by understanding these, we can act to mitigate problems and utilise the potential for greater creative action. Points to remember include:

- Understand your relative preferences for vision, sounds and feelings. Play to your strengths and strengthen your weaknesses. A weak sense is treasure chest of new stimulation.
- Vary your range of attention. Focus in on the problem while maintaining a broad awareness. Notice the unusual: do not ignore what does not quite fit. Be open to opportunities.
- Create a context for inventing, a comfortable place where you feel comfortable and stimulated, and will not be distracted.
- Beware of judging things based on their importance to you. Consider how things may understood in different ways.
- Differentiate between your inner and outer worlds, putting both to good use. Imagination is the pump of invention, but unchecked it can also be a scourge.
- Direct the different facets of your personality to help at appropriate times. Hush the critic when inventing, bringing him or her out when you are evaluating a well-formed idea.
- Challenge your assumptions and beliefs. Ask ‘why’ again, as children do.
- Build values and attitudes that help you invent, such as the importance of openness and persistence.
- Beware of hurried and superficial decisions. Heuristics, and even our best forecasting, are based on the past. Creativity is about new things in the future.

Toolbox 3: Psychological

Having discussed in some detail how the brain really works, it is now time to get closer to the bone and start looking at how we can turn around nature's greatest invention from being a thing that drives our lives to a tool for enjoyable and profitable invention. In this chapter, we will pull together the key parts of the previous three chapters and build some critical tools for use in subsequent chapters.

The basic equation

The basic technique of producing creative ideas can be summed up in a simple equation:

Problem + Stimulus – Blocks = Ideas

This toolbox thus contains two chapters: one on removing the blocks and one on providing the stimulus that should light the fires of creation to produce wonderful new ideas!

10 Getting Past the Blocks

The main reason that people do not create and do not consider themselves creative is because they have implemented an effective series of blocks that stifle new ideas, as has been discussed in previous chapters. If we can identify our blocks, then we can start to dismantle these barriers to effective innovation.

Three sources of blocks

Blocks can come from a number of places, although these may be reduced to three common sources.

First and very commonly, blocks come from other people, which is perhaps why many inventors prefer to work alone. There is nothing more damaging to a fledgling idea that having the boot put in by a well-meaning, let alone a jealous, critic. In fact we do not even need the critic to say anything: the thought that someone just *might* criticise our idea is enough to dissuade many of us from proposing ideas in public, even with close friends and family. The threat of rejection or loss of social position is a severe punishment we would rather avoid.

Secondly, the environment can contain blocks. Being creative in a cramped room which is cold and damp or hot and stuffy is not as easy as dreaming up ideas in a comfortable and familiar environment. We also associate types of thinking with different places, for example many people take off their creative hat the moment they walk through the doorway of their workplace, where the formal clothes and interactions with other people all confirm that this is a place of logical action, rather than off-the-wall thinking.

Finally, we create our own blocks, such as a mental model we might have of ourselves that tells us we are unable to invent anything of value. In fact, all blocks fall into this category, as although people and places might provide the stimuli for blocking, it is the meaning that we place upon these that leads us to feel uncreative.

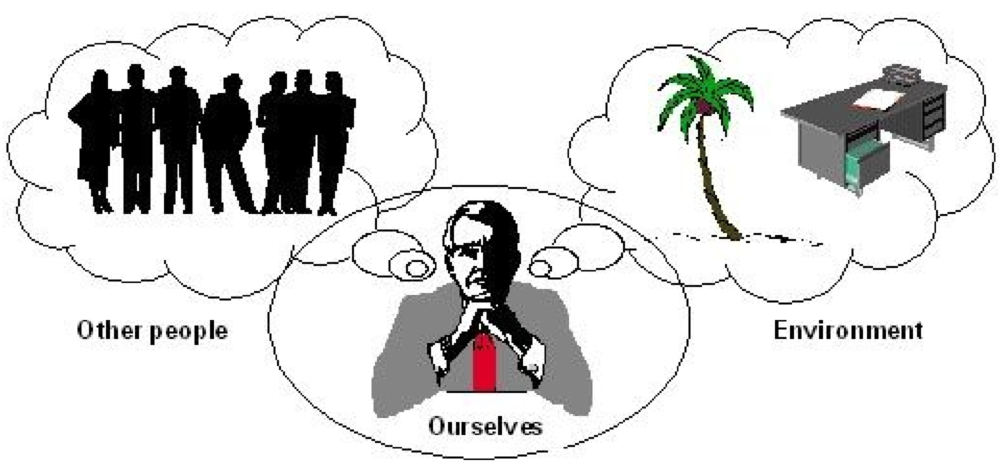


Fig. 10.1 Three sources of blocks

Three types of block

When marching down the road of creativity, there are three things that can conspire to prevent us from reaching our goals.

Obstacles are things that get in our way, preventing us from progressing. Many mental blocks are obstacles. We have internal voices that tell us that it cannot be done, it is not worth it or we are just not cut out for this sort of work. We may also lack access to critical resources, such as special measurement instruments. You can batter your way through obstacles, get help from others, take them down a brick at a time or find some other way to go around, over or under them. Turn obstacles into creative challenges.

Distractions lead us off the path. They can be interesting side issues (which sometimes are worth following, but not now). Procrastination is a classic distraction strategy, when just as we are finding things difficult, we find the need to make a coffee or watch a television program. A clear purpose and goal (including time) is a fair way of helping to avoiding distractions. An ‘ideas’ book is also useful to write down interesting ideas that are not immediately relevant. Give yourself no excuse to wander off: have coffee and biscuits to hand and ask not to be disturbed.

Holes are obstacles that are not there and appear when we run out of steam or otherwise seem to have reached the end of the road. ‘Writer’s block’ is a typical hole, where even famous authors lose inspiration and are left grasping at the empty air. Almost all creative efforts have points where we lose sight of the either the finish line or the once-clear route by which we might get there. Sometimes, to get past holes, you just have to clamber down into the darkness, make your way across the muddy bottom and somehow climb out the other side. This is where determination and perseverance pay off.

Mental blocks

Given that all blocks are eventually internal, we can now use our knowledge of how the mind works to identify what internal systems are affected and consequently how we can get past the blocks.

When our deep needs are threatened, we are likely to fall into the fight-or-flight reaction, which has a strong tendency to kill ideas, even within our minds and before we have had a chance to bring them out and consider them fully. Consider again the needs in Fig. 10.2. Anything that negatively effects any of these is likely to lead to creative blocks. We can mitigate many of the blocking effects of such fundamentally important drivers by recognising the effects and using self-talk to reassure ourselves that we will not be harmed by creative activity.

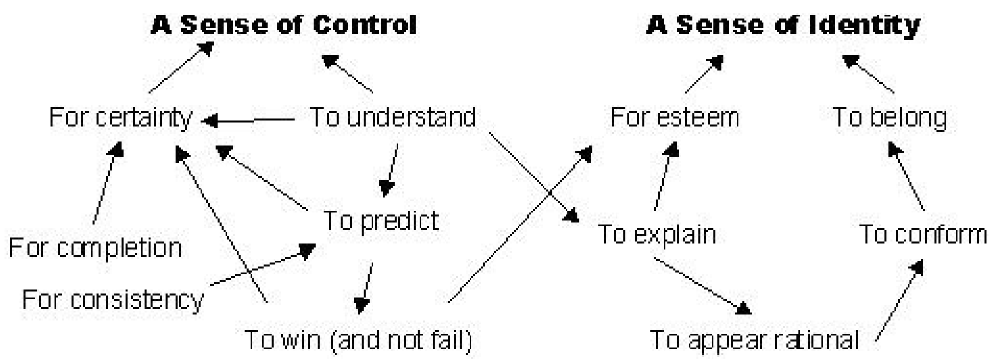


Fig. 10.2 Remember the deep needs

When we come up against ideas that are outside of our mental models, beliefs and assumptions about how the world works are challenged, we are likely to either ignore the ideas or force-fit them into our existing systems. If I look out of the window and see a person shoot upwards past it, I would not even consider that they may be flying, preferring to rationalise it into existing knowledge (Are they on a trampoline? Attached to a wire?).

What will people say?

One of the most common blocks to creative thinking is the fear of what other people will say. Our deep needs for esteem and belonging are so strong that even when other people are not there, we imagine what they might say. Our self-talk often takes on the voice and tone of a disapproving superior (possibly even a person from the past, such as an old junior school teacher). We may even imagine how someone in the room might tell us what a bad idea it is, or we may suppose that when others are talking together, they are talking about our ridiculous suggestion.

Did you know that US Navy commandos in Vietnam wore women's pantyhose? When marching through the jungle, these cut down on friction burns. They also could be peeled off at night, removing all the leeches that had attached themselves to the men's legs. Imagine the brave soul who first voiced the idea. Many people would have rejected the idea outright, but, it would seem, the potential benefits outweighed the emotional cost.

When working with other people, it is important to explicitly give each other permission to voice 'silly' and half-formed ideas. Even when working alone, you need to consider the inner critic and it can be very useful to tell yourself that this is a special situation in which it is good to play with ideas that in other circumstances would, indeed, be unacceptable.

I don't understand (so that can't be a very good idea)!

When we are being creative, we expose ourselves to new or partially formed ideas. This uncertainty affects our control needs which sends us scurrying for psychological cover, ignoring or discounting the idea.

One of the most important abilities when being creative is to suspend judgement, separating the creation from the evaluation. By accepting that confusion is a *normal* part of the creative process, we can reassure our inner thoughts, enabling us at least to forecast that there *will* be a better outcome, even though it is not currently visible.

Silencing the inner critic

Many of the blocks we create for ourselves come from that inner critic that tells us how we cannot invent or how poor our inventions really are. Would it be useful to be able to turn off that annoying voice at will? Here are a couple of techniques that may work for you.

Mickey Mouse

Notice the sound of the voice that the critic is using. Is it like a teacher or a strict parent? Now change it to sound like Mickey Mouse. Is it as powerful a dissuader now? Probably not. Play with other voices to find the one that works best for you. Make it softer, quieter, rounder, kinder. Now, when starting to invent, tell the critic that it will be Mickey Mouse (or whoever you choose) for the duration of the creative period.

You can also change the critic's location. Move it onto your shoulder, then down to the end of your finger. Or push it down onto your big toe. When it is so far away, it should be less of a distraction.

Bite your tongue

When we talk to ourselves, our tongue tends to move very slightly. Hold your tongue between your teeth and see how much more difficult it is to hear the inner voices. A less painful form of stilling the tongue that Yogic meditators have known for centuries is to push your tongue gentle against the inside of your upper teeth.

I'm not expert enough

How can I, an unworthy mortal, challenge the scientific deities? How could I dare assume that I have greater knowledge in scientific and engineering matters than the highly qualified experts?

Scientific historian Thomas Kuhn, in 'The Structure of Scientific Revolutions' pointed out how virtually all great scientific discoveries were made by people who were new to the field, probably because of the way that established experts tend to become trapped by existing paradigms, unable to challenge or even see the presuppositions on which their branch of science is founded.

Look at the side panel on experts. If a bicycle mechanic can invent the first powered aircraft, you can invent anything.

This is the way to do it (I'm an expert)

What is most precious to an expert? Why their expertise, of course. They have spent a lifetime building it, and are not going to be very keen on anyone taking it away from them. If you consider yourself to be an expert, stop it! You have knowledge, but that comes from the past. Creativity and invention are about the future, where your knowledge may or may not be relevant. Experts often see only one best solution; in creative situations there are many, equally good ideas.

Being an expert is the corollary to being inexpert. Both can be useful, but both can also be a block to creative thought and new ideas. Knowing the rules can be an advantage, because you know what to break. Deliberately challenging what you have taken as gospel truth for many years can be a remarkably revealing technique. Another good technique for experts is to ask inexpert people for ideas (and then *really* listen).

I know that

A variation on the expert trap is the ‘I know that’ syndrome. Having learned something once, we assume that (a) what was once true stays true for ever, and (b) we learned about *all* of the subject in question. The ‘closure’ effect described in Chapter 6 means that once we have understood something (or even just *believed* we have understood it), we close the door on future learning.

But as futurist Alvin Toffler said, “The illiterate of the 21st Century will not be those who cannot read and write, but those who cannot learn, unlearn and relearn.” Unlearning can be harder than learning, but to be creative we may well have to throw away all that we have held as true and start again from scratch. Many great discoveries and successes overturned previous truths: the theory of relativity overturned Newtonian mechanics, whilst Amazon.com’s business design led to a massive increase in share value without making any profit whatsoever.

To make such leaps needs both unlearning and freedom from the past, so let go and be prepared for the discomfort of that ‘lost at sea’ feeling, for as novelist Andre Gide said, “One does not discover new lands without consenting to lose sight of the shore for a very long time.”

Who needs experts?

Many great inventions were produced by people who were not only outside the field of invention, but were not even scientists or engineers. The following table shows but a small fraction of such people:

Invention	**Inventor**	**Occupation**
Cotton gin	Eli Whitney	Lawyer
Fire extinguisher	George Manby	Army captain
Ballpoint pen	Ladislao Biro	Proof reader
Disposable razor	King Camp Gilette	Salesman
Powered flight	Wright brothers	Bicycle mechanics
Typewriter	Christopher Scholes	News editor

And just listen to what the experts have said:

'The phonograph is not of any commercial value.' — *Thomas Edison, 1880*

'The abdomen, the chest and the brain will forever be shut from the intrusion of the wise and humane surgeon.' — *Sir John Eric Ericson, Surgeon to Queen Victoria, 1873*

'Stocks have reached what looks like a permanently high plateau.' — *Irving Fisher, Professor of Economics, Yale, 1929, just before the Wall Street crash*

'640K ought to be enough for anybody.' — *Bill Gates, 1981*

'Heavier-than-air flying machines are impossible.' — *Lord Kelvin, President of Royal Society, 1895*

'That bomb will never go off, and I speak as an expert in explosives.' — *Admiral William D. Leahy, 1945 on the atomic bomb*

'There is no likelihood man can ever tap the power of the atom.' — *Robert Millikan, Nobel prize winner in physics, 1920*

'Flight by machines heavier than air is impractical and insignificant, if not utterly impossible.'
— *Simon Newcomb, astronomer, 1902 (Wright brothers flew in 1903)*

'Louis Pasteur's theory of germs is a ridiculous fiction.' — *Pierre Pachet, Professor Physiology, Toulouse, 1872*

And, more than once, the invention experts have over-reached their mark:

'Inventions reached their limit long ago and I see no hope for further development.' — *Julius Sextus Frontinus, prominent Roman engineer, circa 40-103 AD*

'Everything that can be invented has been invented.' — *Charles H. Duell, Commissioner, US Patent Office, in 1899*

That won’t work

Even non-experts have opinions and it can be surprising difficult to stop evaluating ideas. When we see a new idea, we immediately try to fit it to our mental models and then forecast how successful the idea will be. Unfortunately, new ideas seldom fit well with existing mental models and their associated assumptions and beliefs.

If you catch yourself rejecting ideas before they have had a fair chance to incubate, pause and turn the spotlight on *how* you are deciding that the ideas are no good. What mental models are you using? What assumptions? How might these be limited? Even challenge or ignore for now established scientific or engineering rules.

You do not know what will or will not work until you try it. And even then, beware of throwing the baby out with the bathwater. Edison tried around 1800 different methods before he found the right combination for the light bulb. One of his comments was that ‘Our greatest weakness lies in giving up. The most certain way to succeed is always to try just one more time.’

This is not a creative problem

Another trap of mental models is that when we classify things, we do not consider any use outside that classification. This is what Karl Dunker called *functional fixedness*, and blinds us to many possibilities. We also suffer from other forms of blindness, including assuming that because customers do not complain, they are satisfied, and that what worked yesterday will also work tomorrow.

We do overcome classification. Have you ever used a screwdriver to open a tin of paint, or a paintbrush to dust a delicate object? That is not their intended purpose, but you have learned to adapt the tool to other uses. The trick is to see the assumptions that you are making and to challenge them.

I’m not creative

This is a very common belief block, often rooted in early childhood where you were taught to conform and that being creative with your food or mother’s lipstick was not acceptable behaviour.

Of course, like any ability or skill, there are talented people for whom being creative is easier than for others, but in no way does that mean that you are not creative. Most people operate far below their creative potential. In fact we are constantly being creative, having thoughts, saying and doing things we have never thought, said or did before.

The block is the belief, not the ability. You have been very creative before; all you need to do is remember how to do it (and the memory *is* there).

Environmental unblocking

We are very sensitive to the world around us and respond, often subconsciously, to cues in our environment. We can work on de-sensitising ourselves to such contextual triggers, but the simplest way to manage environmental effects is to leverage them, creating an environment where we can consistently feel *more* creative.

Think about when you feel most creative. Is it in your workshop, or study, or walking in the woods? For many people, the ‘three Bs’ (bed, bath and bus) represent relaxed places in which they can think, unhindered by associations with the world around them. Wherever it is, or wherever you want to be creative, start to work on making it even better.

Go and look at the place where you invent. Is it really conducive to creative thought? Do you feel sufficiently relaxed and yet sufficiently stimulated? What would be the effect of changing furniture, the lighting or the colour of the walls? Are all your tools and materials to hand?

Many people have ideas when dropping off to sleep, when their physical environment is virtually nil. Picasso reputedly had a technique of sitting in a chair while holding a spoon above a tin plate on the floor. As he dozed off, the spoon would slip, falling to the plate with a clatter, waking him up. He would then quickly write down what was in his mind at the time.

Consider what you are wearing. Is it comfortable? Does it constrict you anywhere? Do you invent best washed and clean or when you are a bit grubby.

Does the furniture help? Is your chair comfortable? Is your desk at the right height? Is the lighting adequate? Would more natural light help? Does facing the window or a particular wall make a difference?

Is there the right amount of stimulation there? People who work more with internal thoughts may prefer a plain environment, whilst for others pictures and magazines can provide useful thought triggers.

How does eating affect you? Many people find that carbohydrates slow thinking and that proteins (not too much, though) enhance it. Try orange juice, fruit and eggs for breakfast, rather than coffee, cereal and toast. Also eat little and often, rather than big meals that lead to your digestive system robbing your brain of blood.

What about the time of day? Some people work best by coming up with the basic ideas in the morning and developing them in the afternoon. Others are night hawks, performing best when the rest of us are sound asleep.

Sounds also can help. Is the environment quiet enough? Do you like music? Some people like Bach or Mozart, whilst others prefer more modern music.

And finally, consider distractions. Do people interrupt you? Is there a phone nearby which could disturb you? Will going somewhere quiet (or noisy!) help?

The overall answer to building a truly creative environment is to experiment. Try varying any of the above and more. Notice how you feel and notice how well you work (being too relaxed may not be the right state for you).

Block demolition

Think of a time when you felt blocked, when you felt unable to reach inside for ideas or when you had ideas but felt unable to let them out. How did you feel? Frustrated? Unworthy? Uncreative?

Here are a few techniques that can help to weaken or demolish internal creative blocks. Try them: they are easy and have worked for many other people. If they work for you they could be worth the price of this book.

1. Timeline review

Visualise time as along a physical line. It may be back and forward, side to side or any other shape and orientation. Now imagine floating up above it. Turn to face the past and float back along the line until you get to above and just to the future of the earliest time you can remember when you felt blocked. Look down at the blocked event. Then float just above it, looking down on it, then go down into the event and notice the feeling.

Now for the tricky bit. Float up back out of the event, and go to a position about 15 minutes before you felt blocked and look diagonally down towards the event. Notice how the blocked feelings just leak away. If any part of them remain, float up and backwards until they disappear. Then float forward back towards the present, noticing how events change as a result of the blocked feelings disappearing.

2. Negating

How do you 'do uncreativity'? Think of a time when you were not as creative as you wanted to be. Slow it right down and consider the detail of what you did to be uncreative. What did you say to yourself? What visual images did you make or not make? How did your feelings change? In what order did things happen?

Now deliberately change some of those things. For example, if you told yourself that you were not good enough, imagine that you had told yourself that you were really creative. If you imagined people rejecting you, imagine them being really impressed by your ideas. With each modification, notice how things change, including the pictures, the sounds and your feelings, as well as the ideas that appeared.

3. Streaming

A way that writers get past 'writing blocks' is to write. Just anything that comes into their head, endlessly. They might write non-stop rubbish for hours or even days until the ideas and writing become more useful again. You can do the same with ideas. Just write down any ridiculous idea that comes into you head, then another and then another. Keep doing this without stopping until some useful ideas start appearing.

An alternative approach is to do the same thing, but verbally. Just say out loud the ideas, one after another, non-stop. It can be helpful to have a tape recorder running, so you can capture any useful ideas. It may seem simple, but this can be a very powerful way of unleashing your inner creativity. We do overcome classification. Have you ever used a screwdriver to open a tin of paint or a paintbrush to dust a delicate object? That is not their intended purpose, but you have learned to adapt the tool to other uses. The trick is to see the assumptions that you are making and to challenge them.

Other programmed responses

Remember the short-cut decision-making that we use? We have many rules of thumb, habits and programmed responses that steer us away from considered creative acts. Some of these are easy to break–all we need to do is recognise them and decide to act otherwise. Other internal programs are very subtle and difficult to spot or are so deeply imbedded that they require significant extra work to dislodge, possibly even with the help of a professional psychologist.

Unblocking entire companies

A question that is on the lips of many executives is, ‘How can I create a culture of invention and creativity within my company?’ The key word here is ‘culture’, which means values, beliefs and attitudes that lead to specific behaviours. It also implies the ‘climate’, which is the specific environment in which innovation may occur.

