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A CURRICULUM FOR DEVELOPING CREATIVE  
THINKING SKILLS IN ENGINEERING STUDENTS.

by

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A dissertation submitted in partial  
fulfilment of the requirements for  
the degree of Master of Education

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N. Lawrence

#### DECLARATION

I certify that this dissertation contains no material which has been accepted for the award of any other degree or diploma in any institute, college or university, and that to the best of my knowledge and belief, it contains no material previously published or written by another person, except where due reference is made in the text of the dissertation.

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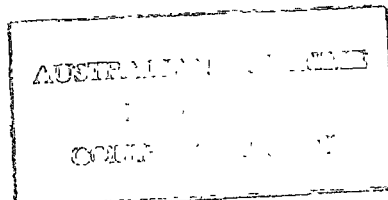
## ABSTRACT

The Institution of Engineers, Australia produced a report in 1993, which contained a set of National Competency Standards designed to act as a benchmark for identifying the overall balance of knowledge, skills, judgement, ethical standards and experience required by Professional Engineers. In that report it was recommended that engineers should undertake professional development in lateral analysis and creative thinking skills.

This dissertation examines the main themes in the creative thinking literature with a particular interest in the information relating to left and right brain thinking skills and how mental blocks can inhibit creative thinking from occurring. Visual thinking skills are examined.

The dissertation outlines the development of a curriculum to introduce first year undergraduate engineering students to a variety of creative thinking skills. A representative set of teaching material is presented for each of the six topics contained in the curriculum. The curriculum has been designed to provide students with a set of learning experiences that will help them to personalise the knowledge.

The curriculum has not yet been presented to students but it has been very favourably commented on by the nine professional colleagues from the field of education who evaluated the curriculum. Recommendations are presented for initially implementing the curriculum with a group of volunteer students. This would be a valuable part in the process of formative evaluation of the curriculum and be a help in improving the fidelity between the written and taught curriculum.



## CHAPTER 1

### INTRODUCTION

#### 1.1 A CHANGING WORLD

Engineers carry out a wide range of functions, encompassing research, design, manufacturing, testing, development, selling and management. Given sufficient resources, there seems to be few limits to what engineers can achieve in a physical sense, for example as a result of the Apollo space program, mankind first walked on the moon in 1969. However, the Arab-Israel war of 1972 and the resulting reduction of oil supplies brought home to the Western World the reality of living on a planet with limited resources. The need to protect our atmosphere from the pollution in the 1980's resulted in legislation being enacted to limit the amount of hydrocarbon and nitrous oxides being emitted in the exhaust gases of cars. A hole in the ozone layer above Australia, identified during the late 1980's, has resulted in a reduction in the use of chlorofluorocarbons.

Environmental issues provide important challenges for engineers to face as we move towards the 21st Century. Lumsdaine (1993, pxiii) says that "Our world needs thinkers who can see how problems and solutions are connected with people and cultural values, with ecology, with global economic concerns, with quality and ethics." The challenge is to see what engineers can do in an everyday sense when resources are strictly limited. This will require a degree of creativity.

Peters (1987, p1) believes that we should not expect our future life to be steady state without change. He recommends that we should embrace change with a new set of basics: world class quality and service, enhanced responsiveness through increased flexibility and

continuous short cycle innovation and improvement aimed at creating new markets for both new and apparently mature products and services. Peters (1987, p22) says that the key to survival in the future lies in enhancing employee flexibility and creativity, diffusing responsibility for innovation and giving workers a stake in productivity through profit-linked bonus. Peters (1987, p244) sees the need to support committed champions of innovative changes wherever possible.

Botkin, Elmandjra and Matilza (1979, p10) argue that there is a great disparity between what is being accomplished towards achieving the potential of human beings for learning and what could be accomplished. They distinguish between maintenance learning, which they claim has sufficed in the past, and innovative learning which they believe is needed for long-term survival. Maintenance learning by their definition is the acquisition of fixed outlooks, methods and rules for dealing with known and recurring situations. It enhances our problem solving ability for problems that are given. It is a type of learning designed to maintain an existing way of life. While maintenance learning has been and will continue to be indispensable, Botkin et al. (1979, p10) say that it will not be enough; innovative learning is required if we are to cope with the problem of anticipating and dealing effectively with turbulence and change.

Each of these contributions outlined above are concerned with among other things, creative responses to stimuli.

## 1.2 ENGINEERING COMPETENCY STANDARDS

The Institution of Engineers, Australia (I.E.Aus) is responsible for accrediting engineering undergraduate courses, to determine their suitability for preparing

professional engineers. I.E.Aus has prepared a set of National Competency Standards (1993) to act as a benchmark for identifying the overall balance of knowledge, skills, judgement, ethical standards and experience required by Professional Engineers. The I.E.Aus recognises the professional responsibilities of academic staff for the determination of course structure and teaching methods and thus they state that the competency standards are to act as guidelines for course development.

I.E.Aus. (1993, p 8) state that engineering is a profession directed towards the application and advancement of skills based upon a body of knowledge in mathematics, science and technology, integrated with business and management, acquired through education and professional formation in an engineering discipline. Professional Engineers undertake and lead varied work that is essentially intellectual in nature and requiring discretion and judgement.

According to I.E.Aus (1993, p9) a graduate engineer should have the ability to work under guidance, creatively and innovatively in Professional Engineering tasks of limited scope and complexity, then developing through experience and increased responsibility to work under general guidance on normal Professional Engineering work, exercising individual judgement and initiative in the application of engineering principles, techniques and methods.

Graduate engineers should:

Exercise creativity and initiative in performing, investigating, analysing and conceptualising tasks to determine possible concepts to meet design criteria.

(I.E.Aus, 1993, p18)

Undertake professional development in lateral analysis and creative thinking skills.

(I.E.Aus, 1993, p20)

### 1.3 CREATIVITY

The Collins dictionary (1990, p196) defines creativity as having the ability to cause something to come into existence or that creativity is being imaginative or inventive. A similar view is held by Herrmann (1990, p186) who believes that creativity in its fullest sense involves both generating an idea and making something happen as a result. To strengthen creative ability, he says that we need to apply the idea in some form that enables both the experience itself, our own reaction and the reaction of others to reinforce our performance. Herrmann (1990, p186) believes that as we and others applaud our creative endeavours, then we are likely to become more creative.

Nolan (1989, p90) notes that creativity has been seen in the past as being a God-given gift bestowed at best on one or two per cent of the population. However he believes that creativity is a natural attribute available to all normal people. Nolan (1989, p90) says that creativity is under-utilised as a result of the conditioning processes of our society, education systems and business organisations. The highly creative minority, he claims, are those who have escaped or resisted successfully the conditioning processes which cause most of us to repress our creativity. According to Nolan (1989, p91), at an unconscious level we all have a self-censor or internal critic that tends to block the flow of creative material even before it reaches the conscious mind. He says that when we cease to concentrate on a problem and do something completely different, the self-censor relaxes its control on a problem and the sub-conscious mind starts to work. This is when a new idea can sneak past the self-censor and also why people develop the strategy of sleeping on a problem or going for a walk. Nolan (1989, p91-96) believes this is an ineffective way of being creative and

suggests the following five step strategy for organisations to manage their creative resources.

1. Make a conscious shift in attitude to creativity, to view creativity as a resource to be managed rather than a random, accidental phenomenon.
2. Adopt a different attitude towards people, to stop thinking in terms of creative and non-creative people and see everybody as a potential creative resource.
3. Try to make everyone in an organisation realise they can be creative.
4. Direct the creativity at the needs of the organisation, especially the major strategic needs of the organisation.
5. Create and maintain a culture in the organisation which fosters and values creativity equally with other skills such as technical competence, quality assurance, financial wisdom and analytical ability.