The biggest task of managing for innovation is not so much asking people to invent as removing the subtle blocks that prevent them from doing so. An unblocked environment can have a negative impact on the sense of control of managers who are accustomed to the command and control approach, but the evidence of innovative companies shows clearly that inventing to order is not easy. Even using the methods in this book is no guarantee of success, especially in the face of the huge walls that many organizations have built. Companies seldom deliberately set out to stifle innovation: their rules and systems are primarily aimed at encouraging conformity, but these same rules become powerful deterrents to anyone daring to think outside the ‘corporate genetic coding’.

The real question for many companies is thus not so much ‘How can I make people innovative’ as ‘How can I *allow* people to be innovative.’

Leadership

People are not stupid. They do not accept values from a poster or from managers reading from a little card. They deduce your values and act accordingly. It is thus very important for leaders to display and use behaviours that motivate people to invent. Here is a quote from David Packard’s ‘The HP Way’:

> “Upon first being approached by a creative inventor with unbridled enthusiasm for a new idea, Bill immediately put on a hat called ‘enthusiasm’. He would listen, express excitement where appropriate and appreciation in general, while asking a few gentle and not too pointed questions. A few days later, he would get back to the inventor wearing a hat called ‘inquisition’. This was the time for very pointed questions, a thorough probing of the idea, lots of give-and-take.

> Without a final decision the session was adjourned. Shortly thereafter, Bill would put on his 'decision' hat and meet once again with the inventor. With appropriate logic and sensitivity, judgement was rendered and a decision made about the idea."

This is very similar to Walt Disney's approach, as described by one of his animators:

> "…there were actually three Walts: the dreamer, the realist and the spoiler. You never knew which one was coming into your meeting."

Notice how this is the action of leaders of the organization, the people at the very top who set the tone and the culture in everything they say and do. An innovative company has innovative leaders who model appropriate behaviours and both encourage and empower their employees to do likewise.

Values and other rules

Values, as Chapter 8 indicates, are the basic rules that underlie much behaviour. Values that encourage invention are not only are directly about innovation, but also lead to the prevention or removal of blocks. Hewlett-Packard have values of innovation and contribution. They also have values of trust and integrity.

3M have an informal rule that 15% of their people's time may be spent on personal projects, which is how Post-it Notes started. This encourages people to be curious and experimental. Another variation of this is the 'skunk works', where projects that got cancelled simply went underground. Hewlett-Packard's DeskJet is just one product that originated in this way. The bottom line is to give people space to play, even if it means turning a blind eye.

Visions and things

A vision is a *motivating* view of the future that drives a whole company towards a common future. This means everyone understands it (so it must be well communicated), can remember it (so it must be short) and buy into it (so it must be inspiring).

Hewlett-Packard’s ‘Process of Management’ system says ‘build a shared vision’, where a vision is a ‘motivating view of the future.’ The manager’s main task is then to remove blocks so their people can achieve the vision. This is only broken down so far, as their ‘Management By Objectives’ approach is to tell people *what* is wanted, but not *how*. This is followed by ‘Managing By Wandering Around’, where managers are always visible, interested and are actively seeking to *remove* blocks, not create them.

How you can use visions to turn an organization into a company of inventors is best summed up by Harvey Robbins and Michael Finley in their book, ‘Why Change Doesn’t Work’:

> “The way to make effective long term change is to first visualize what you want to accomplish, and then inhabit this vision until it comes true. And change is an act of the imagination. Until the imagination is engaged, no important change can occur.”

Communication

The values of a company are propagated through its communications, as well as the actions of its leaders. Communications that create or remove blocks include:

- The objectives that managers give to their subordinates.
- The company newsletters, magazines and journals.
- Promotions, PR and other communications outside the company.
- The stories that people tell one another at the coffee machine.
- The myths and legends that perpetuate.

If these communications are about meeting financial targets and saving money, then this is what will be perpetuated. Similarly, if the communications are about individuals who persisted and circumvented the system to invent great new products, then this will also tell the organization what is valued most.

Mixed messages can be very damaging. If you tell someone to bend the rules to create new ideas, then punish them for doing so, then they will get the message loud and clear: never, ever offer ideas again. Communications and actions must align with vision and business plans.

Recruitment and promotion

Although all people have far more ability to create and invent than they or their managers may think, you can help this along by recruiting people who are already unblocked and have the enthusiasm to invent. When Hewlett-Packard interviews people they keep in mind the fact that that person may do many jobs in the company, and that attitude and enthusiasm are as important as skills for the immediate job in question.

Promotion sends loud messages about values and leads to managers who either inhibit or encourage innovation. To be a senior manager at General Electric, you need to have visibly embraced and gained real results from their ‘Six Sigma’ business improvement system.

Overall, there are no half-measures when managing for innovation. If you value people, they will value you. If you trust them, they will act in a trustworthy way. If you challenge them with visions and objectives, they will strive to achieve those goals. If you remove the blocks to their achieving, they will achieve greatly.

11 Stimulating Ideas

Once we have cleared enough of our mental blocks out of the way, we can then start to prod our brains into creating new and inventive ideas. This chapter uses our understanding of the how our inner systems work to describe a wide range of techniques that we can use to bounce our thinking out of the everyday ruts of entrenched thought patterns and into new and creative possibilities.

We offer five principles that can be used to stimulate ideas, within each of which a number of tools are described:

- Challenging assumptions and beliefs.
- Creating inner tension and driving need.
- Changing viewpoint, perceiving things differently.
- Paying attention and making great user of our senses
- Combining things around the problem.

Although many methods use a combination of the above approaches, we are utilising them here as a sorting mechanism that highlights the major principles in the techniques offered.

Challenging

A simple approach to discovering new alternatives is to challenge and question the status quo, breaking out of a constrained mindset by dint of mental force.

Challenge

The simplest creative technique is to challenge anything and everything, perhaps in the way that children question things. Ask ‘Why’, not as an analytical approach to find the cause but as a challenge to make you think when you might otherwise have passed by a potential invention opportunity.

For example, you could as ‘Why do I have to double lock the doors of my house every night?’ Is security more important at night? Why could I not have a system which locked the door securely every time I shut it? Why do I need a key? How could the door recognise me and open as I approach? How could I not even need a door?

You can also challenge any of your deep systems, including mental models, beliefs, values and goals. Take anything that you have not questioned for a long time and question it. Watch yourself as you work and think. Watch yourself judging yourself and challenge that part of you that says ‘I can’t do it’ or ‘That won’t work.’

Assumption-Busting

Chapter 9 described how we make constant assumptions through the mental models we use to manage the complexity of the world around us. Assumption-Busting simply means to perceive those presuppositions and challenge them. Although this may sound simple, it can be rather difficult, as many of our assumptions are so embedded in the way we live our lives, we tend to over look them.

For example, many of us assume that the way to eat pasta is to buy it dried and then cook it. But this assumption was spotted and challenged, with the result that it turned into a mega-money-spinning business selling fresh pasta through supermarkets.

You can challenge assumptions about boundaries (e.g. ‘This is for engineers only’), what customers will put up with (e.g. soap getting messy), possibilities and assertions (e.g. ‘You can’t do that’) and any other aspect of the problem. You can also challenge more fundamental assumptions such as our beliefs (‘We all have a right to free education’) and values (‘We must look after our customers’).

PO

PO is a word invented by Edward DeBono. It stands for ‘provocative operation’ and is used to prefix a statement that is deliberately intended to provoke different ideas, breaking out of the current pattern of thought. It can be a nonsense statement like ‘PO: The road to a solution is nowhere’ or a deliberate juxtaposition such as ‘PO: The subject learns the child’.

The prefix ‘PO’ acts as a warning ‘Look out, here comes a radical stimulus.’ It also legitimises the strangeness of what is being said, effectively saying ‘This is not the normal me–I am just saying this as a provocation.’

Creating inner tension

Necessity, as Plato said, is the mother of invention. By creating an inner need that sets powerful goals, the dissonance that is created between reality and what we want compels the subconscious to join in the hunt for ideas that will reduce the tension that is felt.

Incubation

Graham Wallas, in his 1926 book ‘The Art of Thought’ described four stages in creativity: preparation, incubation, illumination (the ‘Eureka’ or ‘aha’ experience) and verification. The incubation stage is singularly unexciting in execution. All you basically do is to immerse yourself in the problem and then forget about it, allowing the subconscious to go to work on the problem, in its own time and in its own way.

The great German author, Johann Wolfgang von Goethe explains it well:

> “The worst is that the very hardest thinking will not bring thoughts. They must come like good children of God and cry, ‘Here we are.’ You expend effort and energy thinking hard. Then, after you have given up, they come sauntering in with their hands in their pockets. If the effort had not been made to open the door, however, who knows when they could have come.”

Goal-setting

This method is simply to set yourself a goal. This seems simple, but if you can really commit to it, goal-setting can be a simple and effective method of creating a internal compulsion to work on your problem until you achieve the goal.

An acronym that is sometimes used for objectives and goals is ‘SMART’, which means you should have a Specific and clear goal which is Measurable so you can tell when you are getting there, Achievable so you do not take on the impossible, Relevant to your overall problem and Timely, so you have a defined ‘by when’ associated with the goal.

Remember the difference between needs, wants and like-to-haves. To make a powerful goal, you should make it a strong need. Think of a time when you really needed something, and were prepared to move heaven and earth to get it.

Notice how you thought and felt about that need and bring it back with you and put it into your goal. Feel how you really need to achieve this. See the discomfort of not achieving it. What would you say to yourself if you did not reach the goal?

You can also strengthen goals by writing them down or by telling other people (the more the better) what you are going to do. The prospect of losing esteem is a powerful motivator which you can use to prod your subconscious into creative action.

Pre-inventive Forms

If you give one person a few toys, another a few random scraps of assorted materials and a third person nothing, and then ask them to invent a new toy, experiments have shown that the following events are likely to occur. The first person is likely to come up with variations on the toys they were given. The third person will come up with some interesting ideas. But the greatest number and most creative ideas are most likely to come from the second person.

What happens here is that the first person gets anchored by the conventional forms of the toys they were given, whilst the third person is anchored by their own mental models of toys. The random shapes, however, act as external stimuli to the second person, pulling them away from the anchors that entrap the other two people.

So to use pre-inventive forms, simply find some random bits of metal, paper, and so on, which are deliberately taken from areas well away from the problem domain. Then play with them, wondering how you could use them to solve your problem, for example as in Fig. 11.1.

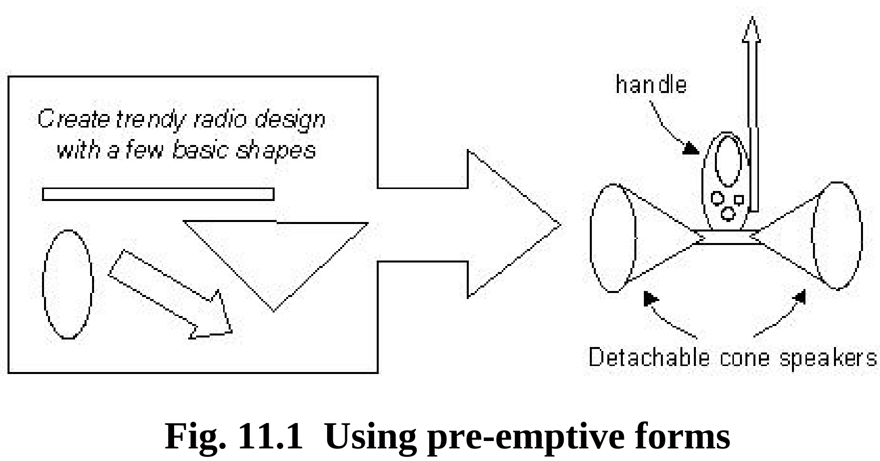


Fig. 11.1 Using pre-emptive forms

Truth and Vision

This is a carrot-and-stick method to create internal tensions that impel your subconscious mind into creative action. By increasing discontent with the status quo you can break free of the present and move towards a desirable future.

First, shake yourself out of any complacency or procrastination by telling the honest and naked truth about your current situation. Create a deep desire to change through the use of deep thinking and self-talk that highlights what will and will not happen if you stay where you are and do nothing. For example, admit your current level of poverty and your desperate need to escape it. You may also confront the limitations of the area in which you want to invent, such as inability of a motor to rotate faster than its theoretical limits (although beware here of creating limiting thoughts that reduce, rather than enhance, your creativity).

Next, forge a psychological magnet by identifying a clear and desirable future. See yourself being successful, receiving what accolade and reward that you truly want. Notice what you see, hear and feel. Also see the completed invention being used as it should, working perfectly according to your designs.

As with goals, you can strengthen these by writing them down and telling other people. We identify with what we write and say, and making these outer commitments will also build a powerful inner impetus.

An extra trick you can use is to state your vision in the present tense. This accentuates the difference between reality and the vision (you can also use this technique with any idea, stating it as if it were true now).

Wishing

Wishing is a surprisingly simple and effective method. Just say ‘I wish…’ followed by an idea. Read the following two statements and notice carefully inside your head how they affect you differently:

> Make every understand.
> I wish everyone understood.

What tends to happen is that the second statement creates more tension, challenging you to think of other ideas to make the wish come true. You could also use phrases that will act in a similar way, such as ‘Wouldn’t it be nice if…’, although ‘I wish…’ is probably the shortest version.

Compressed Conflict

Take two essential aspects of the problem and create a pair of words which fight together, but somehow represent an interesting element of what is happening. For example, an engineer seeking to create a ratchet effect might use the term ‘intermittent directionality’ or ‘staged success.’

Now let the discomfort that this term creates work on you subconscious, letting it produce ideas. The ‘intermittent directionality’ could cause thoughts about why the ratchet should work in one direction, and how it could be made to work when the ratchet lever worked in both directions. ‘Staged success’ may lead to ideas on using a number of different ratchets, with smaller steps leading to the achievement of larger steps.

Changing viewpoint

A simple way of seeing the problem in a different light is to change your viewpoint, to look at it from a different place, whether further out or closer in. We can look at both the physical attributes of the problem or the more abstract concepts or perceptions around the situation

Remember how we base our perception of the world on mental models, beliefs, values and goal? By examining and modifying these inner presuppositions we can change how we interpret various aspects of the situation. This does not mean that we have to change our inner viewpoints permanently; a temporary shift in perspective can be sufficient to stimulate new ideas.

Reframing

When we look at a problem, we do so through the frame of our beliefs, values, attitudes and mental models. We can see things differently and consequently see new ideas by changing or challenging any of these. For example if you were trying to create a video panel that could be viewed from different angles, then reframing might be to challenge your beliefs that there must only be one panel.

Sometimes the simple act of self-observation can make us realise how the frame through which we are viewing the problem is limiting our perception of possible solutions and thus change various aspects of the frame, enabling us to think more creatively.

Frames are often based around our assumptions of what *causes* what (this is very helpful to our need to forecast future events). Challenge and change your models of cause and effect around the problem and you may well be rewarded with new insights.

Role-play

One of the simplest ways of reframing a problem is to steal a frame from someone else. Take a random character who may be alive or historical, real or fictional, human, cartoon, animal or alien. Ask a question of them, such as, ‘What would they say in this situation?’ ‘What would they do?’ or ‘If they were inserted in some strange way into the problem, what would happen?’ Use the response as a stimulation to create new ideas.

For example, if Napoleon was asked to help create a personal warming device, he might say, ‘Let’s use the cannons’ which might trigger a line of thought about explosion and chemical reactions, or about remote delivery of energy.

Reversal

Reversal is a simple but powerful technique that breaks you out of the current situation by taking you to some form of opposite. Simply ask, ‘What if I looked at this from the reverse view, or backwards in some way?’ For example, as a designer, you could reverse your view to that of the user or you could look at the spaces in your invention rather than the shapes.

You could also use the reversal principle in a more radical way to stimulate other ideas, such as ‘The apple eats itself’ or ‘the clothes wear the person.’ You can reverse concepts, attitudes, physical viewpoints, positions, and virtually anything else about your problem.

Metaphor

Metaphors are rather useful modes of speech where, for example when we are having trouble expressing ourselves, we can use words and phrases completely out of their true context in order to illustrate a point. Thus, when we say, ‘He is a real puppy’, we do not mean that he has become a canine, but that he is soft, pliable and perhaps a bit naïve. Notice how the attributes and other associations from our mental models of the referenced word (dog) are brought into the target situation along with it.

We can use this effect to stimulate ideas, by asking ‘What is this *like*?’ taking pretty much anything that comes to mind, even if the link is a bit tenuous, and then finding what comes along with the metaphor. For example, if you were trying to find a non-battery power source for an underwater torch, you might say, ‘It’s like squeezing light from a stone’ and from this start wondering how you could use the external water pressure, perhaps from the increasing pressure as you go deeper, to drive a small generator.

Whole worlds of stimulation can also be found by first distilling the essence of the problem and then finding a situation where there are similar essential elements. For example, designing a door that opens at a light touch, an essence might be ‘balance’. An analogous situation for ‘balance’ could be ‘walking a tightrope’, from which ideas such as ‘keep centre of gravity low’ and ‘keep the wire tense’ may lead to a door with the weight at the bottom and a tensile wire hinging system. You can also take more radical inspirations, such as balancing a bank account, where ‘ensure positive incomes’ could lead to ideas for creating good feelings as you walk through the door.

Storying

We have been rational scientists and engineers for only a few hundred years; our history is steeped with storytelling which still can be a surprisingly effective way of accessing our subconscious minds. Stories can be used to create complete scenarios and put possibilities into real contexts. With a few words we can paint a thousand pictures of imagined futures.

The basic storying technique is to put the problem or solution into a fictional context, for example, telling a tale of how the solution may be used in real life. You can also use metaphors in more fantastic approaches, such as giving each part of the solution a personality of its own, and let them the parts play out a drama between themselves.

An additional benefit of this method is that the writing of the story is, in itself, a creative stimulant as it forces you to consider aspects of the problem and ruminate about interesting possibilities.

Thesaurus

We easily get trapped by the mental models that we associate with individual words, and can find it difficult to think outside of this conceptual box. A simple way of getting another viewpoint is to find another word meaning roughly the same thing. And a useful place to find such words is a thesaurus (you can even use the one in a word processor).

For example, the word ‘flexible’ yields supple, lithe, elastic, plastic, stretchy, bendable, adaptable, accommodating, variable, compliant and open, any of which can suggest other ways of flexing. You can even follow chains of synonyms, going from flexible to stretchy to pliable to malleable to supple to sinuous.

Thought experiment

The basic principle of this method is to do an experiment in your mind, in which you can zoom around and take extraordinary views of what is going on. You can construct a realistic model of your idea and fly around and inside it as you bend and adjust the parts. You can also use a fantastic metaphor to gain new insights.

Einstein was an inveterate user of this technique and famously ‘rode on a beam of light’ to see what would happen as you approached the speed of light. Tesla was another mental constructor, who could design a complete machine in his mind, run it for a few months and then take it apart to see which parts had worn!

Sensing

Recall from Chapter 8 how we tend to constrain our zone of our attention and use our five senses in a limited way, focusing more on one sense that others. By deliberately extending and broadening our sensing, we can see, hear, feel, taste and smell the problem differently and potentially discover new aspects.

One of the limitations of brainstorming, the most common creative technique used today, is that is based on spoken and written words, which can be constraining for people who have a lower affinity for words. Methods that extend beyond words can take advantage the capabilities we have in using our other senses, such as touch and vision.

Collage

Take a pile of magazines and cut pictures and words, sticking them together on a large sheet of paper (such as a page from a flipchart) to represent aspects of the problem. Then stand back and try to interpret the result or find inspiration in the shapes and words. For example, a problem around a wheel bearing might show footballs to represent rollers. You could use this to imagine flexible, rather than hard steel rollers.

This method often appeals to people with visual preferences. It also has tactile elements, in the cutting and gluing. The smell of the glue and paper and the overall act may also trigger childhood memories of such activities and hence reawaken creative feelings.

Doodling

Many of us are have vision as a primary sense, yet much creativity is through words. A simple approach to creating stimulus is to use a visual variant of the 'random word' technique, drawing a random pattern, without any aim of creating pictures at all. It can be surprising what pictures you can subsequently see in it. The pictures you see can then be used as a stimulus for finding useful ideas for the problem.

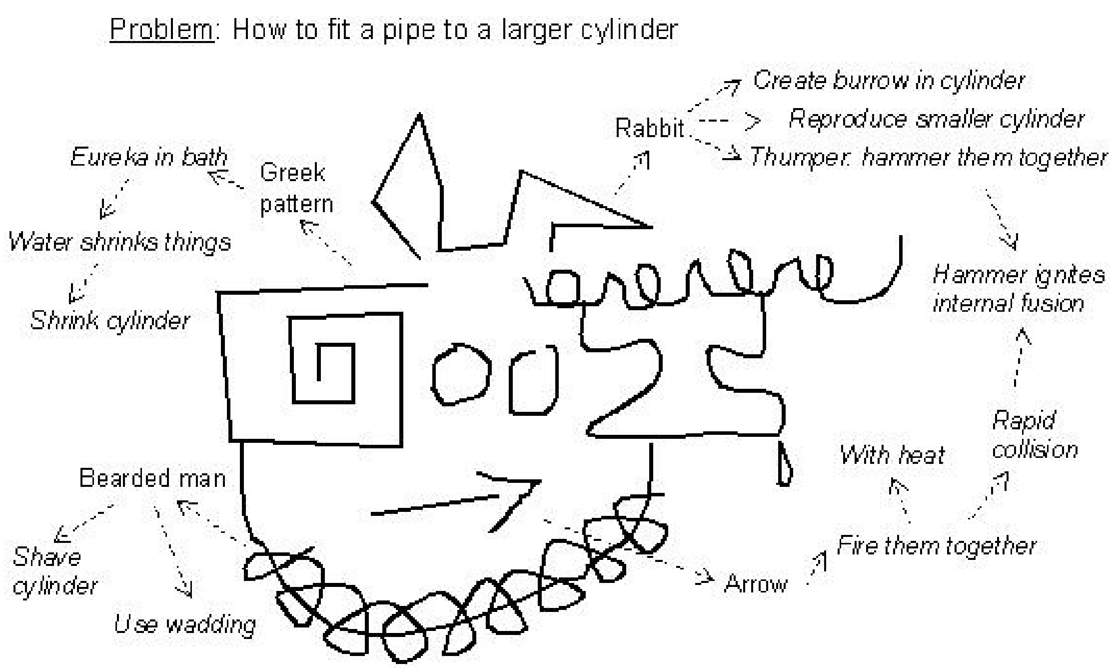


Fig. 11.2 Doodling

Modelling

Remember how many people are more focused on sights or sounds? Well this technique is for the more tactile of us, stimulating our three-dimensional senses. It can also provide a surprising and thus useful new dimension of thought for the visual and auditory people.

The technique is simply to take some modelling materials, such as clay or cardboard and sticky tape, and make something. It may be connected with the problem in some way or can even be an abstract shape. When you are done, look at the model and, in a similar way to Doodling, notice what you see in it, then link it back to the problem, using what you see as stimulation for new ideas.

Modelling can work by allowing the subconscious to guide your hands, it can become a pre-inventive form or it might simply give space for incubation.

Sensory immersion

As Chapter 8 indicated, we make limited use of our senses and hence miss much of what is going on in the world around us. This limited attention can also lead us to miss much of the problems that are under our noses.

To immerse yourself in the problem area, simply pay attention to each of your senses in turn. Look, really look deeply at that pillar, brick or material. Notice its texture and colour, see the boundaries and how things fit together. Close your eyes and touch things, noticing how rough, sharp or rounded the parts are. Notice any associated sounds or smells.

You also use imaginative sensory immersion. If you are facing a chemical problem, imagine feeling the atoms molecules: What do they feel like? Shrink yourself down to microbe size and float through the problem items. Talk to them. Smell, lick and taste them.

Thought experiments

Albert Einstein was probably the most famous thought experimenter, imagining himself riding on a beam of light to discover the theory of relativity. It was a method he used frequently, doing experiments in his head and putting himself into imaginative positions within it, watching what was happening. Nikola Tesla also used this method, building and running complete machines in his mind.

The method is simply to do as the title says, creating and running experiments in your head. The advantage of this is that you can not only use imaginative approaches, your experiments will also be quick, easy and cheap.

Visualisation

When we think of ideas and situations, we can either do so from a dissociated position, standing back objectively, or we can associate ourselves fully into the situation, seeing and hearing *as if* we were there. Our subconscious has a great deal of difficulty in differentiating between reality and powerfully imaginings, which we can use to our advantage by internal visualisation around any part of the problem.

Guided visualisation is where we listen to a script (from a tape or read by someone else) that leads our subconscious into deliberate situations whereby it can give us a message. The script below gives opportunities for written/drawn (the paper by the stile), verbal/interpersonal (the person in the tower) and physical/tactile (the gift) messages.

This method can be used as a follow-up to a period of immersion in the problem where our subconscious may have ideas or comments that are not getting through. It is not a very predictable method and sometimes our subconscious gives us information about other things which are on our minds. It can also be quite literal or metaphoric and what it gives us may take some deep thought to interpret its potential meanings.

Visualisation Script

Tape this script. Find yourself a comfortable place. You can sit or lie down as you like. Then play the script back.

Are you comfortable? Good. Now stretch and take a few moments to relax. Close your eyes and notice any tensions in your body and just let each of them go….That's right.

Now, imagine yourself sitting in a field, the grass soft and sweet-smelling beneath you, the sun comfortably warm above and a soft breeze gently rustling the leaves of the trees around the field. You smile within and stand up. As you look around the field, you spot an old gate on one side. You walk over to it, open it and go through into the deserted lane beyond.

Beneath the archway of branches from the trees either side, you walk slowly down the lane, listening to the soft sounds of the breeze in the trees and distant birds calling to one another. Seeing a stile at the side of the road which leads to a path up a hill, you walk up to it, grasp the stile firmly and climb over. Just as you are about to walk on up the path, you notice a piece of paper on the ground. It seems to have something written on it. With a sense of anticipation, you pick it up and look carefully at it.

Walking on up the path, you gaze around at the placid woodland scenery as you stride easily between the trees. As the hill starts to level out, the trees end and you see that the upper part of the hill is grassy. Continuing upwards, you see that there is a stone tower at the top, with a single wooden door at the bottom and deep windows at various points on the walls. You reach the door, turn the handle and enter into a single, musty-smelling, dimly-lit room, from which a stairway goes up the tower.

You walk up the stairway until you come to a closed door at the top. You knock on the door and a vaguely familiar voice bids you enter. You turn the handle and walk into the tower room, which is bare apart from a table and couple of chairs, from one of which a person is rising. The person smiles, walk over to you and greet you warmly.

Knowing you can trust this person, you talk about important things. They listen carefully, then pause for a while, considering, before giving you a valuable reply. You continue in deep discussion for a while, and then both go to the window to look out across the trees and the fields, pondering what has been said.

Eventually, you feel that is time to go, and say so. The person agrees and leads you over to the door. Just before you leave, they hand you something. Surprised, you thank them, and then depart, going back down the stairs and out into the sunlight. You then retrace your steps, back to the trees, down the hill, over the stile, along the lane and through the gate, back into the field.

There, you sit down on the flattened grass where you were before and, holding the gift that the person in the tower gave you, you look carefully at it, turning it about in your hand…..You then muse for a while, remembering your conversation in the tower…..Then you recall the paper you found by the stile, take it out and look at it again.

After a while, you stretch, open your eyes and come back into the room, bringing with you the insights and discoveries you found on your journey.

Combination

Arthur Koestler called it 'bisociation' whilst others call it 'forced combination.' The basic principle of combination is to conceptually bang two things together and see what happens. The tension created by the way the two things do not fit naturally together leads to a new thought which bridges the gap between the problem and the mis-fitting stimulation.

The simplest form of combination is to take two objects and see how they work together. For example, someone at 3M thought about combining a Post-it Note with a flipchart page, coming up with flipchart pages that attach directly to any wall.

Morphology

With a name like this, this method had to be invented by an engineer. It was: his name was Fritz Zwicky and he worked for the Aerojet Corporation in the 1960s. As with many other methods with fancy names, it is actually quite simple in practice, as illustrated in Fig. 11.3.

First take a number of elements of the problem that can be varied, and list a number of possible values these variables can have. Now select a random set of these values and force them together to create a stimulus, asking 'how can all of these be combined?' You can also do this in a more rigorous way, by forcing together every combination, although this is only practical if there are limited lists of items to combine.

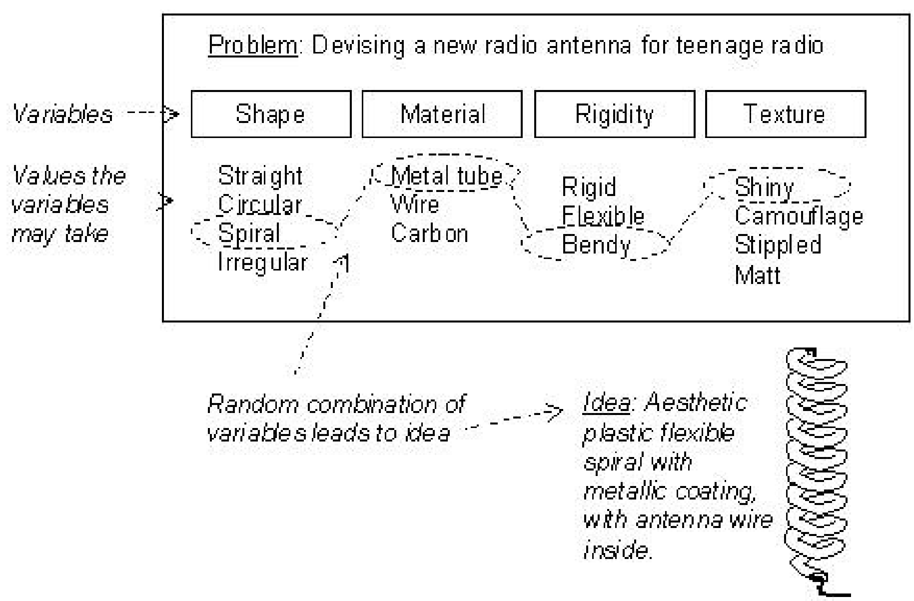


Fig. 11.3 Morphology

Post-up

The Post-up is a very simple method of extending brainstorming into a more flexible form. The basic method is to capture ideas on Post-it Notes. What makes this method useful is both the flexibility of capturing ideas and also the way in which ideas can then be shuffled around.

Write one idea per Post-it Note either in one session or anywhere and any time. You can do it in a standard brainstorming session, where ideas are produced in a rapid-fire manner, or anywhere or any time. Many good ideas appear when you are relaxing, going for a walk or lying in bed, so carry a Post-it pad and a pen everywhere. When you think of an idea, write it on a Post-it Note and then transfer the Note to the back of the pad, leaving a clean note on top, ready for the next idea.

Now pull together random pairs of Post-it Note ideas and use these as a stimulus for further ideas, either trying to combine them or finding any other ideas. You can also cluster ideas, weed out weaker ideas and prioritise lists of ideas.

Pyramid

Start with a single idea, writing it down at the top-middle of a page (see Fig. 11.4).

Next write two completely different and unrelated ideas beneath it. On the third row, continue the triangle with three ideas, putting two more different ideas on the outside, but the middle idea must be formed by combining the two ideas above in some way.

Keep repeating this principle until you run out of ideas, with the outside edge of the triangle made up of original and unconnected ideas and the inner ideas made from forcing a connection between the two ideas above. Thus the fourth row will contain two original ideas and two ideas made from the ideas above. You can, of course, do this with Post-it Notes.

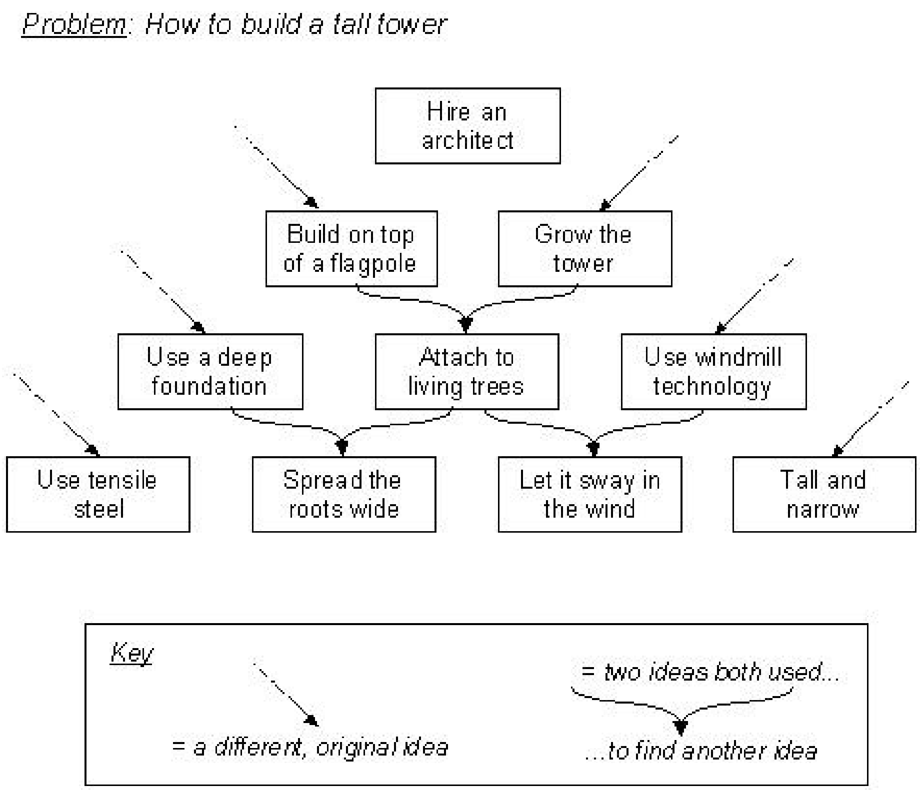


Fig. 11.4 Pyramid

Random Word

Open up a book to a random page and pick a random verb or noun. Words that stimulate several different lines of thinking are useful. Thus ‘bank’ could mean a money bank, an earthen bank, or to turn (like an aeroplane). The associations created from the word can then be combined with the problem to find a new idea. For example, if the problem is how to cut a hard metal, then ‘bank’ as money bank could lead to ‘investment’ of effort at a single point, or extra high speed ‘turning’ of a large cutting disk.

Words that are particularly evocative, triggering visual or other sensory memories, are also very useful. Thus ‘explosion’ or ‘Christmas’ are likely to be more stimulating than ‘chair’ or ‘wall’ (although simple words can also provide surprisingly good mental prods).

This method makes use of the way we hang our thoughts off each other, as described in Chapter 7. The random word stimulates conventional memory linkages which are then forced into association with the problem to create new mental pathways.

You can use the principle of random words by selecting a random *anything* as a stimulus. Look around you, grab anything you see, from photographs to newspaper headlines. Actively seek stimulation, see where it leads you, then pull it together with the problem to stimulate new thinking.

Linguistics

Words, as discussed in chapter 9, are poor substitutes for deep meaning, but they do have the effect when we face them of making us think hard about their meaning. The linguistic approach takes a more considered approach than the random word, applying to the problem particular words that normally are used with other words or phrases.

Conjunctions join words, phrases or sentences: After, before, now, since, until, when, while, where, whence, as, since, because, so, unless, although, even if, whether, if, unless, except that, in order, so, such that.

Prepositions join nouns and pronouns, often showing position: About, above, across, after, along, amid, among, around, at, before, behind, below, beneath, beside, between, beyond, by, down, during, except, in, into, near, of, off, on, over, round, through, to, towards, under, until, unto, upon, with, without.

For example, a problem around storing energy, when used with 'unless' might lead to thoughts of 'unless we did not need to store energy' or 'unless the energy came from somewhere else.'

Other parts of speech can also be used, so *verbs* give action which can be applied to the problem (as described in Chapter 1), for example 'use' could trigger ideas of how energy is being applied. *Adverbs* modify verbs (and typically end in 'ly'), so 'intermittently' could be used to consider how an energy source could be turned on and off. *Adjectives* act similarly to modify nouns, so 'large' or 'flexible' could also trigger additional lines of thinking.

Part C: Pulling it all Together

So there we have it. The cold ‘left-brained’ logic of analytic invention, the fundamental understanding of simple science and TRIZ, and the softer ‘right-brained’ creative side. Pulling these all together gives us a whole-brained, comprehensive approach that leads to the widest possible range of approaches and consequent ideas.

Toolbox 4: Holistic

The trick to using this 'all-in-one' approach is, as Chapter 11 explains, is to use each method as a different lens. We can thus switch back and fore between lenses to get a broad and stereoscopic picture, which is at least an order of magnitude better than the monochromic results of using a single technique or viewpoint.

The formula is thus:

NOT: Analytic <u>or</u> Simple science <u>or</u> TRIZ <u>or</u> Creative

BUT: Analytic <u>and</u> Simple science <u>and</u> TRIZ <u>and</u> Creative

12 The TAO Design Process

Having looked at invention from the analytical, scientific, TRIZ and psychological creative viewpoints, this leaves us with the question of ‘Which approach should we use?’ The creative answer, of course, is ‘yes’. All methods are valid and may be used in many different ways. Still confused? Good: confusion without damaging frustration is a splendid place from which to invent.

To help nudge the confusion in the right direction, this chapter offers an integrating mental model from which you can hang the different principles and methods from the previous chapters, thus providing an overall approach to creating new and wonderful inventions.

The problem with defining a process for creative invention is that there is no one right way. You cannot say ‘start at step one and then do step two’ and so on with any guarantee that you will be successful. The TAO Design Process is thus deliberately vague in parts, because to say ‘at this point, do this’ would miss all of the other possibilities.

You can think of TAO as standing for Thinking Around Objectives or you can create your own words. The casual suggestive nature of ‘thinking around’ deliberately contrasts with harder ‘objectives’. Alternatively you can just think of it

as Tao, which means 'The Way' (We like ancient wisdom!).

You can choose to take any of the sections at any time and follow the idea path it suggests. Jump around, be playful, start one and then jump to another. Each time you work on one of the steps you should be slowly building a better understanding of what you are trying to do and have a better set of ideas about how you might do it. Don't forget to take notes not just of your thoughts but where your thoughts have come from–or when you look at them again you may not understand them!

At some point you will arrive at an 'aha' experience where you suddenly see how to put your ideas

together to make it all work. Don’t try to force this–remember what we have said about how to use your brain. If you are feeling you are getting stuck then jump to another step, take a break or consult Chapter 10 on getting past blocks.

If you follow these steps and just let your brain do the work of putting ideas together, somewhere in its hidden depths, then the solution will be created.

At first you may find this wandering around a bit slow and not too easy to put the various ideas together. Think of it as being like learning to juggle. First it is two balls, then three and eventually, with a lot of practice, you will find yourself juggling with all the balls at

once!

The Big Picture

Imagine that you are looking to make your fortune by discovering gold in 'them thar hills'. You cannot just go and dig somewhere, first you need to broadly explore, just getting a feel for the hills and creating a big picture of the territory. You can then start using your experience and knowledge to find a likely-looking place. When you have narrowed it down further, you might do some test digging and finally dig out the mine, extract the gold and refine it down to glorious ingots.

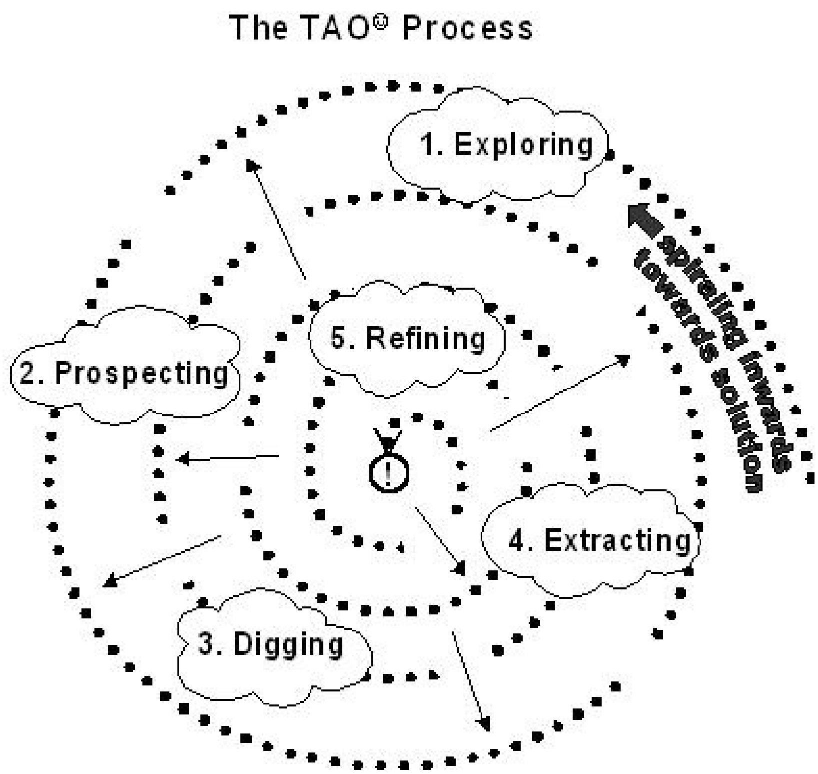


Fig. 12.1 Spiralling process

Inventing is a bit like looking for gold and there is seldom a direct route to the answer you want, but there are broad stages that you may use. It is often like Fig. 12.1, where you gradually spiral in towards the solution, yet can also be throw back out to previous stages. Like the children's game of 'Snakes and Ladders', luck can be both kind and

cruel.

Overall, there are five broad stages you might go through to find the pot of gold that is the final invented solution. Although these could take roughly similar times to complete, different problems are more likely to result in very different time profiles through each of the stages.

1. Exploring

Exploring is a broad wallowing in the overall situation in which you are inventing. You know that you have done some good exploring when things start to look familiar and when you feel you have a good general understanding of the big picture.

If you are starting by saying 'Right. Let's invent something,' then in this stage you might be investigating general areas in which there may be scope for useful invention. For example, you might consider 'home appliances', then finding that area rather overdone you could wander further afield and think about the potential of the internet.

Alternatively, if you already have a known problem, your exploration may be to find out all you can about the situation in its broadest sense. For example when looking at improving the timbre of telephone speakers, you might look at the physics of sound, hi-fi systems, at transducers in general (including non-sound ones), and so on.

The very best exploring happens when you are not looking for anything, because when you are looking for something then your mind filters out all of the other possibilities that pass before your eyes. Cast your attention widely, see things without judgement and just be curious. Sometimes you might even be lucky enough to find a nugget of gold lying on the ground, just waiting to be picked up.