#### 1.4 AIM

The aim of this dissertation is to develop an introductory unit on creative thinking for first year engineering students studying on a Bachelor of Engineering course. It is anticipated that such a curriculum should encourage students to develop whole brain thinking skills and prepare them to be more innovative in their future engineering careers. The development of such a course may also encourage other staff to become more creative in their teaching approach and more attentive to different student learning styles and the need for a creative classroom environment.

## 1.5 PREVIEW OF THE DISSERTATION

In addition to the introductory chapter, this dissertation has five other chapters. A brief overview of each is given below.

### Chapter 2 - Literature review

This chapter reviews the literature relating to three main areas:

- 1) the human mind, memory and thinking;
- 2) the nature of conceptual blocks to creative thinking and how they can occur;
- 3) approaches to creative thinking, including Six Thinking Hats, Lateral Thinking and Visual Thinking.

### Chapter 3 - Curriculum Development

This chapter outlines the thinking behind the development of the curriculum from the perspectives of objectives, content, learning experiences and evaluation.

### Chapter 4 - The Curriculum

The curriculum developed is presented in this chapter. Sample teaching material is included to illustrate how the curriculum is to be presented.

### Chapter 5 - Conclusions

This chapter summarises the main points of the discussion and relates the curriculum to the Aim expressed in Chapter 1.



## CHAPTER 2

### LITERATURE SURVEY

#### 2.1 PURPOSE AND SCOPE OF THE REVIEW

The purpose of this chapter is to bring together the varying knowledge and theories regarding the human brain, the way it stores information, how we think and the methods that will help to foster creativity in our thinking. This chapter seeks to select the main themes on creative thinking from existing literature and to distil the essence in a form that is relevant to both engineering undergraduate students and engineers in their professional careers.

#### 2.2 THE HUMAN BRAIN

The human brain weighs about 1.3 kilograms and is about the size of a small grapefruit. Herrmann (1990, p31) notes that the human brain in cross section has the appearance of three brains superimposed one on top of the other, as shown in Figure 1. This has led to the triune brain theory,

... the first is the inner, or primitive reptilian brain, so called because it strongly resembles the brain found in prehistoric reptiles, as well as in alligators and lizards today. This brain, comprising the brain stem, the mid brain, the basal ganglia, and the reticular activating system, is a slave to precedent. Driven by instinct it seems to contain the ancestral lore of the species. The second and next oldest brain is the limbic, or mammalian brain, which encircles the more primitive brain and which consists of the limbic system. It is thought to have developed between 200 and 300 million years ago. We share this brain with lower mammals such as rats, rabbits and horses. The limbic brain registers rewards and punishments, it is the seat of emotion, and controls the body's autonomic nervous system. Finally, over the limbic brain lies the neocortex, or 'thinking cap,' the convoluted mass of gray matter that evolved with

such rapidity in just the last million years to produce *Homo sapiens*. We share the neocortex with higher mammals such as chimpanzees, dolphins and whales. What distinguishes the brains of *Homo sapiens* from those of these other animals is that the neocortex of man is so large in relation to both the brain and the body. It is the neocortex that seems to enable us to think, perceive, speak, and act as civilized beings.

(Herrmann, 1990, p31)

The neocortex, which is a pinkish gray tissue, is divided into two cerebral hemispheres, or left and right brains, much like a walnut. Together they have a surface area of about 0.25 square metres. It is about 3mm thick and has about 10,000 million nerve cells or neurons. About 3000 neurons are contained in 1 cubic centimetre and each neuron looks like a tiny starfish or octopus, with synapses - places where nerve cells join - lining the feelers. Each cell is capable of linking up with about 10,000 of its neighbours.

The left and right hemispheres of the brain function independently of each other (Gallant, 1980, p42), but they are physically linked to each other by the corpus callosum which contains about 200 million fibres, as shown in Figure 1. When one part of the brain is actively thinking, the other part is in idle mode in order, apparently not to interfere with the specialized thinking task. However when solving a complex problem or doing an intricate task, more than a single specialised thinking skill is involved. The brain has the ability to switch signals back and forth very rapidly between specialized areas within and across the hemispheres through the fibre network. Gallant (1980, p44) notes that for some patients with advanced cases of epilepsy, researchers, under the leadership of Roger Sperry at the California Institute of Technology, cut the corpus callosum in an effort to protect at least one side of the brain from seizures. These 'split brain' patients had fewer seizures and the seizures were much milder than before.