2. Prospecting

Prospecting is where the serious

search starts. A good indicator that you are finding the right area is a need that seems to be unfulfilled. For example, hotel rooms are not always completely silent and the sounds of the people in the next room can disturb the occupant's sleep. Note that the need here is 'a good night's sleep', not necessarily 'sound-proof walls' (which is only one way of achieving the need).

There are surprisingly simple ways of finding needs, such as really listening to people, seeking the little (and large) things that irritate them, or discovering their deep wishes. Another good approach is to watch people. If you can set up a video camera of them working in the area of interest, then

this gives an even better record that can be studied in detail.

For example, if you want to improve the telephone, watch people closely at every step: how do they pick up, dial and speak? Find how and when they want to use the phone. You can also chunk out to consider communications in general or go deeper into telephone technology.

3. Digging

Having found the need or goal to which a solution would be valued (and hence paid for!), the next stage is to find the specific problem or situation that, if changed, would result in the need or goal being met.

This may need a fair amount of analysis and/or creative thought, and you may also want to go out and do some more exploration around this more constrained area.

Defining the problem can be a critical task, as this will frame the creative question and hence greatly affect what you might invent. In improving the telephone, there is a great deal of different between a problem of 'inaccurate reproduction' and 'caller is unable to understand': the former might lead you to replace the speaker or improve the transmission technology, whilst the inability to understand may simply require greater amplification and a volume control.

4. Extracting

This is the traditional creative stage in the process, where you start pulling out the golden nuggets of brilliant ideas. Unfortunately, this is not always easy and the gold may be buried deep, requiring a lot of patient work.

Sometimes you have to dig a deep hole before you are sufficiently convinced that the mine is empty. When this happens, you can either give up or, more realistically, backtrack to a previous stage and try again.

Many of the creative and inventive methods described in this book may be used in this stage (although this does not preclude

their use in other stages!). Sometimes it may be easy to find the right tool to use, but it can be a more successful strategy to simply try different approaches until something works and the spark of creation is successfully ignited.

5. Refining

When Thomas Edison said ‘one percent inspiration, ninety-nine percent perspiration,’ he was primarily talking about the hard work that goes into turning the bright idea into a usable and marketable product.

Refining is often an iterative process of testing and improvement, with rigorous and creative thought

at every stage. Dreamers often hate this stage as it can lack the joys of raw creation, but this is where the real gold of true value is created, where inventions that better mankind (and, hopefully, your pocket!) are crafted.

Each iteration of refinement may itself involve a complete or partial TAO loop of invention, as you discover and resolve successive problems and contradictions.

Not *or* but *and*

When should you use the analytical scientific approach and when should you take a softer creative way? Sorry, the answer again, is ‘yes’. The secret is not one *or* the other, but one *and* the other. There is great creative power in using more than one system, as multiple lenses on the problem not only lead to more solutions, but their combination can be synergistic, creating even more possibilities. More than one lens also breaks the limiting fixation that a single viewpoint may bring.

Fig. 12.2 shows the TAO Design Process again, this time in the form

of a loosely linked sequence (same thing, different lens, with consequential benefits), along with parallel scientific and psychological tracks. Although there are sequences of activity there are also 'clouds' of methods that are roughly distributed where they might be most used, but which are sufficiently general to be usable in other circumstances.

When using these, if you have a naturally scientific tendency, try the psychological track first. Similarly, if you normally take a softer approach to creativity, try the more rigorous scientific and TRIZ approach. You can also switch back and forth at any stage, using the alternative views to stimulate and challenge

one another. Try different elements, but the bottom line is always ‘what works for you’.

It is a rich and complex model which gives you a wide range of tools. It may seem rather overwhelming at first, but if your goal is serious invention, it is designed to provide serious help. Ross Ashby described the ‘law of requisite variety’ which state that a method must be as complex as the system that it wishes to control. With many tools and broad thinking at your disposal, you will be well-equipped to tackle even the stickiest of inventive problems.

The rest of this chapter explores each of these tracks.

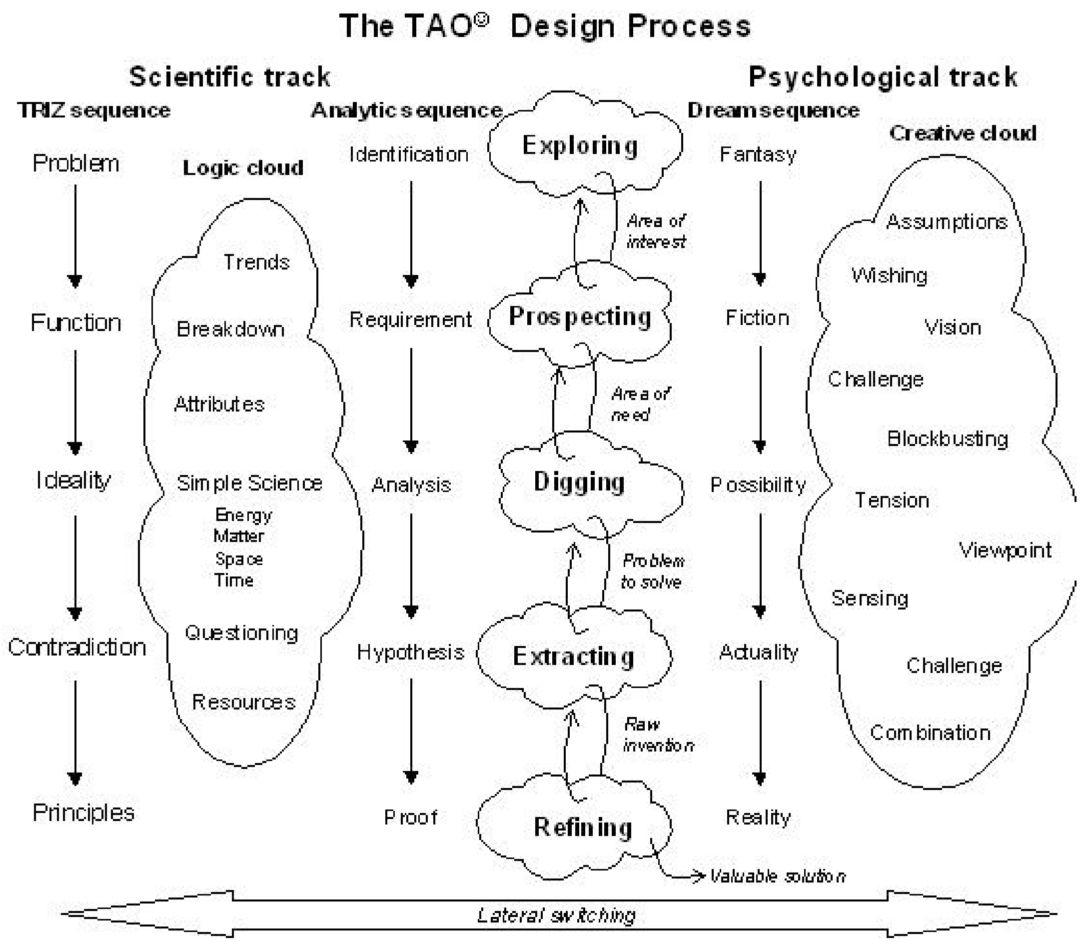


Fig. 12.2 The full TAO Design Process

The Scientific track

The Analytic sequence

In the analytic sequence, we use rigor and structure to ensure that we reach a predictably profitable and satisfactory solution.

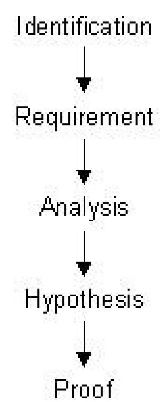


Fig. 12.3 The Analytic sequence

Identification

The first stage of inventing is the

same as the first stage of business, which is to find somewhere where you can make a profit. You may already have an area in mind or you may need to perform a careful analysis of markets, customers, their needs and the products that are currently being sold to them. Some markets are massively competitive and over-farmed to the point where new inventions are hard (but not impossible) to find. In some areas, inventions cannot easily be protected and get rapidly copied.

The ideal domain for an inventor is the green field or undefended hill, where there is clear need and space for ingenious creation, where your expertise is not easily copied and there is not only sufficient window of opportunity to recover your costs, but also further opportunities to invent and grow completely new markets.

Inventions need not be constrained to tangible products: you can also invent around services, strategies, processes, organisations and relationships. Although it may seem that a successful service could be copied by a competitor more easily than a product, in fact the reverse is often true as the subtleties of human interaction cannot easily be duplicated.

Requirement

Having identified a domain within which to invent, the next stage is to

identify specifically what benefits you want to confer, and to whom.

With a careful eye, you will see many gaps between what people need, want, expect and accept, as shown in Fig. 12.4. What we want is not always what we need, often because we do not realise our own needs. We expect what we assume is possible and reasonable, which is often less than we really want. And what we receive does not always live up to our expectations. All such gaps are opportunities for invention, whether in products or services.

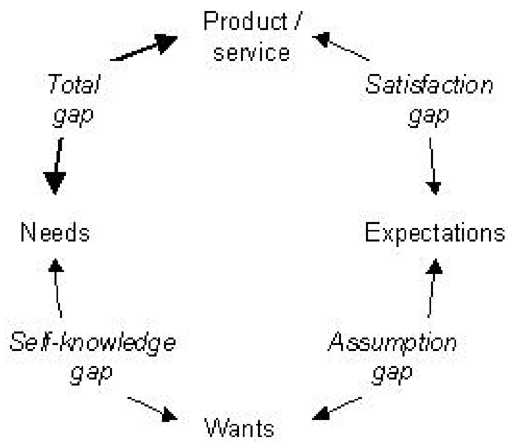


Fig. 12.4 Opportunity gaps

Look at the problems people are having, the things that they are putting up with and all the unmet and often unrealised needs they have. Use decomposition methods to break down their activities and lives. Use causal analysis and questioning methods to find real reasons and details of their situation. Seek out the opportunities for invention where they would gladly pay good money for removal of pain and other improvement in

their lives.

For example, having selected race-goers, by analysing their behaviour you might find that they are putting up with having to stand around all day, carrying a large and unwieldy lunch-bag, along with other paraphernalia.

Analysis

Having found the opportunity for invention, the next step is to understand it in sufficient detail so the invention you create will be finely targeted at specific problems.

Continue chunking and questioning. Use Value Analysis to determine actual value and gaps. Determine real causes. Use critical

thinking to explore the problem. Seek to define the actual problem that, if solved, would be valuable enough to the target customer that they would pay well for the solution.

Keep asking 'why?' 'Why' is a question with many levels. I have a phone. At one level it functions as a way for me to speak to people. Why do I want to speak to people? If I want to send them information I can fax or Email or write. If I want to gauge how they respond to my message I like to hear their voice. Maybe I would like to see their face. Maybe I want to hear their heart rate or see it on a graph, especially if I am a doctor or maybe a salesperson.

Ask why things are wanted.

When you have the answer then ask why that answer is given. What benefits does it bring? If these benefits had been gained years ago, what else would have been possible? If they were available now, how would they change things? Are there circumstances in which other benefits would be preferable? Or more of the same benefits? Keep asking why again and again and do not be too easily pleased with your answers.

For example, the race-goer may be found to have two needs: satisfying hunger and thirst, and being comfortable. The food and drink resolves the first need but, in its present form, exacerbates the second one. Analysis of what they

are carrying might show that the bulk of the lunch-bag is taken up with insulation of vacuum flask to keep drinks hot.

Hypothesis

Once the problem to solve has been defined, the next stage is to find a potential solution. If the analysis has been done well, then this stage may well be almost a formality, although sometimes it can also be a very long and hard cycle of experimentation.

Counterbalance the 'why' of analysis with a 'how' of solution. If the answer to a 'why' is a negative, such as 'because they have no other way of holding it' then this may well

point to a possible answer. Keep asking 'how'. How can drinks be kept warm? With insulation. How can this be done? With vacuum or foam. Keep asking 'how else?' How can drinks be *made* warm? By putting them next to a heat source.

Keep asking other questions, too, until a solution is found that, in theory at least, solves the problem.

For example, the race-goer may be satisfied by a portable seat that also contains and insulates the food and drink, and even utilises the heat from the person sitting on the seat to maintain the temperature.

Proof

The proof of the pudding is in the

eating, as they say. And the proof of an invention is the degree to which it solves the problem. It is that this stage that not only the hypothesis is tested, but all of the other stages as well. If the invention is successful, it will be sufficiently attractive to the target customer base that they will pay enough for it to be a viable product.

Show your idea to open-minded people and listen for their positive thoughts. Make mock-ups out of scrap materials. Build computer models. Eventually, you will have to try it in real circumstances with real customers. When people refuse to give you back your prototype, you might just have a winner on your hands!

For example, the race-goer might not want to sit down, and may not be able to see the race from that position. But the use of body-heat could prove viable, and a flexible container that straps to the body could prove a better solution.

The TRIZ sequence

TRIZ thinking means looking analytically at a problem, but with a paradoxically wide and idealistic viewpoint. In many ways, it embodies both scientific and psychological thinking.

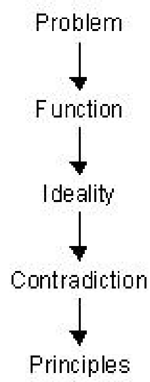


Fig. 12.5 The TRIZ sequence

Problem

Look at how imperfect the things around you are. What is it that you dislike about these things? Are they too complicated? Are they too expensive? Do they really work well? What are their faults? List them.

Most products and devices have all kinds of parts which do not really deliver what you want but simply are there to compensate for some fault

in the design. For example, an ideal table might be a table with no legs. The table top is what you want–the legs are there to keep it in place. A table top with no legs would be nearer to your ideal.

So far, you have probably only asked sensible questions, so now ask some stupid ones. This helps bring to mind some key factors which you may have overlooked. For example, what makes a car move? Is it the engine, the fuel, the battery, the spark, the driver, the wheels…? How about the road? Try imagining the car with the wheels not touching the road and you can see that the road is needed to make the car go forward, in current designs at least.

Keep questioning everything you

see, hear and do. Why do we have a battery? Why do we have wheel nuts? Why do we have seats? Or get really silly! Why do we drive at 1 to 100 mph? Why not drive at 0.00001 mph? Why not drive at 1347.9 mph? What comes to mind when you start asking ever more silly questions?

Why do I write better in the summer? I often write outside–is it to do with light or greenery? What would summer-in-winter look like? Why can't I bring outside inside?

Being curious, silly and playful can open many cans of squirming worms, all waiting for creative solutions.

Function

When you have something to improve or create, seek to make clear what is Primary Functionality (it delivers what you want) and Secondary Functionality (it supports the way in which Primary Functions are delivered). This may take some practice. Look at everyday things around you and list Primary and Secondary Functions.

A window functions primarily to transmit light, but it must also keep apart other elements. In hot countries this is to keep out insects and heat, whilst in cold countries it should to keep the heat in. How could you change the design to manage functions in these different places? For example, to keep

insects out you may have a wire grid. Could you design the wire grid so that it helped lose the heat from the house? Think of shape: could you make it to radiate heat or to aid air flow?

Take time to consider functionality. There are many levels on which you can consider this. Play around on different levels, including very abstract levels. What is the functionality of light when I write? It helps me see, but daylight also creates vitamin D in the skin, and it just makes me happy!

Zoom in and out to see how what you are thinking about works with the things around it. How comfortably does it sit with them? Does it change the climate or mood?

When you zoom in, you are moving into more direct functionality. You can ask yourself how to get the glass to let more light in, how to keep heat in, how to change the colour of the light, how to vary it over time.

If we define function as how one object changes some feature of another (or some parameter – like heat, colour, shape) then we can imagine zooming in on very local activity and ask what is happening between molecules or atoms and the surrounding fields of electromagnetic action.

Draw maps, showing how the parts and functions interact. Having drawn these maps you can then ask yourself, bit by bit, how much you

like the way each part functions. Can you change it so it gives more functionality? Can you use some of your other resources to deliver the function you want–and would they do it better (cheaper, faster, less waste etc.)?

Draw and redraw these maps, playing around with different possibilities. If some of the functions are not clear then just guess (and make a note that this is a guess). There is no point in spending lots of time trying to see if this might or might not work when you may abandon the idea later for a better idea.

Think of the function maps as *possibilities* not *plans*.

Ideality

Having worked through Primary and Secondary Functions now imagine that just one part delivers all the functionality, and with no problems. You may not have a clue as to how you might do this yet but go for complete simplification. You might just find a way to do it!

Take parts out of the current solution. How does this change things? Discover what you can remove without seriously affecting the functionality. Find other ways to simplify without significant loss.

Think about the ideal solution. For example, an apple which does not bruise, collect dirt and does not need wrapping, a wall which displays your TV picture or paper which prints on itself the words you speak to it.

You now should have some idea of what you want to do, but ensure that you describe it in very *loose* terms, with just a simple sentence or two, avoiding too much detail. Lots of detail tells your brain that all these little things are important, distracting you from the purpose of this stage, which is to start from pure need.

For example, you might say, ‘I want to design a conservatory to go on the back of the house’ but this it talking about a solution, not the need that is driving it. Find ways you can rephrase this statement so that it captures just the feature (only one if possible) that is key to your goal. So this might be, ‘I wish I had more

Living Space.' Sensory thinking will expand the ideality and highlight aesthetic benefits, so think about colour, light, fresh scented air, soft textures.

A good test is to imagine you have a superb, fault-free and even totally free solution. What if the whole house was made of glass? Ask yourself if there is anything missing? If so, then you need to do some more work on your ideal solution.

Contradiction

Now that you know perfection, you will be able to see problems in a clearer light. Find the things which are preventing you from creating the

ideal solution. In particular, find things that fight one another, where gaining in one area loses something else in another. Really good inventions minimise loss and maximise benefit.

Look at your ideas for doing something and imagine doing it much more powerfully or much quicker or more accurately. If you imagine increasing this by a very large amount your brain should start shouting at you 'but then …would happen'. That's the start of looking at your contradictions.

Remember the two types of Contradiction suggested in TRIZ. There are *physical contradictions*, where you want the impossible, such as wanting something to be

both fast *and* slow, or hot *and* cold. You can only solve these contradictions by doing these things in a different place or at a different time or with a different structural arrangement. So I can have it cold now and hot a second later, or it can be rigid now and flexible later (a structural change or a change of state of materials), or I can have it hot at this end and cold at another.

There are also *technical contradictions*, which are where it just seems to happen that when you do A then B happens more. For example, when you run your machine faster, it breaks more often. These are easier to address, for example by changing the design or materials used.

What is preventing me from creating more living space? I want garden space too! Increasing living space outside the house also decreases the garden space. Here is a contradiction. It also decreases my wealth, which could be treated as a serious creative problem.

Principles

When you bring together your ideality and contradictions, the resulting creative tension alone is a powerful force for triggering ideas.

The Contradiction Matrix and TRIZ principles in Appendices B and C provide a way of accessing the methods that have been used by many previous inventors. You can

also use other principles, such as the four principles of simple science: energy, matter, space and time.

You can even use the principles of play! We normally take a very narrow view of what resources we have around us to deliver our goals. But you can choose to bypass these limiting thoughts and go crazy, imagining using anything to resolve your problem. How can you get your nice big plant to be a storage cupboard for your knives, forks, and spoons? Its resources are its branches, leaves, flowers, bark, roots, and even seeds?

I buy birthday presents. I do this to please the person with the birthday. But I do not like trying to buy presents they might like because I always feel under pressure of time (spot the contradiction). What if I did not buy birthday presents? This could mean buying presents at any time without thinking of the person you might give it to. You see something that is nice, so you buy it. You keep a stock of future presents. When birthdays arise you choose from your present stock. You can buy nice things when abroad, when browsing, or at any time.

To build a conservatory without affecting the garden I might ask myself, can I get the inside of my house to be like a conservatory with all the benefits of extra space and light but no conservatory. So I might

just sell off lots of things in my house which I don’t use and simply change the windows and the wallpaper so I have a light, spacious living room!

The Logic Cloud

Within the scientific track, there are a number of methods that can be used at various times, in initial investigations and also in later invention, in TRIZ and in the analytic sequence. In practice many of the techniques can be used in many circumstances; this section names a few of the main methods than can be used in this way.

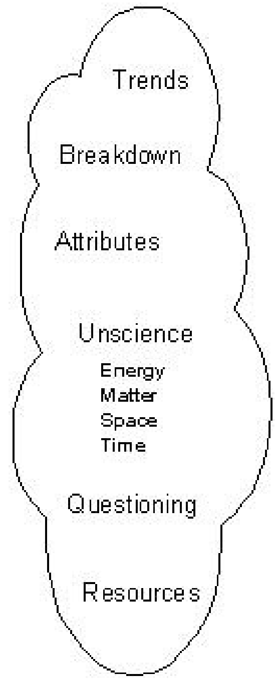


Fig. 12.6 The logic cloud

Trends

When man invented the wheel, he later created the cart and, later again, the train. Trains without wheels would be very slow. Some things lead to other things, and not vice versa. There is a natural progression in invention that you can often spot.

Where are you now? What are your current problems? What were yesterday’s problems? What will be the problems after you have solved today’s problems? It is possible to predict how devices develop simply because after a while someone wants something to work better. To work better you have to use smarter science and smarter science has rules built in.

Look for trends in activities, such as:

- ***Adding.*** **Adding something new (material, process, system). Adding a modification of what we have already. Adding to the surface, filling gaps, improving the environment. We add material at first which has constant properties, then we get smart and add materials which have properties which change the way we want them to change (shape, phase (liquid to gas etc), rigidity, fluidity).**
- ***Taking away.*** **A way of saving work and money is to remove**

things. We start with reducing the number of parts and then eventually find a way to throw whole sections out altogether.