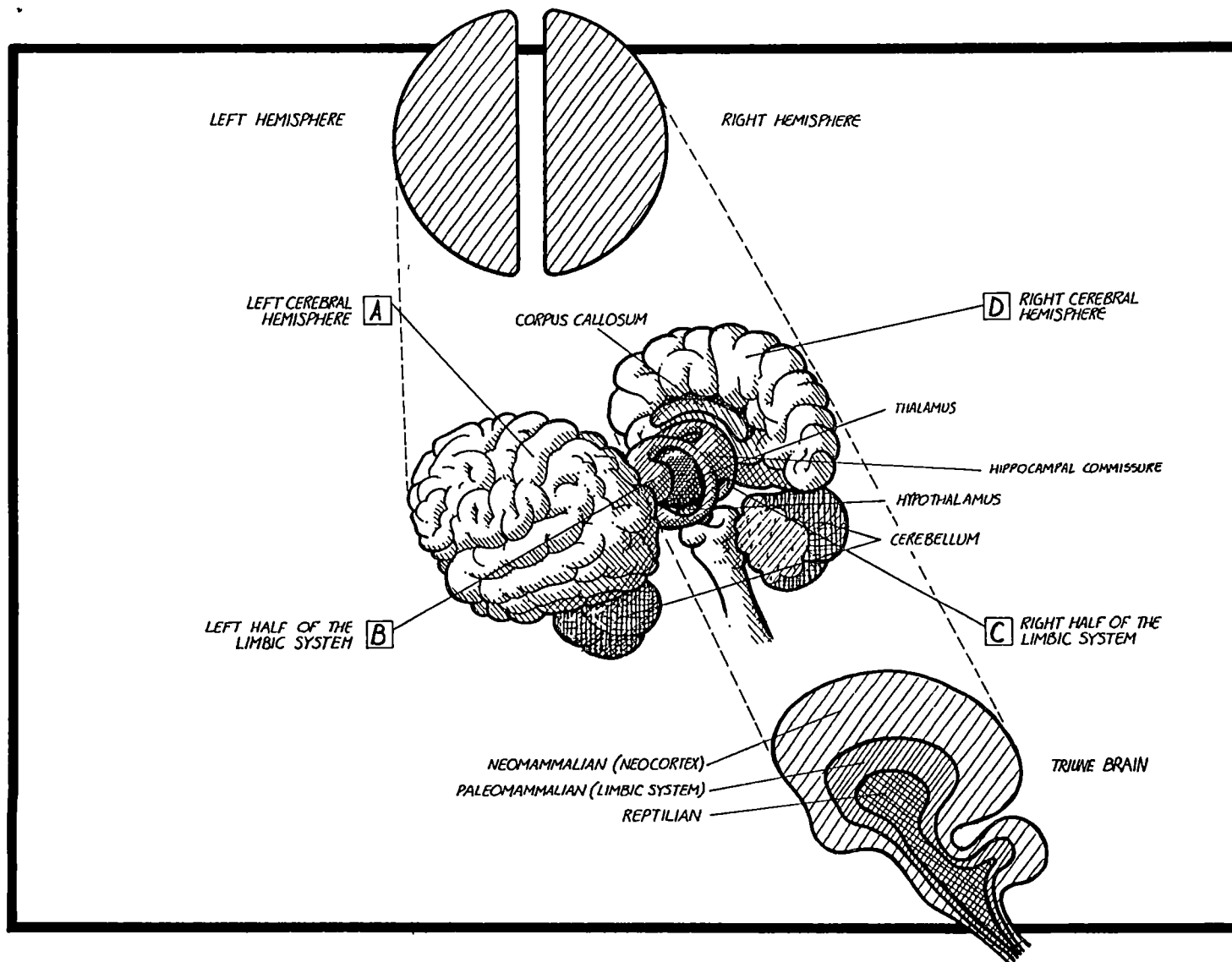


Figure 1. The Right Hemisphere and Left Hemisphere Theory Combined with the Triune Brain Theory (Herrmann 1990, p40).

According to Edwards (1979, p26) the human nervous system is connected to the brain in a crossed-over fashion. The left hemisphere controls the right side of the body and the right hemisphere controls the left side of the body. She says that the function of language and language related capabilities is mainly located in the left hemispheres of the majority of individuals, approximately 98% of the right handed people and 67% of left handed people. Edwards (1979, p30) describes a test that was performed using split brain patients to illustrate the separate reality perceived by each hemisphere and the special modes of processing employed.

Two different pictures were flashed for an instant on a screen, with a split brain patient's eyes fixed on a mid point so that scanning both images was prevented. Each hemisphere then received different pictures. A picture of a spoon on the left side of the screen went to the right brain; a picture of a knife on the right side of the screen went to the verbal left brain. When questioned, the patient gave different responses. If asked to name what has been flashed on the screen, the confidently articulate left hemisphere caused the patient to say, 'knife.' Then the patient was asked to reach behind a curtain with his left hand (right hemisphere) and pick out what had been flashed on the screen. The patient then picked out a spoon from a group of objects that included a spoon and a knife. If the experimenter asked the patient to identify what he held in his hand behind the curtain, the patient might look confused for a moment and then say, 'a knife.' The right hemisphere, knowing that the answer was wrong but not having the words to correct the articulate left hemisphere, continued the dialogue by causing the patient to mutely shake his head. At that, the verbal left hemisphere wondered aloud. 'Why am I shaking my head?'

(Edwards, 1979, p30-31)

A comparison is made in Table 1 between left mode and right mode thinking. Edwards (1979, p46) notes that drawing a perceived form is largely a function for the right hemisphere of the brain. She suggests that it is preferable for the left hemisphere of the brain to be mainly switched off while drawing. One way suggested by

TABLE 1  
COMPARISON BETWEEN LEFT AND RIGHT BRAIN THINKING MODES  
(Edwards, 1979, p40)

LEFT MODE	RIGHT MODE
Verbal: Using words to name, describe, define.	Nonverbal: Awareness of things, but minimal connection with words.
Analytic: Figuring things out step-by-step and part-by-part	Synthetic: Putting things together to form wholes.
Symbolic: Using a symbol to stand for something, eg + stands for the process of addition.	Concrete: Relating to things as they are, at the present moment.
Abstract: Taking out a small bit of information and using it to represent the whole thing.	Analogic: Seeing likeness between things; understanding metaphoric relationships.
Temporal: Keeping track of time, sequencing one thing after another.	Nontemporal: Without a sense of time.
Rational: Drawing conclusions based on reason and facts.	Nonrational: Not requiring a basis of reason or fact
Digital: Using numbers as in counting.	Spatial: Seeing where things are in relation to other things.
Logical: Drawing conclusions based on logic.	Intuitive: Making leaps of insight, often based on incomplete patterns.
Linear: Thinking in terms of linked ideas, leading to a convergent conclusion.	Holistic: Perceiving the overall pattern, leading to divergent conclusion.

Edwards (1979, p50) to experience the effect of switching off the left hand side of the brain and drawing with the right hand side of the brain is to copy a sketch that is upside down. This exercise requires a lot of concentration because the upside down sketch looks so unfamiliar. Surprisingly the finished result is likely to be distinctly better than if the sketch had been the right way up. Edwards (1979, p55-59) attributes this surprising result to the left brain finding difficulty in recognizing patterns, switching off and letting the right brain take over. She recommends this as a method to be used for anyone wanting to experience a shift from left brain mode into right brain mode.