- *Dimensions.* We begin with regular shapes and slowly, and sometimes ever so slowly, think about how maybe we could change something on one dimension, and then two dimensions and finally all three.
- *Simplification*. We start with designs where everything does just one job and then we combine functionality so that one part does two jobs and then slowly we move to a design where one part does all the jobs!
- *Structure.* We start with regular solid things and then we begin to

add voids in them, spaces because we want less material or because we want to use that space. At first we have big voids then we move to having voids with complex patterns and shapes. Our structures begin as rigid devices and then we make them more flexible, or even fluid and gaseous. We move from solid devices, which we can handle easily, to highly unstructured devices, which we can tune in responses to environments (so there is then a trend towards computer control).

Look at how you or someone else does something and see where they are in these trends. Now ask yourself, if I were to move one step or two steps along these trends what benefits would I get. Sometimes moving a long way makes the device simpler. In one invention we were involved in by moving three steps along we made the device a fraction of the price and weight and it had much more functionality and reliability. The less there was there the better it worked!

Breakdown

By breaking down problems and devices, you can get to look at the smallest parts. Ask questions of them. How are they manufactured? How are they assembled? How well

do they fit together? Can they easily be taken apart? Is this and advantage or disadvantage? How do they operate in practice? How do they wear, decompose or decay over time?

You can even look at what the atoms and molecules are doing. This may seem like going too far, but it can be surprisingly constructive. In social invention, you might consider what individual thoughts that people are having. In process invention you can consider the individual micro-movements and actions.

Breakdown can also be done backwards, building upwards to higher viewpoints. This is critical for strategic innovation, but can also be used for other inventing, looking at

the whole vehicle or operation. A higher viewpoint shows the *purpose* of the lower components and allows you to see how the whole is more than the sum of the parts, and where critical regions exist, such as vehicle power trains and crumple zones.

Attributes

At any level during breakdown, the attributes of the components can give us many options for improvement and change. Attributes often appear as indicators of the adjectives that describe the nouns which are the variable parts of the situation. A light can have its brightness, position, colour and

much, much more changed. Adjectives from ‘brightness’ include dim, dazzling and muted.

When we are changing attributes, we can do this in as many ways as there are verbs that can be applied. We can stretch, break, bend, move, reset, open, sharpen and stack.

Ways to change	Change actions	Attributes		Components, relationships, etc.
Adverbs	*Verbs*	*Adjective-indicators*		*Nouns*
Quickly	Move	Size		Door
Evenly	Stretch	Weight	*of*	Handle
Occasionally	Heat	Thickness	*the*	Hinge
Roughly	Fold	Comfort		Catch

Fig. 12.7 Changing attributes

So take your problem and play with the words you can attach to it. What are the nouns that describe its parts, relationships and other factors? What are the adjectives that are the attributes that describe the nouns? What are the verbs that can

be applied to change these? You can even add some adverbs, such as quickly, unevenly, regularly and hotly. Make one list for each of these, then combine them randomly and see what happens!

Simple science: Energy

Energy can come from the chemical action, location, movement, heat and electromagnetic activity. If the wind blows you can use it. If the sun shines you can use it. Even if things simply go from hot to cold naturally you can use it.

- ***Storing energy.*** **Where does the energy that you use come** from? How is it stored? Do you need all of the energy you have stored? Could you manage with less? If use of energy is an important factor, you might like to think about the different forms of storage, from batteries to rubber bands. You can also use external sources, such as solar or wind power.

- *Converting energy.* When you use energy, it gets converted. How efficient is your system at doing this? Can you convert it back again? How many stages of conversion are there? An internal combustion engine goes from chemical conversion to heat to movement up and down, then around and around, losing energy

in each connection between gears, when all you want is to move the vehicle forwards.

- ***Chemical energy.*** **Are there any chemical reactions in your invention? No? If there are atoms involved, and especially if there are more than one type of atom, then some chemical effects will be happening. Chemical reactions are often speeded up by heat, including unwanted ones such as oxidation. They also may be triggered by catalysts. How are these effects happening? How can you use them to your advantage? How can you prevent unwanted reactions? Light bulbs contain inert gases to slow the decay of the tungsten filaments.**

- ***Potential energy*****. What energy is stored by position? What potential is there? What cycles of position are there? How could energy be saved? What are the gravitational effects?**
- ***Movement energy.*** **What energy is used to create movement? What energy is wasted in movement? How can you use movement to gain other benefits? Is motion circular or linear, and what are the effects? What is the locus of movement? Is any of it wasted? Is there any unnecessary movement? Sound is movement: how can this be utilised?**
- ***Heat energy.*** **Heat is often the lowest form of energy. A radio**

start with the chemical energy in a battery, it converts to electrical energy and eventually the movement of air to create sound. But all of the energy eventually turns into heat, which can be a significant problem. What is the residual heat in your invention? How does it build up? How can you change this? What are the effects of expansion and contraction? Of melting and boiling?

- **Heat flows from hot to cold. With a high temperature gradient, heat flows quickly. With a low gradient it flows slowly. What are the heat flows within your invention? Can you channel the heat? Can you put it where it is** needed and remove it from where it is not needed? How can you use conduction, convection and radiation?

- *Electromagnetic energy.* What electric fields are there? What magnetic fields? Can these be used with energy in some way? Light is also electromagnetic: how can this be utilised? Can you use solar energy? How does changing colour affect things? Can magnets be used in some way? How about electric motors?

Simple science: Time

Time may seem like a fixed resource, but there are many ways of turning it to your advantage. Here are a few:

- *Prior action.* Imagine you are going on a picnic. You don’t want to take a cutting board for your sandwiches so you cut them before you go. The bread will start drying out as soon as they are packed so you moisten them just a little before you pack them. For a big box of sandwiches which may squash the ones at the bottom you make little trays to sit in the sandwich box and these are the trays people eat off.
- *Parallelism.* Timing can be *sequential* or *parallel*. What are your options for doing what you want to do while you are also doing something else and what is

best done in sequence? For example, I might design my conservatory while I am taking coffee breaks. Discontinuous and as part of doing something else. Parallel activity usually means preparation by the way, before the activity starts.

- ***Periodicity.*** **Do things happen all of the time or sometimes? If sometimes, how frequently do things happen? What about the beat: is it regular or irregular? Can you turn things off when they are not used? Can you avoid wasted time by using them for other purposes? Is the pattern stop-start or do thing slowly build up and down? When you are washing a car, what would happen if you** change the water flow from a hose from constant flow to pulses? The changes in pressure is far better for knocking off the atoms and molecules.

- *Total time.* If you want to get past a pack of wild dogs it may be best to run! Sometimes minimal harm occurs or minimal risk if you do things very quickly. The faster the better. This even works for cutting. This is partly why an axe works well for chopping wood.

Simple science: Space

Space is not the final frontier, but can still be challenging in the ways that you can use it for invention. These are just a few ways of using it.

- ***Dimensions.*** **There are three dimensions of space which you can increase, decrease and bend, individually or together. Ask why the space is filled with what is there. If it is an object you are making, then is all the material needed, or is some of it there because it was easier to make it that way? Maybe you could have made it a different way. Similarly, business processes are filled with all kinds of things, especially meetings! Take things out of meetings that are not needed. Most can be removed if you try. So, if something is occupying space but has no functional use then take it out.**
- ***Gaps.*** **Look around and see**

how many places there is space which is not used. List them all. The space may be around you or inside what you are making. How might you do something in those spaces. Can you nest something inside something else?

- ***Location.*** **Think also about how you might change the orientation or position of something to use space better. Turn it upside down, rotate it, change angles, slide it, move it relative to other things. What is the overall layout? How are things positioned relative to one another? What do you see when you change the location of your viewpoint zooming in and out? What if everything was together or separated? What if**

one thing was inside another?

- ***Symmetry.*** **Many things are symmetrical because they are easier to make that way or seem simpler. What happens if you make things asymmetrical? Can you use less space? Can you make it more stylish?**
- ***Curvature.*** **List all the ways you could change the shape of what you have, imagining how complex or simple it could be. For example, I could hold my pen better if it was not round, but had curves which fitted my finger shapes. And I could tell which way round I was holding my pen or how far away the nib was. What if curves were straight or straight things were curved?**

- ***Boundaries.*** **Look closely at the edges and surfaces where things interact. Do you want smooth or do you want dimpled, do you want hard or soft, maybe hard in one place and soft in another? Think about varying the features of the surface in as many ways as possible. Make a long list and then go through and ask yourself what benefits you have from changing the surface here, there and everywhere! Consider how you want the shape, strength, colour and texture of edges to be. List all the different ways you might change the edges.**
- ***Movement*****. What is moving? Relative to what? What are the effects of friction, inertia and**

momentum? Think about what the atoms and molecules are doing. How does one push, pull, rotate, vibrate the ones next to it? What is the locus, the path traced out? What cushioning or suspension is there? How do things move over time? What are the effects of starting, stopping, speed and acceleration?

Simple science: Matter

Matter, or material, is things of all sort, sizes and types. Think of the parts in your problem and how matter may be used:

- *Atomic effects*. What is happening to the atoms and

molecules? How are they fitting with one another? How do they move relative to one another? What bonding is there?

- ***Reactions*. What chemical reactions are happening? What are the effects of oxidation or decay? How are different materials reacting with one another? How is the environment affecting things? How could you change the environment to be more inert?**
- ***State.* Matter can be solid, liquid or gas. How can each of these be used? How can they be converted between states? What happens when they do? Can you solidify around things to encase them? What are the effects of**

expansion and contraction? Can you replace one with another?

- *Composition*. Is just one material used? Could you use similar or different materials? Could you use composite materials? How would this change things? How can you mix materials? Layering? Blending? Alloys?
- *Density*. What is the density? What is the weight? Can you use a lighter or heavier material? Can you put holes in it?
- *Quantity.* What if you used more or less? How about much more? Would overdoing it produce new and interesting effects? What is 'just enough'?
- *Rigidity*. Does anything change

shape? How? When? Would it help if it did? In what way? What does it take to change the shape? Does it take even pressure? Are there any weak spots? Do things bend or break? What happens when you press, prod or hit various parts? Do flexible things regain their original shape?

- ***Flexibility.*** **Having flexibility allows us to manage the shape of an object for greater effect or may have protective properties that the main object does not have. Thin membranes can bend and be shaped to fit other things. Ductile substances can be stretched into long fibres or wires. Malleable materials can be shaped.**
- ***Porosity*****. Having a porous**

object may make it lighter. Porosity implies holes and space, which may be left open or filled with a useful substance.

- *Erosion*. How do things wear? What are the effects of friction? Of oxidisation? Of sunlight? What about the lifetime of individual parts? Could you have things that wear out just as you are finishing using them?

Questioning

Question everything. Adopting a questioning attitude allows you to discover new needs and penetrate known problems. Use the questioning methods of Chapter 1, such as SCAMPER, 5W1H and verb

usage. The previous sections in this chapter have offered many questions. Here are a few more:

- **How can you change things? What verbs can you apply? List them. Use them.**
- **Can you throw things away? Can you reuse them?**
- **How can you make the harmful things useful? How can you turn problem into benefit?**
- **How much do things cost? Could you use a cheaper alternative?**
- **Can you use an intermediary item to fit between two incompatible parts?**
- **Can it look after itself? Can more benefits happen during the**

normal course of events?

- **What is the value of each part? To what? How can value be increased?**

Resources

There are many more resources to help you with your invention than you might have realised. Look around you. Reach out and keep asking, 'How can I use this?' For example, consider:

- ***Things.*** **What things can you use? Look around you. What can you use instead? What can you beg, buy, borrow or steal?**
- ***People.*** **What people can help you? What skills would they**

need? What knowledge? What motivation? List the people you know and the ways that they could help. How could you repay their kindness? What could be in it for them?

- ***Places.*** **What places can be utilised? Do you need lots of space? Where could you find it? Does the place need to be attractive? Hot? Wet? Who might know of a place to use?**
- ***Activities.*** **What needs doing? When? Who could do it best? How could it be done cheaply? How could it be eliminated?**
- ***Information*****. What information is needed? By whom? For what purpose? How easy is the information to find?**

The Psychological Track

The psychological track means making full use of your subconscious, recruiting its vast powers to your bidding. The problem is that this is not always easy, and the subconscious may fight back by whispering to you how stupid this is and how the scientific approach is much more sensible and that if people knew what you were doing, they would not think very much of you.

Ignore the nagging! Open your mind and play. Try as many different things as you can. If something does not work, just say 'never mind' and know that it simply means that they

did not work today. Tomorrow is another day! The simple secret of psychological creativity and invention is to keep trying different things until something works. Persistence pays, as does staying relaxed and having fun whilst you wait for your subconscious to come up with the goods.

The Dream Sequence

Dreaming is, in many ways, the ultimate psychological technique, as it is all about what is happening in the subconscious. This is a waking dream, but it is important to start in a dreamy way, and then steadily progress towards reality. In dreams, anything is possible. Starting from the dream will help you to discover much more than if you start from the limited thinking of a waking now.

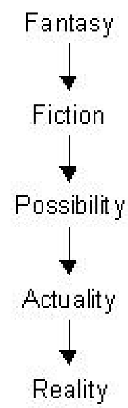


Fig. 12.8 The Dream Sequence

Fantasy: Make a Big Wish

If you are going to go for the Big Wish then think about the points we made about getting your brain working in the right mode. Pin some wonderfully creative pictures on the wall, get some toys out, play and draw and maybe write some poems! Stimulate your brain in lots of

different ways and it will pay you back in connecting your Big Wish to the many different experiences you have had all through your life.

Check out with your senses whether you are in fight or flight mode. If so, then read through Chapter 3 again, check your motives and try the technique for getting yourself in a Creative mood. Make your big wish a fantasy, the impossible and perfect future where all problems are solved and every need is fulfilled.

Fiction: The Dream

The most important first step is to get ready to Dream. This is not about believing in the impossible. It

is about opening your mind to seeing that what you now believe to be impossible, may just be possible.

The future is open to an infinite number of possibilities. Infinity is a big number and we can think of the future as containing an infinite number of impossible and possible events. Rather than wasting time on working out what we think is impossible we can simply start with some dreams and see where these take us. It may seem like an endless list so don't try to force it–just relax, draw, write some nonsense and see where it takes you.

Draw from your fantastic wish and create a story where things just might be possible. Move as slowly as you need to build an almost-

credible fiction.

Possibility: Daydream

A daydream is just a touch closer to reality. Take a dream and then walk yourself through it. What does it look like? How bright? How large? What about the sounds? How sharp and clear are they? What does it feel like? Play with these imagined sensory elements until the dream becomes even more real and stimulating.

Explore your dream through other eyes. Go closer–imagine you are an ant, or a virus, or an atom! What does it look like now? Then go further away. Now you are a tree, or an eagle or looking from a

spacecraft or another planet. What does it look like now?

Imagine you are different–such as 1 year old or 200 years old–how would things seem now? Imagine you have four arms or just one. Imagine you move fast or slow, have strength or are weak. Explore all the changes in how you see the value of your dream as you explore it through other eyes.

Write another story, but not just about a fictional future, but a real future. Stretch back from your dream until you are just touching reality.

Actuality: Plan

The final stage is to turn your

dreams and stories into reality. Pull on the strings of your story, bringing it closer again to present feasibilities. Think about the resources that you have now or can realistically acquire. Think about how your dreams and possibilities may be made real. Let necessity be the mother of invention in ways to turn the dream into reality.

Draw up a plan containing the details of your creation, who it will benefit, how you will create it and how you will profitably get it to the people who will benefit from it. Let this plan pull you forwards into the ideas and solutions that will realise your dream.

Reality: Persist

As you move close and close to real solutions, split your mind in two and hold the two parts both separate and together.

In the first half of the split, think of practicalities, from how you will get parts made to costs and timescales. Also seek out more sub-problems and find answers to these, as you spiral inwards towards the final solution.

In the second part of your thinking, hang onto your dreams. Remember your ideal and always keep the wish up-front and visible. Stay charged up and enthusiastic. Maintain your passion when others might give up, for it is only when we cast our eyes downwards and give up that we fail.

The Creative Cloud

In the creative cloud, although methods generally tend to get used from beginning to end, you can use any methods anywhere. People who tend towards the more psychological/creative end of the spectrum often work holistically, in parallel on many activities at once. Thus they might simultaneously be playing with potential solutions whilst also discovering different needs. Like an Elizabethan multi-voice choral motet, their thoughts wander all over the place, only coming together in a harmonious whole right at the end.

The cloud diagram of Fig. 12.9 shows just the tips of the iceberg of

techniques you can use. The prompts below and the methods of Chapters 10 and 11 provide many more methods to expand your thinking and explore the problem and solution spaces.

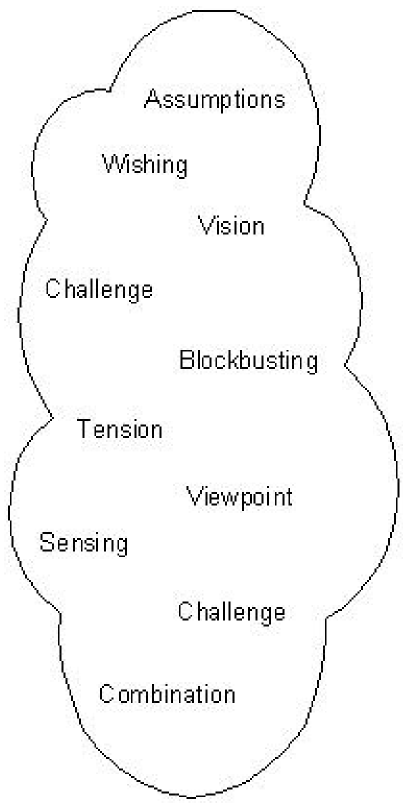


Fig. 12.9 The Creative Cloud

Do things backwards

Start with a solution and see what Problems it might solve. Do this again and again. Keep asking what problems you have with these solutions and explore how these might be solved.

Wish for the world

Close your eyes and make a wish. Write it down, starting ‘I wish…’. Imagine fully and completely that it is totally true. Look at what you have wished for. Feel it: what is the texture and sense of shape? Does it have sounds, smells or taste? ?What is this like? How would the world change if your wish was true? How could you make some of those changes happen

now?

Take a child-like perspective

Take away your knowledge– imagine you see it for the first time. Imagine taking it apart and exploring the bits. Imagine putting them in your mouth to see what they taste like and feel like!

Envision an ideal future

Create a vision of what you want, not what you think is possible. Write it down in a few, powerful words. Carry it with you. Show it to people. Let it tug at your heart and your head, pulling you forwards in the right direction.

Demolish psychological barriers

Take courage and look inside yourself to see what is really stopping you from creating. Is the internal critic chattering in your ear? Tell it to shut up! Are you concerned with what others might think? Ignore them or go elsewhere. What is the one question you could ask yourself that would cause you to be completely unblocked? Go over, around, under or through every barrier you can find until there is nothing that can stop you from succeeding.

Challenge assumptions

Look at the assumptions and

presuppositions people (including yourself!) are making. Are you thinking things cannot be done? Or that they will not be needed? Look at what we are putting up with, just because we think that there is ‘no other way’ or just because ‘that’s the way it is’. Challenge them. Reverse them. Assume all things are possible!

Create tension

Let your wishes and vision build internal tension that breaks down psychological barriers. Make the tension inherent in assumptions visible. Stretch the rubber band until it twangs and snaps you into different thinking.

Use an analogy

Move your mind to another place. What problems exist that are essentially like this problem but very different. How would you create the solution for these analogous problems?

Somewhere the problem has already been solved

Nature is a rich resource of solutions. If you want to make a better door – what in nature is like a door? What is a door for a worm, or a bee, or a tree, or a virus? How are their doors made and how do they function?

Simplify

Take things out. Combine things. Ask how things can be simplified to the point where all that is delivered is that which is wanted. Paint it all one colour. Make it all from one piece. Do it all at the same time. How can you create a really simple invention?

Draw pictures

Engage your visual senses. Draw pictures of the problems and solution. Draw the whole and individual parts. Draw generalisations and complete solutions. Doodle and see what your subconscious is trying to tell you.

Make things

Get out the scissors, card and glue, or may be some modelling clay. Make three-dimensional rough mock-ups of a part or the whole of your idea. Make metaphors or related items or just relax, making anything and let your subconscious be your helpful guide.

Ask a clown–or ask an expert

Your resources for evaluation also include other people. Do not think about others as just being there for expert opinions. There are times when you need to ask a clown and times when you need to ask an expert. The time to ask an expert is when you really know what you want.

If you ask an expert when your ideas are just forming you will be guided to all the known solutions that the expert feels comfortable with. That is, after all, why they are experts.

Always ask the clown first!

Ask a child

Find a child, the younger the better and ask them for ideas. They have even less inhibitions than the clown. Use their ideas to unblock you and stimulate further thinking.

Change your mind and try something absurd

Even when you are really sure you know what you want and how you will put it together it can still be

useful to challenge your ideas by changing your mind.

This will really test your commitment to your ideas. If they do not stand up to the change your mind test then maybe they should be dropped. If you have challenged them and they still come up with roses then you are highly likely to see your idea through to the end, no mater what obstacles are put in your way.

Slay a sacred cow, break some rules, break the mould

And the final test is how different would things be if you took away the rules that are governing your thinking or that of others. If a little bit of rule-breaking really changed

what you would do then maybe you start again when you have changed the rules.

Are your rules really that sacred? Many ancient and modern battles have been lost when someone broke the rules. Army generals plan their campaigns on beliefs about what their opponents will do–the opponents know this so they change the rules–and win!

Maybe your business idea is like that? Which side are you on?

Enjoy yourself

Being an inventor will feel risky, it will take up your energy and can leave it dead on the floor. Make sure you have some fun while doing all

this thinking stuff! It isn't about only having fun–some hard work is needed but this is why the fun is also essential. And take time to relax!

Just do something

Whatever goes on, you need to keep doing something! You started with some energy to do something so however difficult it seems and however lost you feel, keep up the momentum.

And finally…

Being creative means wandering around in your thinking, dancing lightly from place to place to see what your brain comes up with. Sometimes zoom in and sometimes zoom out. And always be playful with a serious purpose!

Use the various guides in this book to analyse, think, wish and wonder, over and over, looking for how you might put several different ideas together. Because it is often the combination of ideas that yields the great 'aha', we cannot and should not try to give you a magic sequence that will guarantee 'results every time'. You will probably need

to get lost before you find your way, which is a perfectly normal part of the inventive business, which is why it needs persistence and a bit of courage.

So don’t forget to give yourself a reward every now and then for your efforts.

But above all - Be happy!

Well, this is what you are here for.
(This is the only bit of religion in the book)

Epilogue

An epilogue is a kind of end piece, a completion marker. Although this is an epilogue for us, it is not for you. For now the journey really begins into invention, with all the excitement, frustration and joy that comes with it.

In a way, we have cheated you, and would like to offer a small apology. Why is this? Although we have covered a lot of territory, what we have missed out is the hardest part for all inventors: getting other people to agree that this is a good idea and hence to put their money into the idea, both initially for further development and also later for

manufacturing and marketing. In today's teeming world of commercialism, it can be surprising difficult to attract investment.

But then we have also given you the tools to attack this problem. The chapters on psychology are a rich source of ideas of how to persuade others. Consider their patterning thoughts: is the idea so new that they cannot fit it with their existing mental models? What about deep drivers? Find out what really motivates them and use this as a lever to open their wallets. Understand how they create meaning from what you present to them and hence change your presentations. And give them the arguments to tell themselves that

you have a serious invention that will help them to achieve their deepest goals.

Just a Note of Caution

As you might be heading off to invent we want to give you a little note of caution about a few things which you may need to consider carefully before trying to be inventive. This is based on experience of working in these fields and dealing with companies who understand the issues.

Inventing for others

It is very attractive to think about being inventive with toys or devices for the disabled. But before you commit significant time, energy and

money, check with the end users! Children are not the same as adults and you may find you have invented a great toy for adults which is of no interest to children. If the adult toy market is good then go ahead but if you think that it would be great for kids then check with the kids. Similarly with things to help disabled people: find out the problems they have first, then check back with your ideas to see if there are any shortcomings in your design.

Health and safety

If you are inventing something for children then you have to consider, and pass all kinds of tests, to make sure it is safe for children.

Children will do all kinds of things to your toys, including totally taking them apart. If any bits are dangerous then you cannot and should not try to sell them. Safety testing is a very professional business and you will need expert help on this.

Food is another are where there is a big health and safety issue. People do all kinds of things to food and if you end up poisoning even one person you could be in serious trouble (and lots of ordinary food can be very poisonous if not treated properly).

Hostile environments

You will always want to consider the environment where your invention will be working, but we would just like to say that the sea (and maybe outer space) is one of the most hostile environments. Everything in the sea is out to get you. Not only will it hit things hard and again and again but it will also throw so many things at you to eat you, corrode you, and destroy you bit by bit!

Children, again, are excellent at taking apart toys and things in their environment, so be aware of the worst treatment your ideas will receive.

The main message is simple: You may be thinking of your invention in a nice predictable environment where your intuitive sense will suggest that all should work perfectly. But children and microbes

are out to do their best to foil your plans.

So fare well and think on and do not let our note of caution dissuade you from contributing your ideas to the world. We believe that invention is the best fun you can have. Period.

Dave and Graham

Appendix A: Altshuller's 39 Parameters

1 Weight of moving object
2 Weight of non-moving object
3 Length of moving object
4 Length of non-moving object
5 Area of moving object
6 Area of non-moving object
7 Volume of moving object
8 Volume of non-moving object
9 Speed
10 Force
11 Tension/pressure
12 Shape
13 Stability of object (resistance to change)
14 Strength
15 Durability of moving object
16 Durability of non-moving object
17 Temperature
18 Brightness
19 Energy spent by moving object
20 Energy spent by non-moving object
21 Power
22 Waste of energy
23 Waste of substance
24 Loss of information
25 Waste of time
26 Amount of substance
27 Reliability
28 Accuracy of measurement
29 Accuracy of manufacturing
30 Harmful factors acting on object
31 Harmful side-effects
32 Ease of manufacture
33 Ease of use
34 Ease of repair
35 Adaptability (to external conditions)
36 Complexity of device
37 Complexity of control
38 Level of automation
39 Productivity

Appendix B: The Contradiction Matrix

To use this matrix with the other appendices to solve problems using TRIZ, use the following steps:

1. Critical parameters

Use the table of 39 Parameters (in Appendix A) to identify critical parameters of your problem.

2. Contradictions

Identify contradictions between these critical parameters, which is where one parameter causes problems with another parameter.

3. Find numbers of resolution principles

Use the Contradictions Matrix to find the numbers for the Principles (which are in Appendix C) that can be used to resolve the contradictions.

4. Investigate the resolution principles

Use the numbers from the Contradiction Matrix to look up resolution in the list of 40 Principles (in Appendix C). Use the principles as a guide and stimulation to find solutions to the problem. For more details, consult Chapter 5, Basic TRIZ.

	Undesired result (Conflict) / Feature to Change	1 Weight of moving object	2 Weight of non-moving object	3 Length of moving object	4 Length of non-moving object	5 Area of moving object	6 Area of non-moving object	7 Volume of moving object	8 Volume of non-moving object
1	Weight of moving object			15, 8, 29, 34		29, 17, 38, 34		29, 2, 40 28	
2	Weight of non-moving object				10, 1, 29, 35		35, 30, 13, 2		5, 35, 14, 2
3	Length of moving object	8, 15, 29, 34				15, 17, 4		7, 17, 4, 35	
4	Length of non-moving object		35, 28, 40, 29				17, 7, 10, 40		35, 8, 2, 14
5	Area of moving object	2, 17, 29, 4		14, 15, 18, 4				7, 14, 17, 4	
6	Area of non-moving object		30, 2, 14, 18		26, 7, 9, 39				
7	Volume of moving object	2, 26, 29, 40		1, 7, 4, 35		1, 7, 4, 17			
8	Volume of non-moving object		35, 10, 19, 14	19, 14	35, 8, 2, 14				
9	Speed	2, 28, 13, 38		13, 14, 8		29, 30, 34		7, 29, 34	
10	Force	8, 1, 37, 18	18, 13, 1, 28	17, 19, 9, 36	28, 10	19, 10, 15	1, 18, 36, 37	15, 9, 12, 37	2, 36, 18, 37
11	Tension, pressure	10, 36, 37, 40	13, 29, 10, 18	35, 10, 36	35, 1, 14, 16	10, 15, 36, 25	10, 15, 35, 37	6, 35, 10	35, 24
12	Shape	8, 10, 29, 40	15, 10, 26, 3	29, 34, 5, 4	13, 14, 10, 7	5, 34, 4, 10		14, 4, 15, 22	7, 2, 35
13	Stability of object	21, 35, 2, 39	26, 39, 1, 40	13, 15, 1, 28	37	2, 11, 13	39	28, 10, 19, 39	34, 28, 35, 40
14	Strength	1, 8, 40, 15	40, 26, 27, 1	1, 15, 8, 35	15, 14, 28, 26	3, 34, 40, 29	9, 40, 28	10, 15, 14, 7	9, 14, 17, 15
15	Durability of moving object	19, 5, 34, 31		2, 19, 9		3, 17, 19		10, 2, 19, 30	
16	Durability of non-moving object		6, 27, 19, 16		1, 10, 35				35, 34, 38
17	Temperature	36, 22, 6, 38	22, 35, 32	15, 19, 9	15, 19, 9	3, 35, 39, 18	35, 38	34, 39, 40, 18	35, 6, 4
18	Brightness	19, 1, 32	2, 35, 32	19, 32, 16		19, 32, 26		2, 13, 10	
19	Energy spent by moving object	12, 18, 28, 31		12, 28		15, 19, 25		35, 13, 18	
20	Energy spent by non-moving object		19, 9, 6, 27						

	Undesired result (Conflict) / Feature to Change	9	10	11	12	13	14	15	16
		Speed	Force	Tension, pressure	Shape	Stability of object	Strength	Durability of moving object	Durability of non-moving object
1	Weight of moving object	2, 8, 15, 38	8, 10, 18, 37	10, 36, 37, 40	10, 14, 35, 40	1, 35, 19, 39	28, 27, 18, 40	5, 34, 31, 35	
2	Weight of non-moving object		8, 10, 19, 35	13, 29, 10, 18	13, 10, 29, 14	26, 39, 1, 40	28, 2, 10, 27		2, 27, 19, 6
3	Length of moving object	13, 4, 8	10, 17, 4	1, 8, 35	1, 8, 10, 29	1, 8, 15, 24	8, 35, 29, 34	19	
4	Length of non-moving object		28, 10	1, 14, 35	13, 14, 15, 7	39, 37, 35	15, 14, 28, 26		1, 40, 35
5	Area of moving object	29, 30, 4, 34	19, 30, 36, 2	10, 15, 36, 28	5, 34, 29, 4	11, 2, 13, 39	3, 15, 40, 14	6, 3	
6	Area of non-moving object		1, 18, 35, 36	10, 15, 36, 37		2, 38	40		2, 10, 19, 30
7	Volume of moving object	29, 4, 38, 34	15, 35, 36, 37	6, 35, 36, 37	1, 15, 28, 4	28, 10, 1, 39	9, 14, 15, 7	6, 35, 4	
8	Volume of non-moving object		2, 18, 37	24, 35	7, 2, 35	34, 28, 35, 40	9, 14, 17, 15		35, 34, 38
9	Speed		13, 28, 15, 19	6, 18, 38, 40	35, 15, 18, 34	28, 33, 1, 18	8, 3, 26, 14	3, 19, 35, 5	
10	Force	13, 28, 15, 12		18, 21, 11	10, 35, 40, 34	35, 10, 21	35, 10, 14, 27	19, 2	
11	Tension, pressure	6, 35, 36	36, 35, 21		35, 4, 15, 10	35, 33, 2, 40	9, 18, 3, 40	19, 3, 27	
12	Shape	35, 15, 34, 18	35, 10, 37, 40	34, 15, 10, 14		33, 1, 18, 4	30, 14, 10, 40	14, 26, 9, 25	
13	Stability of object	33, 15, 28, 18	10, 35, 21, 16	2, 35, 40	22, 1, 18, 4		17, 9, 15	13, 27, 10, 35	39, 3, 35, 23
14	Strength	8, 13, 26, 14	10, 18, 3, 14	10, 3, 18, 40	10, 30, 35, 40	13, 17, 35		27, 3, 26	
15	Durability of moving object	3, 35, 5	19, 2, 16	19, 3, 27	14, 26, 28, 25	13, 3, 35	27, 3, 10		
16	Durability of non-moving object					39, 3, 35, 23			
17	Temperature	2, 28, 36, 30	35, 10, 3, 21	35, 39, 19, 2	14, 22, 19, 32	1, 35, 32	10, 30, 22, 40	19, 13, 39	19, 18, 36, 40
18	Brightness	10, 13, 19	26, 19, 6		32, 30	32, 3, 27	35, 19	2, 19, 6	
19	Energy spent by moving object	8, 15, 35	16, 26, 21, 2	23, 14, 25	12, 2, 29	19, 13, 17, 24	5, 19, 9, 35	28, 35, 6, 18	
20	Energy spent by non-moving object		36, 37			27, 4, 29, 18	35		

	Undesired result (Conflict) / Feature to Change	17 Temperature	18 Brightness	19 Energy spent by moving object	20 Energy spent by non-moving object	21 Power	22 Waste of energy	23 Waste of substance	24 Loss of information
1	Weight of moving object	6, 20, 4, 38	19, 1, 32	38, 12, 34, 31		12, 36, 18, 31	6, 2, 34, 19	5, 35, 3, 31	10, 24, 35
2	Weight of non-moving object	28, 19, 32, 22	19, 32, 35		18, 19, 28, 1	15, 19, 18, 22	18, 19, 28, 15	5, 8, 13, 30	10, 15, 35
3	Length of moving object	10, 15, 19	32	8, 35, 24		1, 35	7, 2, 35, 39	4, 29, 23, 10	1, 24
4	Length of non-moving object	3, 35, 38, 18	3, 25			12, 8	6, 28	10, 28, 24, 35	24, 26
5	Area of moving object	2, 15, 16	15, 32, 19, 13	19, 32		19, 10, 32, 18	15, 17, 30, 26	10, 35, 2, 39	30, 26
6	Area of non-moving object	35, 39, 38				17, 32	17, 7, 30	10, 14, 18, 39	30, 16
7	Volume of moving object	34, 39, 10, 18	2, 13, 10	35		35, 6, 13, 18	7, 15, 13, 16	36, 39, 34, 10	2, 22
8	Volume of non-moving object	35, 6, 4				30, 6		10, 39, 35, 34	
9	Speed	28, 30, 36, 2	10, 13, 19	8, 15, 35, 38		19, 35, 38, 2	14, 20, 19, 35	10, 13, 28, 38	13, 26
10	Force	35, 10, 21		19, 17, 10	1, 16, 36, 37	19, 35, 18, 37	14, 15	8, 35, 40, 5	
11	Tension, pressure	35, 39, 19, 2		14, 24, 10, 37		10, 35, 14	2, 36, 25	10, 36, 3, 37	
12	Shape	22, 14, 19, 32	13, 15, 32	2, 6, 34, 14		4, 6, 2	14	35, 29, 3, 5	
13	Stability of object	35, 1, 32	32, 3, 27, 15	13, 19	27, 4, 29, 18	32, 35, 27, 31	14, 2, 39, 6	2, 14, 30, 40	
14	Strength	30, 10, 40	35, 19	19, 35, 10	35	10, 26, 35, 28	35	35, 28, 31, 40	
15	Durability of moving object	19, 35, 39	2, 19, 4, 35	28, 6, 35, 18		19, 10, 35, 38		28, 27, 3, 18	10
16	Durability of non-moving object	19, 18, 36, 40				16		27, 16, 18, 38	10
17	Temperature		32, 30, 21, 16	19, 15, 3, 17		2, 14, 17, 25	21, 17, 35, 38	21, 36, 29, 31	
18	Brightness	32, 35, 19		32, 1, 19	32, 35, 1, 15	32	19, 16, 1, 6	13, 1	1, 6
19	Energy spent by moving object	19, 24, 3, 14	2, 15, 19			6, 19, 37, 18	12, 22, 15, 24	35, 24, 18, 5	
20	Energy spent by non-moving object		19, 2, 35, 32					28, 27, 18, 31	

	Undesired result (Conflict) / Feature to Change	25	26	27	28	29	30	31	32
		Waste of time	Amount of substance	Reliability	Accuracy of measurement	Accuracy of manufacturing	Harmful factors acting on object	Harmful side-effects	Manufacturability
1	Weight of moving object	10, 35, 20, 28	3, 26, 18, 31	3, 11, 1, 27	28, 27, 35, 26	28, 35, 26, 18	22, 21, 18, 27	22, 35, 31, 39	27, 28, 1, 36
2	Weight of non-moving object	10, 20, 35, 26	19, 6, 18, 26	10, 28, 8, 3	18, 26, 28	10, 1, 35, 17	2, 19, 22, 37	35, 22, 1, 39	28, 1, 9
3	Length of moving object	15, 2, 29	29, 35	10, 14, 29, 40	28, 32, 4	10, 28, 29, 37	1, 15, 17, 24	17, 15	1, 29, 17
4	Length of non-moving object	30, 29, 14		15, 29, 28	32, 28, 3	2, 32, 10	1, 18		15, 17, 27
5	Area of moving object	26, 4	29, 30, 6, 13	29, 9	26, 28, 32, 3	2, 32	22, 33, 28, 1	17, 2, 18, 39	13, 1, 26, 24
6	Area of non-moving object	10, 35, 4, 18	2, 18, 40, 4	32, 35, 40, 4	26, 28, 32, 3	2, 29, 18, 36	27, 2, 39, 35	22, 1, 40	40, 16
7	Volume of moving object	2, 6, 34, 10	29, 30, 7	14, 1, 40, 11	25, 26, 28	25, 28, 2, 16	22, 21, 27, 35	17, 2, 40, 1	29, 1, 40
8	Volume of non-moving object	35, 16, 32, 18	35, 3	2, 35, 16		35, 10, 25	34, 39, 19, 27	30, 18, 35, 4	35
9	Speed		18, 19, 29, 38	11, 35, 27, 28	28, 32, 1, 24	10, 28, 32, 25	1, 28, 35, 23	2, 24, 35, 21	35, 13, 8, 1
10	Force	10, 37, 36	14, 29, 18, 36	3, 35, 13, 21	35, 10, 23, 24	28, 29, 37, 36	1, 35, 40, 18	13, 3, 36, 24	15, 37, 18, 1
11	Tension, pressure	37, 36, 4	10, 14, 36	10, 13, 19, 35	6, 28, 25	3, 35	22, 2, 37	2, 33, 27, 18	1, 35, 16
12	Shape	14, 10, 34, 17	36, 22	10, 40, 16	28, 32, 1	32, 30, 40	22, 2, 1, 35	35, 1	1, 32, 17, 28
13	Stability of object	35, 27	15, 32, 35		13	18	35, 24, 30, 18	35, 40, 27, 39	35, 19
14	Strength	29, 3, 28, 10	29, 10, 27	11, 3	3, 27, 16	3, 27	18, 35, 37, 1	15, 35, 22, 2	11, 3, 10, 32
15	Durability of moving object	20, 10, 28, 18	3, 35, 10, 40	11, 2, 13	3	3, 27, 16, 40	22, 15, 33, 28	21, 39, 16, 22	27, 1, 4
16	Durability of non-moving object	28, 20, 10, 16	3, 35,31	34, 27, 6, 40	10, 26, 24		17, 1, 40, 33	22	35, 10
17	Temperature	35, 28, 21, 18	3, 17, 30, 39	19, 35, 3, 10	32, 19, 24	24	22, 33, 35, 2	22, 35, 2, 24	26, 27
18	Brightness	19, 1, 26, 17	1, 19		11, 15, 32	3, 32	15, 19	35, 19, 32, 39	19, 35, 28, 26
19	Energy spent by moving object	35, 38, 19, 18	34, 23, 16, 18	19, 21, 11, 27	3, 1, 32		1, 35, 6, 27	2, 35, 6	28, 26, 30
20	Energy spent by non-moving object		3, 35, 31	10, 36, 23			10, 2, 22, 37	19, 22, 18	1, 4

	Undesired result (Conflict) / Feature to Change	33	34	35	36	37	38	39
		Convenience of use	Repairability	Adaptability	Complexity of device	Complexity of control	Level of automation	Productivity
1	Weight of moving object	35, 3, 2, 24	2, 27, 28, 11	29, 5, 15, 8	26, 30, 36, 34	28, 29, 26, 32	26, 35, 18, 19	35, 3, 24, 37
2	Weight of non-moving object	6, 13, 1, 32	2, 27, 28, 11	19, 15, 29	1, 10, 26, 39	25, 28, 17, 15	2, 26, 35	1, 28, 15, 35
3	Length of moving object	15, 29, 35, 4	1, 28, 10	14, 15, 1, 16	1, 19, 26, 24	35, 1, 26, 24	17, 24, 26, 16	14, 4, 28, 29
4	Length of non-moving object	2, 25	3	1, 35	1, 26	26		30, 14, 7, 26
5	Area of moving object	15, 17, 13, 16	15, 13, 10, 1	15, 30	14, 1, 13	2, 36, 26, 18	14, 30, 28, 23	10, 26, 34, 2
6	Area of non-moving object	16, 4	16	15, 16	1, 18, 36	2, 35, 30, 18	23	10, 15, 17, 7
7	Volume of moving object	15, 13, 30, 12	10	15, 29	26, 1	29, 26, 4	35, 34, 16, 24	10, 6, 2, 34
8	Volume of non-moving object		1		1, 31	2, 17, 26		35, 37, 10, 2
9	Speed	32, 28, 13, 12	34, 2, 28, 27	15, 10, 26	10, 28, 4, 34	3, 34, 27, 16	10, 18	
10	Force	1, 28, 3, 25	15, 1, 11	15, 17, 18, 20	26, 35, 10, 18	36, 37, 10, 19	2, 35	3, 28, 35, 37
11	Tension, pressure	11	2	35	19, 1, 35	2, 36, 37	35, 24	10, 14, 35, 37
12	Shape	32, 15, 26	2, 13, 1	1, 15, 29	16, 29, 1, 28	15, 13, 39	15, 1, 32	17, 26, 34, 10
13	Stability of object	32, 35, 30	2, 35, 10, 16	35, 30, 34, 2	2, 35, 22, 26	35, 22, 39, 23	1, 8, 35	23, 35, 40, 3
14	Strength	32, 40, 28, 2	27, 11, 3	15, 3, 32	2, 13, 28	27, 3, 15, 40	15	29, 35, 10, 14
15	Durability of moving object	12, 27	29, 10, 27	1, 35, 13	10, 4, 29, 15	19, 29, 39, 35	6, 10	35, 17, 14, 19
16	Durability of non-moving object	1	1	2		25, 34, 6, 35	1	10, 20, 16, 38
17	Temperature	26, 27	4, 10, 16	2, 18, 27	2, 17, 16	3, 27, 35, 31	26, 2, 19, 16	15, 28, 35
18	Brightness	28, 26, 19	15, 17, 13, 16	15, 1, 19	6, 32, 13	32, 15	2, 26, 10	2, 25, 16
19	Energy spent by moving object	19, 35	1, 15, 17, 28	15, 17, 13, 16	2, 29, 27, 28	35, 38	32, 2	12, 28, 35
20	Energy spent by non-moving object					19, 35, 16, 25		1, 6