Herrmann's (1990, p63) work into thinking preferences led him to conclude that his data fell into four clusters, rather than two cerebral hemispherical divisions. Realising that the limbic system was also divided into two parts giving essentially a brain divided into four quadrants, enabled Herrmann to organise his data into a four, quadrant whole brain model as a descriptive metaphor. In Herrmann's metaphorical model, the brain is visualised as divided into four quadrants, with upper left quadrant designated A, followed in a counter-clockwise direction by B,C and D. This is illustrated in Figure 2.

### 2.3 MEMORY

According to Gallant (1980, p20) we have three memory stages: (1) a sensory-information store; (2) a short term memory; and (3) a long-term memory. Memory stage no 1 works chiefly when our sense organs, eyes, ears, skin, tongue and nose, are stimulated. The information in our sensory information store can be transferred to short term memory by repetition or rehearsal. For example when we read a number from a telephone directory, we might place a finger under the number and dial that number, or

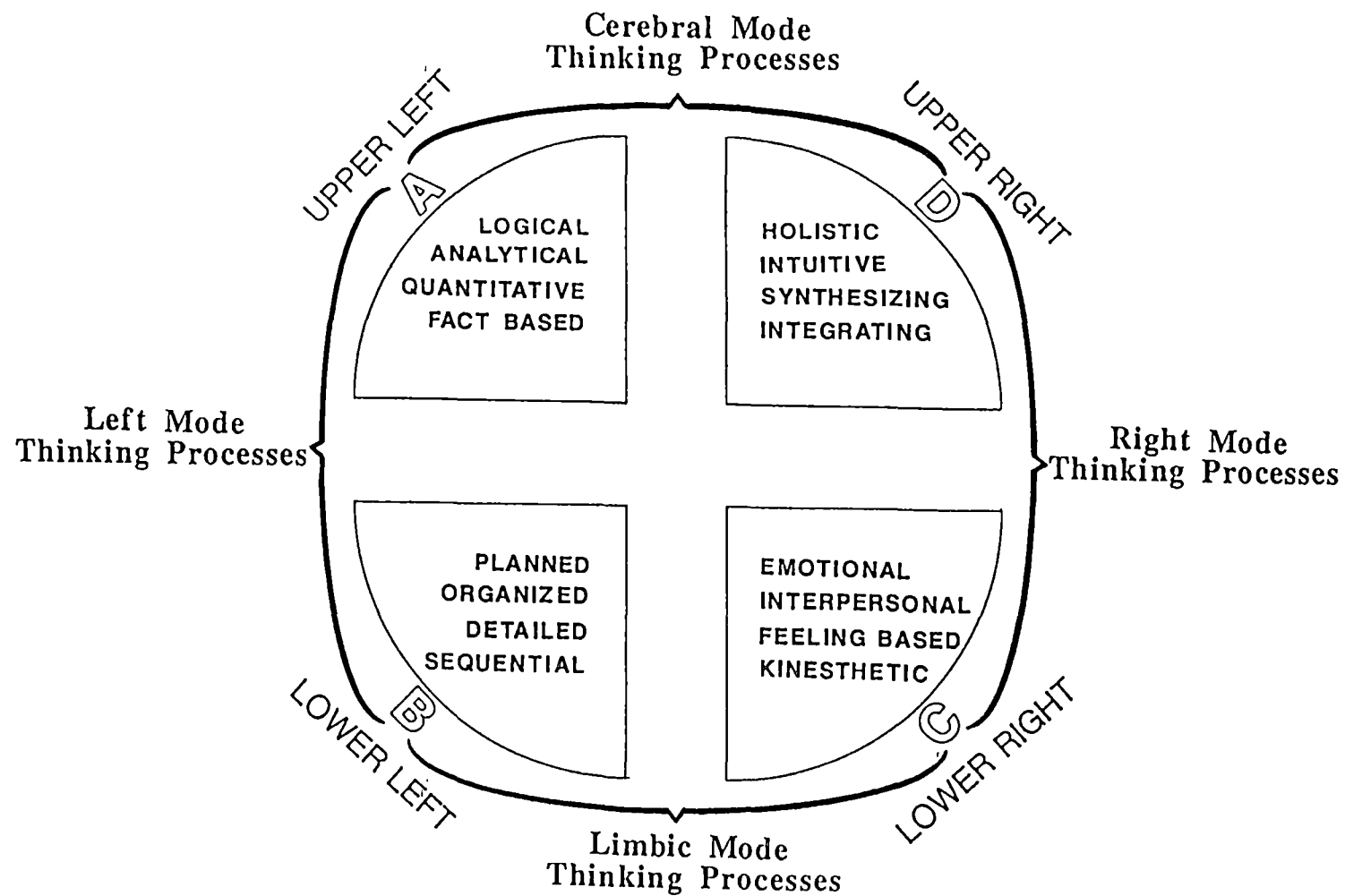


Figure 2. Herrmann's Whole Brain Model. (Herrmann 1990, Appendix E)

we might commit the number to our short term memory by repeating it a few times before dialling. Short term memory enables us to retain a question someone has just asked us long enough for us to answer. However our short term memory seems to be limited in the amount of information it can contain. Selected information can pass from our temporary file or short term memory into our permanent file or long term memory. Gallant (1980, p24) suggests that rehearsal is also important for transferring information from short term memory into our long term memory. He says that concentration on what is being rehearsed is extremely important in being able to commit to memory or learn something new. He recommends mentally warming up by reading a newspaper article or short story before settling down to the learning task requiring deep concentration.

Apparently our brains go through both physical and chemical changes when we store new information as a result of learning. Gallant (1980, p33) says that active learning sessions cause the brain to produce increased amounts of RNA, (ribonucleic acid) which in turn causes an increased amount of protein production. According to Gallant incoming sensory signals cause chains of neurons to start transmitting. Each nerve cell making up the network passes on its vibrations to neighbouring neurons in the network circuit. Gallant (1980, p34) believes