	Undesired result (Conflict) / Feature to Change	1	2	3	4	5	6	7	8
		Weight of moving object	Weight of non-moving object	Length of moving object	Length of non-moving object	Area of moving object	Area of non-moving object	Volume of moving object	Volume of non-moving object
21	Power	8, 36, 38, 31	19, 26, 17, 27	1, 10, 35, 37		19, 38	17, 32, 13, 38	35, 6, 38	30, 6, 25
22	Waste of energy	15, 6, 19, 28	19, 6, 18, 9	7, 2, 6, 13	6, 38, 7	15, 26, 17, 30	17, 7, 30, 18	7, 18, 23	7
23	Waste of substance	35, 6, 23, 40	35, 6, 22, 32	14, 29, 10, 39	10, 28, 24	35, 2, 10, 31	10, 18, 39, 31	1, 29, 30, 36	3, 39, 18, 31
24	Loss of information	10, 24, 35	10, 35, 5	1, 26	26	30, 26	30, 16		2, 22
25	Waste of time	10, 20, 37, 35	10, 20, 26, 5	15, 2, 29	30, 24, 14, 5	26, 4, 5, 16	10, 35, 17, 4	2, 5, 34, 10	35, 16, 32, 18
26	Amount of substance	35, 6, 18, 31	27, 26, 18, 35	29, 14, 35, 18		15, 14, 29	2, 18, 40, 4	15, 20, 29	
27	Reliability	3, 8, 10, 40	3, 10, 8, 28	15, 9, 14, 4	15, 29, 28, 11	17, 10, 14, 16	32, 35, 40, 4	3, 10, 14, 24	2, 35, 24
28	Accuracy of measurement	32, 35, 26, 28	28, 35, 25, 26	28, 26, 5, 16	32, 28, 3, 16	26, 28, 32, 3	26, 28, 32, 3	32, 13, 6	
29	Accuracy of manufacturing	28, 32, 13, 18	28, 35, 27, 9	10, 28, 29, 37	2, 32, 10	28, 33, 29, 32	2, 29, 18, 36	32, 28, 2	25, 10, 35
30	Harmful factors acting on object	22, 21, 27, 39	2, 22, 13, 24	17, 1, 39, 4	1, 18	22, 1, 33, 28	27, 2, 39, 35	22, 23, 37, 35	34, 39, 19, 27
31	Harmful side-effects	19, 22, 15, 39	35, 22, 1, 39	17, 15, 16, 22		17, 2, 18, 39	22, 1, 40	17, 2, 40	30, 18, 35, 4
32	Manufacturability	28, 29, 15, 16	1, 27, 36, 13	1, 29, 13, 17	15, 17, 27	13, 1, 26, 12	16, 40	13, 29, 1, 40	35
33	Convenience of use	25, 2, 13, 15	6, 13, 1, 25	1, 17, 13, 12		1, 17, 13, 16	18, 16, 15, 39	1, 16, 35, 15	4, 18, 39, 31
34	Repairability	2, 27, 35, 11	2, 27, 35, 11	1, 28, 10, 25	3, 18, 31	15, 13, 32	16, 25	25, 2, 35, 11	1
35	Adaptability	1, 6, 15, 8	19, 15, 29, 16	35, 1, 29, 2	1, 35, 16	35, 30, 29, 7	15, 16	15, 35, 29	
36	Complexity of device	26, 30, 34, 36	2, 36, 35, 39	1, 19, 26, 24	26	14, 1, 13, 16	6, 36	34, 25, 6	1, 16
37	Complexity of control	27, 26, 28, 13	6, 13, 28, 1	16, 17, 26, 24	26	2, 13, 15, 17	2, 39, 30, 16	29, 1, 4, 16	2, 18, 26, 31
38	Level of automation	28, 26, 18, 35	28, 26, 35, 10	14, 13, 17, 28	23	17, 14, 13		35, 13, 16	
39	Productivity	35, 26, 24, 37	28, 27, 15, 3	18, 4, 28, 38	30, 7, 14, 26	10, 26, 34, 31	10, 35, 17, 7	2, 6, 34, 10	35, 37, 10, 2

	Undesired result (Conflict) / Feature to Change	9	10	11	12	13	14	15	16
		Speed	Force	Tension, pressure	Shape	Stability of object	Strength	Durability of moving object	Durability of non-moving object
21	Power	15, 35, 2	26, 2, 36, 35	22, 10, 35	29, 14, 2, 40	35, 32, 15, 31	26, 10, 28	19, 35, 10, 38	16
22	Waste of energy	16, 35, 38	36, 38			14, 2, 39, 6	26		
23	Waste of substance	10, 13, 28, 38	14, 15, 18, 40	3, 36, 37, 10	29, 35, 3, 5	2, 14, 30, 40	35, 28, 31, 40	28, 27, 3, 18	27, 16, 18, 38
24	Loss of information	26, 32						10	10
25	Waste of time		10, 37, 36, 5	37, 36, 4	4, 10, 34, 17	35, 3, 22, 5	29, 3, 28, 18	20, 10, 28, 18	28, 20, 10, 16
26	Amount of substance	35, 29, 34, 28	35, 14, 3	10, 36, 14, 3	35, 14	15, 2, 17, 40	14, 35, 34, 10	3, 35, 10, 40	3, 35, 31
27	Reliability	21, 35, 11, 28	8, 28, 10, 3	10, 24, 35, 19	35, 1, 16, 11		11, 28	2, 35, 3, 25	34, 27, 6, 40
28	Accuracy of measurement	28, 13, 32, 24	32, 2	6, 28, 32	6, 28, 32	32, 35, 13	28, 6, 32	28, 6, 32	10, 26, 24
29	Accuracy of manufacturing	10, 28, 32	28, 19, 34, 36	3, 35	32, 30, 40	30, 18	3, 27	3, 27, 40	
30	Harmful factors acting on object	21, 22, 35, 28	13, 35, 39, 18	22, 2, 37	22, 1, 3, 35	35, 24, 30, 18	18, 35, 37, 1	22, 15, 33, 28	17, 1, 40, 33
31	Harmful side-effects	35, 28, 3, 23	35, 28, 1, 40	2, 33, 27, 18	35, 1	35, 40, 27, 39	15, 35, 22, 2	15, 22, 33, 31	21, 39, 16, 22
32	Manufacturability	35, 13, 8, 1	35, 12	35, 19, 1, 37	1, 28, 13, 27	11, 13, 1	1, 3, 10, 32	27, 1, 4	35, 16
33	Convenience of use	18, 13, 34	28, 13, 35	2, 32, 12	15, 34, 29, 28	32, 35, 30	32 40, 3, 28	29, 3, 8, 25	1, 16, 25
34	Repairability	34, 9	1, 11, 10	13	1, 13, 2, 4	2, 35	11, 1, 2, 9	11, 29, 28, 27	1
35	Adaptability	35, 10, 14	15, 17, 20	35, 16	15, 37, 1, 8	35, 30, 14	35, 3, 32, 6	13, 1, 35	2, 16
36	Complexity of device	34, 10, 28	26, 16	19, 1, 35	29, 13, 28, 15	2, 22, 17, 19	2, 13, 28	10, 4, 28, 15	
37	Complexity of control	3, 4, 16, 35	36, 28, 40, 19	35, 36, 37, 32	27, 13, 1, 39	11, 22, 39, 30	27, 3, 15, 28	19, 29, 39, 25	25, 24, 6, 35
38	Level of automation	28, 10	2, 35	13, 35	15, 32, 1, 13	18, 1	25, 13	6, 9	
39	Productivity		28, 15, 10, 36	10, 37, 14	14, 10, 34, 40	35, 3, 22, 39	29, 28, 10, 18	35, 10, 2, 18	20, 10, 16, 38

	Undesired result (Conflict) / Feature to Change	17 Temperature	18 Brightness	19 Energy spent by moving object	20 Energy spent by non-moving object	21 Power	22 Waste of energy	23 Waste of substance	24 Loss of information
21	Power	2, 14, 17, 25	16, 6, 19	16, 6, 19, 37			10, 35, 38	28, 27, 18, 38	10, 19
22	Waste of energy	19, 38, 7	1, 13, 32, 15			3, 38		35, 27, 2, 37	19, 10
23	Waste of substance	21, 36, 39, 31	1, 6, 13	35, 18, 24, 5	28, 27, 12, 31	28, 27, 18, 38	35, 27, 2, 31		
24	Loss of information		19			10, 19	19, 10		
25	Waste of time	35, 29, 21, 18	1, 19, 26, 17	35, 38, 19, 18	1	35, 20, 10, 6	10, 5, 18, 32	35, 18, 10, 39	24, 26, 28, 32
26	Amount of substance	3, 17, 39		34, 29, 16, 18	3, 35, 31	35	7, 18, 25	6, 3, 10, 24	24, 28, 35
27	Reliability	3, 35, 10	11, 32, 13	21, 11, 27, 19	36, 23	21, 11, 26, 31	10, 11, 35	10, 35, 29, 39	10, 28
28	Accuracy of measurement	6, 19, 28, 24	6, 1, 32	3, 6, 32		3, 6, 32	26, 32, 27	10, 16, 31, 28	
29	Accuracy of manufacturing	19, 26	3, 32	32, 2		32, 2	13, 32, 2	35, 31, 10, 24	
30	Harmful factors acting on object	22, 33, 35, 2	1, 19, 32, 13	1, 24, 6, 27	10, 2, 22, 37	19, 22, 31, 2	21, 22, 35, 2	33, 22, 19, 40	22, 10, 2
31	Harmful side-effects	22, 35, 2, 24	19, 24, 39, 32	2, 35, 6	19, 22, 18	2, 35, 18	21, 35, 2, 22	10, 1, 34	10, 21, 29
32	Manufacturability	27, 26, 18	28, 24, 27, 1	28, 26, 27, 1	1, 4	27, 1, 12, 24	19, 35	15, 34, 33	32, 24, 18, 16
33	Convenience of use	26, 27, 13	13, 17, 1, 24	1, 13, 24		35, 34, 2, 10	2, 19, 13	28, 32, 2, 24	4, 10, 27, 22
34	Repairability	4, 10	15, 1, 13	15, 1, 28, 16		15, 10, 32, 2	15, 1, 32, 19	2, 35, 34, 27	
35	Adaptability	27, 2, 3, 35	6, 22, 26, 1	19, 35, 29, 13		19, 1, 29	18, 15, 1	15, 10, 2, 13	
36	Complexity of device	2, 17, 13	24, 17, 13	27, 2, 29, 28		20, 19, 30, 34	10, 35, 13, 2	35, 10, 28, 29	
37	Complexity of control	3, 27, 35, 16	2, 24, 26	35, 38	19, 35, 16	19, 1, 16, 10	35, 3, 15, 19	1, 18, 10, 24	35, 33, 27, 22
38	Level of automation	26, 2, 19	8, 32, 19	2, 32, 13		28, 2, 27	23, 28	35, 10, 18, 5	35, 33
39	Productivity	35, 21, 28, 10	26, 17, 19, 1	35, 10, 38, 19	1	35, 20, 10	28, 10, 29, 35	28, 10, 35, 23	13, 15, 23

	Undesired result (Conflict) / Feature to Change	25	26	27	28	29	30	31	32
		Waste of time	Amount of substance	Reliability	Accuracy of measurement	Accuracy of manufacturing	Harmful factors acting on object	Harmful side-effects	Manufacturability
21	Power	35, 20, 10, 6	4, 34, 19	19, 24, 26, 31	32, 15, 2	32, 2	19, 22, 31, 2	2, 35, 18	26, 10, 34
22	Waste of energy	10, 18, 32, 7	7, 18, 25	11, 10, 35	32		21, 22, 35, 2	21, 35, 2, 22	
23	Waste of substance	15, 18, 35, 10	6, 3, 10, 24	10, 29, 39, 35	16, 34, 31, 28	35, 10, 24, 31	33, 22, 30, 40	10, 1, 34, 29	15, 34, 33
24	Loss of information	24, 26, 28, 32	24, 28, 35	10, 28, 23			22, 10, 1	10, 21, 32	32
25	Waste of time		35, 38, 18, 16	10, 30, 4	24, 34, 28, 32	24, 26, 28, 18	35, 18, 34	35, 22, 18, 39	35, 28, 34, 4
26	Amount of substance	35, 38, 18, 16		18, 3, 28, 40	13, 2, 28	33, 30	35, 33, 28, 31	3, 35, 40, 39	29, 1, 35, 27
27	Reliability	10, 30, 4	21, 28, 40, 3		32, 3, 11, 23	11, 32, 1	27, 35, 2, 40	3,5 2, 40, 26	
28	Accuracy of measurement	24, 34, 28, 32	2, 6, 32	5, 11, 1, 23			28, 24, 22, 26	3, 33, 39, 10	6, 35, 25, 18
29	Accuracy of manufacturing	32, 26, 28, 18	32, 30	11, 32, 1			26, 28, 10, 36	4, 17, 34, 26	
30	Harmful factors acting on object	35, 18, 34	35, 33, 29, 31	27, 24, 2, 40	28, 33, 23, 26	26, 28, 10, 18			24, 35, 2
31	Harmful side-effects	1, 22	3, 24, 39, 1	24, 2, 40, 39	3, 33, 26	4, 17, 34, 26			
32	Manufacturability	35, 28, 34, 4	35, 23, 1, 24		1, 35, 12, 18		24, 2		
33	Convenience of use	4, 28, 10, 34	12, 35	17, 27, 8, 40	25, 13, 2, 34	1, 32, 35, 23	2, 25, 28, 39		2, 5, 12
34	Repairability	32, 1, 10, 25	2, 28, 10, 25	11, 10, 1, 16	10, 2, 13	25, 10	35, 10, 2, 16		1, 35, 11, 10
35	Adaptability	35, 28	3, 35, 15	35, 13, 8, 24	35, 5, 1, 10		35, 11, 32, 31		1, 13, 31
36	Complexity of device	6, 29	13, 3, 27, 10	13, 35, 1	2, 26, 10, 34	26, 24, 32	22, 19, 29, 40	19, 1	27, 26, 1, 13
37	Complexity of control	18, 28, 32, 9	3, 27, 29, 18	27, 40, 28, 8	26, 24, 32, 38		22, 19, 29, 28	2, 21	5, 28, 11, 29
38	Level of automation	24, 28, 35, 30	35, 13	11, 27, 32	28, 26, 10, 34	28, 26, 18, 23	2, 33	2	1, 26, 13
39	Productivity		35, 38	1, 35, 10, 38	1, 10, 34, 28	18, 10, 32, 1	22, 35, 13, 24	35, 22, 18, 39	35, 28, 2, 24

	Undesired result (Conflict) / Feature to Change	33	34	35	36	37	38	39
		Convenience of use	Repairability	Adaptability	Complexity of device	Complexity of control	Level of automation	Productivity
21	Power	26, 35, 18	35, 2, 10, 34	19, 17, 34	20, 19, 30, 34	19, 35, 16	28, 2, 17	28, 35, 34
22	Waste of energy	35, 22, 1	2, 19		7, 23	35, 3, 15, 23	2	28, 10, 29, 35
23	Waste of substance	32, 28, 2, 24	2, 35, 34, 27	15, 10, 2	35, 10, 28, 24	35, 18, 10, 13	35, 10, 18	28, 35, 10, 23
24	Loss of information	27, 22				35, 33	35	13, 23, 15
25	Waste of time	4, 28, 10, 34	32, 1, 10	35, 28	6, 29	18, 28, 32, 10	24, 28, 35, 30	
26	Amount of substance	39, 29, 25, 10	2, 32, 10, 25	15, 3, 29	3, 13, 27, 10	3, 27, 29, 18	8, 35	13, 29, 3, 27
27	Reliability	27, 17, 40	1, 11	13, 25, 8, 24	13, 35, 1	27, 40, 28	11, 13, 27	1, 35, 29, 38
28	Accuracy of measurement	1, 13, 17, 34	1, 32, 13, 11	13, 35, 2	27, 35, 10, 34	26, 24, 32, 38	28, 2, 10, 34	10, 34, 28, 32
29	Accuracy of manufacturing	1, 32, 35, 23	25, 10		26, 2, 18		26, 28, 18, 23	10, 18, 32, 39
30	Harmful factors acting on object	2, 25, 28, 39	35, 10, 2	35, 11, 22, 31	22, 19, 29, 40	22, 19, 29, 40	33, 3, 34	22, 35, 13, 24
31	Harmful side-effects				19, 1, 31	2, 21, 27, 1	2	22, 35, 18, 39
32	Manufacturability	2, 5, 13, 16	35, 1, 11, 9	2, 13, 15	27, 26, 1	6, 28, 11, 1	8, 28, 1	35, 1, 10, 28
33	Convenience of use		12, 26, 1, 32	15, 34, 1, 16	32, 26, 12, 17		1, 34, 12, 3	15, 1, 28
34	Repairability	1, 12, 26, 15		7, 1, 4, 16	35, 1, 13, 11		34, 35, 7, 13	1, 32, 10
35	Adaptability	15, 34, 1, 16	1, 16, 7, 4		15, 29, 37, 28	1	27, 34, 35	35, 28, 6, 37
36	Complexity of device	27, 9, 26, 24	1, 13	29, 15, 28, 37		15, 10, 37, 28	15, 1, 24	12, 17, 28
37	Complexity of control	2, 5	12, 26	1, 15	15, 10, 37, 28		34, 21	35, 18
38	Level of automation	1, 12, 34, 3	1, 35, 13	27, 4, 1, 35	15, 24, 10	34, 27, 25		5, 12, 35, 26
39	Productivity	1, 28, 7, 19	1, 32, 10, 25	1, 35, 28, 37	12, 17, 28, 24	35, 18, 27, 2	5, 12, 35, 26	

Appendix C: The 40 Principles

These are the 40 principles that Altshuller discovered as being common to many inventions. You can use the Contradictions Matrix to find a principle that may be useful in a specific situation or you can use one or more of the principles as tools to help you solve any inventive problem. All the Principles should be seen as *opportunities* to modify things!

1. Segmentation

Segmentation means to separate into smaller parts. A modular design can result in parts which plug together in different ways, or is easy

to manufacture, assemble and take apart, such as when repairing or transporting it. Open office 'cubicles' use segmentation to allow the layout of offices to be easily changed. As you now have separate parts you can treat these parts differently or they can be made of different materials and have different shapes.

2. Extraction

Extraction means to take out or separate something, such as removing a painful tooth or singling out the critical parts of a system. Sometimes simply placing a bad art of the system in a different place lessens the bad effect or removes it completely, as with our lamp post example. Seek the value of different

parts or aspects. Low-value items may be eliminated or high-value items may be extracted and used elsewhere in different circumstances.

3. Local Quality

Do not assume that the current placing or usage of parts cannot be changed–the reasons may be buried in history or may be more for manufacturing convenience than for the value they give in operation. Local Quality means to single out specific parts and then to change them or place them in an environment such that they are optimally useful.

4. Asymmetry

As aesthetic people, we are often attracted to symmetry, which leads us to not question whether asymmetry may be more useful. Symmetrical objects are often easier to manufacture, but may not be the most useful design. To use asymmetry, make uniform objects asymmetrical; make things asymmetrical in each of the different dimensions of the object and for more than one parameter. Fashion designers use asymmetry to create a wide range of interesting styles. Varying shapes give the opportunity for one shape to do one thing and another shape to perform another function.

5. Combination

The principle of combination is bring together things which happen at the same time or in the same place. This can mean doing things in parallel or creating single devices where previously there were more. A washing machine that also acts as a tumble-drier uses the principle of combination. Combination gives you the opportunity to simplify!

6. Universality

Universality is used where objects can perform multiple functions, such as ‘Swiss army’ knives or sofa beds. It is particularly useful where you can eliminate an object by having another object perform the same function.

7. Nesting

Nesting means putting one thing inside another like a Russian doll, or fitting things together in some way. An object which is contained within another object is protected and makes the overall device smaller. The telescope uses nesting both for focusing and to fold it up into a smaller and more portable device.

8. Counterweight

When a system results in an undesirable force in one direction, a counterweight is a deliberate change to balance out or improve the situation by acting in the opposite direction. Traction control systems in vehicles can change the suspension system to shift the positioning of the body to balance out a tendency to roll.

9. Prior Counteraction

When you know that an undesirable situation is going to happen, you may be able to do something ahead of when it would occur, either to prevent it from happening or to reduce the impact that might be felt when it does happen. Methods to do this includes reinforcing and setting up counterweights so the problem is managed at all times.

10. Prior Action

When something is to be done at some time, Prior Action means preparing or taking some action beforehand to smooth and ease the event when it does occur. For example, laying the table for breakfast last thing in the evening will save time and stress on the following morning in the sleepy hurry to eat and get to work. It is far too easy to design a device or

manufacturing process so that something is done when it is needed to be done. But that may not be the best time for it to happen so think about when you want an action/function and choose the best time!