that it is the vibrating activity that temporarily stores the incoming information in the short term memory. He notes that for long term memory the neurons grow larger, and there is an increase in the number of dendrites projecting from the cell bodies. This increases the opportunity for the dendrites from one neuron to come in contact with those of neighbouring neurons. This means that the pathways of the brain are enlarged, increasing the ability of nerve cells to transmit information to one another through synapses, which are the connection site between cells. Gallant (1980, p34) says that these



connected nerve cells then serve as memory molecules for storing information.

Gallant (1980, p36) states that our ability to do repetitive tasks well is encoded in a unit of memory called an engram. DeBono (1978, 84-112) uses the term "pattern" and perhaps others would simply use the word "habit" to convey the same meaning as engram. Gallant (1980, p38) makes the point that acquiring these engrams (i.e., learning to do a task or skill) comes as the result of much mental or physical effort. Learning he says is like an exercising of the brain. As muscles improve with exercise so the brain also seems to improve with use. Learning, Gallant (1980, p38) observes, does not increase the number of brain cells but it does, however, increase their size and ability to form ever more complex and efficient networks.

## 2.4 THINKING

De Bono (1978, p33) defines thinking as 'the deliberate exploration of experience for a purpose.' That purpose may be understanding, decision making, planning, problem-solving, judgement or action. The words intelligence and thinking are often used synonymously but De Bono identifies clear distinctions between each of these terms. He identifies intelligence as being something that is generally considered to be related to genes and early environment, whereas he considers thinking to be a skill that can be acquired and developed through use. Articulateness and fluency in talking are often mistaken as thinking according to De Bono (1978, p35). The ability to generate thoughts and to link them together in a coherent way obviously involves a degree of thinking skill, but in itself is seen by De Bono as being no more than a skill in linking together in a grammatical fashion a number of ideas. Skill in expression is no more than 'skill in expression' and De Bono (1978, p36) says it

would be wrong to assume that a skilled language user is a skilled thinker. De Bono (1978, p33) defines thinking as an operating skill through which intelligence acts upon experience.