11. Cushion in Advance

Another form of doing things ahead of an event is to prepare for things which will fail or go wrong in some way. This can range from mistake-proofing a process to creating uninterruptible power supplies for computers.

12. Equipotentiality

A lot of work involves lifting and lowering things, for example to access parts underneath them. Equipotentiality means finding ways

to avoid this heavy work. For example, a chest of drawers was a simple solution to the problems of a single chest, where to get to things at the bottom you had to take out all of the things on top (and then put them back again).

13. Inversion

Inversion means doing the opposite of what might seem normal, such as having a tray come out of a hi-fi system to accept a CD, rather than having to insert the CD into a static part of the system. You can lift instead of lower, do things in reverse order, turn things upside down and a thousand other inverting actions.

14. Spheroidality

We tend to like flat surfaces and

often do not challenge them. Spheroidality asks us to consider curves, in all of their various forms. We can use ball bearings to reduce friction, bend metal smoothly to retain strength or move things around in smooth curves rather than angular jerks. Where there already is curvature, change the radius, or let a flat curve take off into another dimension.

15. Dynamicity

If a system is made up of parts which are all connected rigidly together, then any force applied to the system is felt equally by all parts. When things are fixed, then when their environment changes, they are unable to cope well with the change. Dynamicity means creating

systems which are able to cope with change and intrusions from outside it. Separating parts, using suspension systems, flexible connections and cushioning all are methods of achieving dynamicity.

16. Partial, overdone or excessive action

Sometimes perfection is either impossible or too expensive to consider. What you can always consider is how you can do things at less than or even more than 100%, and to what degree you can do this. Animals cope with varying food supplies by storing food that is not needed now as body fat (which can also double up as insulation) or slowing down their metabolic rate, such as by hibernating or sleeping.

17. Moving to a new dimension

When you are having problems that has to do with straight lines, try using a second or third dimension. Go upwards, sideways or around corners. Reflect energy, bend metal, change your route. You can also move dimensions by rotating the object, changing your viewpoint, or even changing the number of objects.

18. Mechanical vibration

Vibration is effectively a way of injecting energy into an object, which can break it away from other things or allow it to be moved ('bounced') easily. You can do this by shaking, vibrating, sound waves or ultrasonics. By varying both the frequency and amplitude, you can create different effects.

19. Periodic action

A vibration is a constant series of energy bursts. We can also put gaps between those energy bursts to create Periodic action. If you are using continuous force, pulsed energy can be more effective (this is what a hammer drill does). You can change the force, how long it is applied and how long between each application. Rear cycle lamps were once all constantly red, then someone came up with the idea of a flashing light which not only saves energy, it also attracts motorists' attention.

20. Continuity of useful action

Not all parts of all machines are being optimally used all of the time. We can thus improve matters by reducing this idle time or putting it to better use. For example a reciprocating saw has a dead time at the end of each stroke which is eliminated by the circular saw. An alternative may be to put the reciprocation to good use, such as actuating a pump which removes the sawdust.

21. Rushing through

Doing things at high speed reduces the time during which problems may occur. For example, if you are cutting a soft material slowly, it will deform, making the cutting a difficult job. By doing it very fast, the material does not have time to deform.

22. Convert harm into benefit

Sometimes harmful or undesired

effects, such as the creation of waste, result from the process. A simple conversion of harm to benefit is when the heat from a vehicle engine is used to warm the people in the car. Many industries born from inventively looking at how waste can be not only recycled but also put to good use. If something does not work well, ask ‘where else would this limited effect be useful?’ You can even increase the harm to create benefit, such as making enough flammable waste gasses to heat the building.

23. Feedback

Feedback is taking or sensing the output of a system and using this to change events which happen before, such as a thermostat being used to control temperature. You can also reverse feedback, perhaps to exaggerate or accelerate change or to cancel out an undesirable effect. Pop stars use positive feedback to create howling guitar noises. People who like silence can use noise cancelling feedback.

24. Mediator

Sometimes you need an action carried out which cannot easily be done by the system as it is. In this case, you have the option of either adding a new part or temporarily bringing in something to perform the action. To remove liquid from a vessel, you can build in a tipping mechanism or bring in a pump when it is needed.

25. Selfservice

Can your device do things for itself, even occasional actions such as testing or maintenance? To create a hole into which a tube must fit very snugly, you might be able to get the tube to drill the hole itself by heating or sharpening the end, perhaps in combination with another principle such as vibration.

26. Copying

Rather than use the expensive, delicate or inaccessible original, can you use a simple copy. This may be done physically or optically, such as using an image of some sort. Once you have a copy, you can change it different ways to achieve the desired benefit. Image intensifiers work by taking a copy of the light available and amplifying it. It may, for example, be easier to measure a copy of an object than the object itself.

27. Inexpensive short life

When something is relatively expensive or causes other problems, you might be able to replace it with something cheaper that works for the moment. This is a principle than has been used many times to create a disposable society. From Gillette’s razor blades onwards, many inventors have found that a lucrative income can be created with cheap devices that people buy regularly.

28. Replacement of a mechanical system

Mechanical inventors sometimes get trapped by their discipline and opportunities arise for those with knowledge of other subjects can improve the system. You can even replace physical systems with invisible effects, for example replacing wheels on a train by a magnetic lift system. You can also create different effects by varying fields such as using high frequencies or pulsing.

29. Use pneumatic or hydraulic systems

In its most general form, this principle is about replacing solids with liquids or gases, which can easily be channelled and have different properties such as their flexibility, which can be useful for cushioning. Pneumatic and hydraulic systems are particularly useful for channelling energy to a desired place, using flexible pipes.

By changing the bore of the pipe, pressure can also be easily increased or decreased.

30. Flexible film or thin membranes

Thin films have a number of useful properties, such as low cost, low space, flexibility and usage. They can be used to separate, isolate and protect, such as the 'cling film' that is used to wrap food. The film can be bought in a roll, but it can also be created in situ (paint is just such a useful thin film).

31. Use of porous materials

Porous material allow some substances through them and block others, which allows them to be used for separating and filtering out desired or undesirable elements. As with mops, they also can be used for

absorbing and collecting liquids or gases, which can subsequently be released in a controlled manner as required. Where porosity is an undesirable effect, then you may want to clog up the pores rather than utilise them.

32. Changing the colour

Colour can be an aesthetic factor or it can have practical uses, such as signalling danger. It can also be used as a detection mechanism, such as the use of litmus paper to determine acidity levels. You can also change the transparency of colours, such as in optical filters.

33. Homogeneity

A homogeneous substance is made up of the same material. So what if you made your device out of different materials? What would be the effect of each part? How would these interact? What if you used all the same material? The principle of homogeneity can also be used in other areas, such as the behaviour of parts of the system. In an electronic system all plugs could be the same to reduce costs, or they could be different to prevent accidentally plugging things into the wrong place.

34. Rejecting and regenerating parts

When a part has been used and is no longer needed, what do you do with it? Typically you either throw it away, restore it or recycle it somehow. Whichever approach you use, you will probably need to include some system to cope with this.

35. Transforming physical or chemical states

Sometimes changing the object in some way, such as its temperature, concentration or density, is useful. Think of the chemical composition of the substances. What is the relationship between the atoms and molecules? Are they tightly bound together, do they slide around or come apart easily? Look at the effects on flexibility, load-bearing, chemical reactions, and so on.

36. Phase transition

Substances often go through changes, such as expanding, evaporating, cooling or changing shape. Think about how this happens and how you can start, stop or otherwise control the change. Is the effect reversible? Can you use a simple catalytic effect?

37. Thermal expansion

When you heat things up, they usually expand at varying rates. This can either be a problem that you need to handle or it can be a tool to solve problems. The bimetallic strip is a simple example where two connected metal strips, each of which expands at a different rate, resulting in a device which bends when it is heated, thus giving the basis of many thermostats and thermometers.

38. Use strong oxidisers

The oxygen in the air reacts with many substances, from iron (creating rust) to flammable substances (enabling fire). This effect can be increased by using materials which combine with oxygen more easily or by adding more oxygen to the system, for example in a blowtorch.

39. Inert environment

When oxygen and other reagents in the environment are a problem, sometimes a good solution is to take them away, replacing them with chemicals that will not react with your device. For example, light bulbs are partially evacuated and filled with inert gases to prevent the thin filament from oxidising and thus breaking.

40. Composite materials

When things are made of all the same substance, they are vulnerable to problems that affect that material. By using a combination of materials, synergistic effects can be created where the different materials used not only contribute their different properties, they also act together to provide something that is better than any individual part. For example, composite bows can fire arrows further and more consistently than bows made of any single material.

Not a Normal Bibliography

Bibliographies are usually just a boring list of books and papers which have more to do with saying how well-read the author is than helping the reader find more useful detail. There is no way that we could put everything about inventing into a single book (although we have had a good go at it!) so we have tried to make this bibliography more useful than the usual list. You will thus find below:

- **Grouping by broad subject area rather than alphabetic listing.**
- **Not *all* of the books that we**

have read (this would be hundreds or even thousands), but the ones that we have found particularly stimulating or which we think you might find useful in some way.

- A brief description of the book to help you decide whether it is worth following up.
- Websites that we know about. As the web is a pretty dynamic place, we cannot guarantee that these will stay as they are, but we thought that it was still worth giving them here.

Inventing, innovating and general creativity is a journey without end. These resources are here to help you keep travelling. Bon voyage.

Analytic invention

M. Neil Browne, Stuart M. Keeley, *Asking the Right Questions : A Guide to Critical Thinking,* Prentice Hall, 1997

A stimulating book about critical thinking and especially, as the title says, asking questions.

David Levy, *Tools of Critical Thinking: Metathoughts for Psychology*, Prentice Hall, 1997

Do not be put off by the title. This is an entertainingly written and useful book on critical thinking.

Some analytic websites

www.sjsu.edu/depts/itl/graphics/m

San Jose State’s excellent site on critical thinking.

www.criticalthinking.org/

A good site for educators from Sonama State university.

www.changingminds.org/disciplin

A big section in Dave's site on logical thinking and fallacies.

www.mindtools.com/index.html

A good collection of tools and techniques in this ‘Mind Tools’ site.

Science

Richard Feynman, *Six Easy Pieces*, Penguin, London, 1998

Feynman is one of the geniuses of the 20th Century and a great writer. How easy you fins his pieces depends on how you think but fun to read anyway.

Richard Feynman, The Meaning of it all, Penguin, London, 1998

Some philosophy things about science and things–a book we just like!

J. E. Gordon, *The New Science of Strong Materials (or why you don't fall through the floor)*, Penguin 1991

Although quite old in that it came out originally in 1968 it really is a book to help you think about what molecules are doing in simple engineering situations.

J. E. Gordon, *Structures (or why things don't fall down)*, Penguin, 1991

A man whose simple approach seems to be coming back into fashion!

Edward Tenner, *Why Things Bite Back*, Fourth Estate, 1996

Some great stories to entertain you but also to remind you that what you have invented may, unless you get it really right, not have the outcomes you thought.

Steven Vogel, *Cats Paws and Catapults*, Penguin Books, London, 1999

Is nature the greatest inventor?

Steven Vogel says 'no' while showing how it invents mightily whilst coping with the limitations of growth and biological materials.

Some science websites:

www.ems.psu.edu/~fraser/BadSci

Some splendid explanations of how conventional thinking is not always true.

www.eskimo.com/~billb/miscon/m

More incorrect science as taught in schools.

www.invent.org/

The inventor's hall of fame, including details on many inventors.

TRIZ

John Terninko, Alla Zusman and Boris Zlotin, *Systematic Innovation*, St. Lucie Press, Boston, 1998

TRIZ in excellent detail by probably the foremost experts in TRIZ in the Western world.

Genrich Altshuller, *40 Principles– TRIZ keys to Technical Innovation*, Technical Innovation Centre, Worcester, MA

Great cartoons to help you understand the 40 principles of TRIZ from the originator of TRIZ.

Genrich Altshuller, *The Innovation Algorithm*, Technical Innovation Centre, Worcester, MA

A number of TRIZ stories to help you understand the thinking of this

great man

Genrich Altshuller, *And Suddenly the Inventor Appeared (TRIZ, the Theory of Inventive Problem Solving)*, Technical Innovation Centre, Worcester, MA, 1996

A simple guide to TRIZ using examples of problems

Darryl Mann, *Hands-on Systematic Innovation*, Creax, 2002

Perhaps the best TRIZ expert in the world, this book is the 'systematic' one for those who like systems approaches. Darrel has several other great books on TRIZ too.

Some TRIZ websites:

www.invention-machine.com

Software for TRIZ and knowledge recovery and management

www.ideationtriz.com

Software for learning and using all the extended TRIZ tools that Ideation have developed - a members section allows you to log on to chat with other TRIZZERS!

www.aitriz.org

A club where you can join in the fun!

www.triz-journal.com

A great source of articles on TRIZ to which you could contribute! The standard ‘go to’ site for those thinking of connecting to TRIZ but

use others as well!

www.creax.com
A great TRIZ company and website.

www.nextstepassociates.co.uk
This is Graham’s site, so of course it's worth visiting.

Psychology

Calvin, W.H., *The Six Essentials? Minimal Requirements for the Darwinian Bootstrapping of Quality.* Journal of Memetics - Evolutionary Models of Information Transmission, 1. 1997
Contains the basics of Darwinian thought.

Guy Claxton, *Hare, Brain, Tortoise Mind*, Fourth Estate, London, 1997

A thorough but readable review of research into the mind and creative thinking. If you want proof that managing the mind can change creativity then read this.

John S. Dacey and Kathleen H. Lennon, *Understanding Creativity*, Jossey Bass, San Francisco, 1999

A good summary of the latest academic research on the inner reaches of creativity.

Daniel C. Dennett, *Kinds of Minds - towards an evolution of consciousness,* Harper Collins, New

York, 1996

A thought provoking book linking evolution and processes for thinking.

Lone Frank, *Mindfield*, Oneworld, 2007

Some pretty startling findings about brains and thinking.

Malcolm Gladwell, *Blink: The Power of Thinking Without Thinking*, Penguin, 2005

Daniel Goleman, *Vital Lies, Simple Truths*, Bloomsbury, London, 1997

Something on why we think like we do and how we trick ourselves.

Morgan D. Jones, The Thinker's Toolkit, *14 Powerful Techniques for Problem Solving*, Three Rivers Press, 1998

The title says it all, though we might not agree with everything he says!

Jonathan Leherer, *How We Decide*, Houghton Mifflin Harcourt, 2009

This really shows up some myths we all carry around about our thinking.

V.S. Ramachandran and Sandra Blakesee, *Phantoms in the Brain*, Fourth Estate, 1998

"If you are at all interested in how your brain works, this is the book

you must read" - this is the cover quote from Francis Crick of DNA fame

Kathryn Schultz, *Being Wrong: Adventures in the Margin of Error*, Harper Collins, 2010

Some basic things about why we get things wrong, things everyone should know.

Some psychology websites

www.nlpu.com/archive.htm

A good list of articles on NLP techniques, including Disney's creativity strategy.

www.socialpsychology.org

A huge list of links to many sites

on psychology, with a bias to those which discuss how we interact with others.

www.thinking.net

Another good set of articles and links to useful sites.

www.wynja.com/psych/

Includes details of the key themes of many famous psychologists and psychiatrists as well as some more alternative approaches.

changingminds.org/

This is Dave's site of around 5000 pages on how the mind works and how to change it.

Creativity

Paul Birch and Brian Clegg, *Imagination Engineering*, Pitman, 1996

A simple, practical and well written book including well-categorized techniques.

Jonne Ceserani and Peter Greatwood, *Innovation and Creativity*, Kogan Page, 1996

An easy guide to creativity and innovation written by Synectics consultants.

Edward DeBono, *Serious Creativity*, HarperCollins, London, 1993

A condensation of many of the ideas of this famous originator of lateral thinking.

Robert B. Dilts with Gino Bonissone, *Skills for the Future*, Meta Publications, Capitola, CA, 1993

NLP and creativity in detail from the man who modelled many geniuses.

Helen Graham, *Visualisation*, Judy Piatkus, London, 1996

Techniques to develop images for creativity.

Michael Michalko, *Thinkertoys*, Ten Speed Press, Berkeley, CA, 1991

A well-written and wide-ranging on creativity for business.

Sidney Parnes (ed), *Sourcebook for Creative Problem Solving*,

Creative Education Foundation Press, Buffalo, NY, 1992

A compilation of some of the best papers on creativity over 50 years, stretching out from Osborn's original 1943 paper on Brainstorming.

David Straker, *Rapid Problem Solving with Post-it Notes*, Fisher Books, 1998 (Gower in UK)

A simple and easy to use guide using Post-it Notes to structure qualitative problems.

David Straker, *A Toolbook for Quality Improvement and Problem Solving*, Prentice Hall, Hemel Hempstead, UK, 1995

A comprehensive book of around

100 tools for problem solving.

Some creativity websites

www.directedcreativity.com

Paul Plsek’s site with a generous range of original tools available.

enchantedmind.com

Many ideas for the dreamer’s end of the creativity spectrum.

www.botree.com

The ‘Hot Rod Your Head’ site of creativity guru Win Wenger.

creatingminds.org/

This is Dave's site containing many tools, articles and quotes on creativity.

Some other useful invention websites:

www.inventored.org/index.html

Inventor’s resources. All sorts of information for inventors.

www.patentcafe.com/

Very professional site offering much information for inventors.

www.inventionconvention.com/nc

The National Congress of Inventor Organisations. Online resources for inventors.

inventors.about.com/education/in

About.com’s excellent set of links for inventors.

www.globalideasbank.org

Many collected ideas about many

areas, in particular around social situations.

www.patents.ibm.com/

IBM’s patent server. Look up US patents here.

www.uspto.gov/ patft/index.html

The US Patents and Trademarks Office. Find patents from the horse’s mouth.

www.patent.gov.uk/

The UK Patents Office.

www.european-patent-office.org/online/index.htm

The European Patent Office’s page containing many links to online patent information.

Quotes about the book

Ellen Domb, editor, The TRIZ Journal and US TRIZ trainer and facilitator:

"TRIZ students will find many parts of "How to Invent (Almost) Anything" very useful. The chapter on TRIZ is succinct, and includes all the basic techniques of TRIZ. I really liked a lot of the approaches, and several I had never seen before and will start using right away. The sections on logical tools and scientific analysis methods are excellent companions to TRIZ, and incorporate the TRIZ concepts of using available resources, while showing the reader how to be technically creative about what is available and what is a resource. "How to Invent" is an exciting addition to the literature of TRIZ in English."

George Prince (Founder of Synectics Inc., a USA and World Creativity and Innovation

Consultancy, for which Graham used to work):

“I found the book both light-hearted and profound. It deals with complex subjects with clarity and converts the complex into understandable fundamentals I can readily use as tools to see a problem in a different light.

TRIZ is a powerful, proven invention tool and this is a wonderfully useable introduction to it.”

Vincent Nolan, former Chairman, Synectics Ltd., author of Open to Change (1981), The Innovators Handbook (1989) and, with Martin Brooks, The Changemakers Toolkit (1996):

"An exciting integration of the art of scientific analysis and the science of creativity."

Jeffrey Hyman, Director, The Innovation Exchange, Rank Hovis

McDougall:

“This is a very important book. It sums up the essence of inventiveness in a way that all others have failed to thus far.”

Paul Birch, Innovation Consultant and former Corporate Jester for British Airways:

“If you really want to invent something, whatever it is, then read this book!”

***Ian Mitchell, Senior Design Engineer, Ilford Ltd*:**

"This is a well written book covering scientific analysis and the psychology and methods associated with the way we solve problems. These subjects are presented in a clear, concise and thought provoking manner. I would not hesitate in recommending it to anyone who has to solve problems on a daily basis."

About the authors

David Straker

David Straker has worked in Research and Development of some sort or another for a large part of his life. With an original degree in Electronic Engineering, and after a dalliance in teaching Mathematics, he swiftly moved into Software Engineering, where he went from big, corporate stuff down to programming one-armed bandits and video games (where he was awarded a couple of patents).

After a Masters degree in Management and Technology, he moved to Hewlett Packard, where his engineering questions of ‘How do things work? How can we make them work better?’ found fertile soil. This led him through software quality to business quality to marketing (pausing for a Diploma here) to business methods research, development and deployment. Today, he manages global programs in Agilent Technologies where he applies inventive principles to solve strategic and tactical problems in new business integration.

For fun, he writes books on improving business (this is his fifth) and for relaxation he practices Tai Chi. In between, he is totally average, being married with two children (one of each), a dog and a mortgage. He has just started work on a fighting robot. Can you imagine a limpet robot?

Graham Rawlinson

Graham's first career as a psychologist led to a wide variety of experiences in education, from working with children with special needs to writing T.V programmes and software for basic numeracy, from lecturing students in Hong Kong to a position as Director of Enterprise at the University of Surrey.

His second career has developed over the last few years as a facilitator of change, for education and business. Developing from his change management role at the

University he worked for a period for Synectics Ltd as an innovation consultant. He has been involved in innovation sessions with leading companies such as Kellogg, Marks and Spencer, Mars and Coca-Cola.

When he found TRIZ he saw it as a tool which enabled him to link creativity with science so for the last 3 years he has been running innovation sessions to invent everything from simple fasteners to wave machines to electronic gadgets!

Dedications

Dave

This book is for Heledd, my daughter.

Understand,
love,
create.

That's all!

Graham

To my two sons, Andy and David – friends for life!