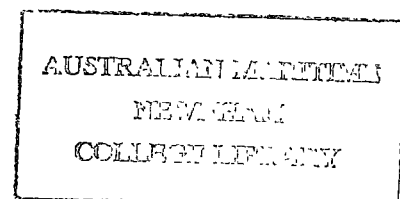
De Bono (1978, p46) uses an analogy of a car and how it is driven to distinguish between intelligence and thinking. The power of a car, the effectiveness of its brakes, its road holding ability and so on are all part of the innate qualities of that car. The skill with which that car is driven is something apart. A powerful car may be driven with little skill and a humble car may be driven with great skill. Innate intelligence or IQ can be compared to the intrinsic qualities of the car. The skill with which these qualities are used might be thought of as the skill of thinking. Thinking is the operating skill through which innate intelligence is put into action. A high intelligence may be linked to a high degree of thinking skill, but this is not necessarily generally true.

In the normal course of events we develop skills in walking, talking and so forth as we deal with the world around us. Thinking skills are also generally developed in this way but is this the best method for developing such skills? In reply to this question, De Bono (1978, p47) quotes the example of people who teach themselves to type using two fingers. They do not set out to learn typing, they only want to use typing in their work. With two fingers they can more quickly acquire a tolerable level of competence than if they tried to develop skill with all ten fingers. So they learn a two finger skill to cope with their immediate needs. Yet a person who trains to be a typist can, within weeks, develop a much higher degree of touch typing skill. The typist has acquired the full skill by paying direct attention to learning the skill. De Bono (1978, p47) points out the disadvantage of skills acquired for particular situations

can be that they are not much use in coping with other situations.

Prejudice he says is an effective thinking skill in coping with certain situations because it gives instant judgements, decisions, and quick reactions. It is only in the wider context that prejudice is seen as a failure of thinking skills. In the same way that two finger typing is a skill and yet in the wider context it can be a block to developing further skills because one has sufficient proficiency to "get by". De Bono (1978, p48) maintains that we cannot rely on skills developed in the natural course of events unless the natural course of events has been especially rich in a variety of broad and narrow situations. In the ordinary course of events De Bono cites that children tend to use their personality as much as their minds when arguing. They tend to insist on their own point of view and to shout down other points of view. In a sense he says this is a two finger skill which they have developed in the natural course of events. After a deliberate attempt to teach thinking skills to children, De Bono (1978, p48) noted the following changes.

- . More listening to other people and less talking across people.
- . Less egocentricity.
- . Thinking used as exploration instead of just to support or defend a particular point of view.
- . Less abuse and shouting down and more tolerance of other views.
- . Use of thinking modes other than the purely critical.
- . Knowing what to do instead of just waiting for an idea to arrive.
- . Less wandering off into irrelevancy.
- . More willingness to think about new subjects instead of dismissing them as ridiculous or irrelevant.



De Bono (1978, p49) pointed out that we tend to feel that skills ought to be natural, because we feel that a skill is something about which we don't have to think consciously. He identifies riding a bicycle, swimming, and skiing as all being skills that need to be learnt before they become natural skills. He suggests that the unnatural phase in learning a skill creates a huge problem in the teaching of thinking as a skill. According to De Bono (1978, p49) we know that thinking ought to be natural and we often claim that the natural 'two finger' thinking skill is sufficient. We are therefore reluctant to go through an unnatural and artificial stage and yet this stage may be necessary in order to create new habits and new ways of directing attention.

De Bono (1978, p51) believes that being skilled in thinking is a broad skill rather like being skilled in woodwork; knowing what to do, when to do it, how to do it, what tools to use, the consequences and what to take into consideration. It is more than knowing the rules of logic or learning how to avoid logical error. Skill in thinking has much to do with perception and with attention directing. It is a matter of exploring experience and applying knowledge. It involves planning, decision making, looking at evidence, guessing, creativity and very many other aspects of thinking.

#### 2.5.1 CONCEPTUAL BLOCKS

Adams (1987, p 10,11) defines conceptual blocks as

... mental walls that block the problem solver from correctly perceiving a problem or conceiving its solution.

Everyone has conceptual blocks according to Adams who identifies the four most important ones as perceptual blocks, emotional blocks, cultural and environmental blocks, and intellectual and expressive blocks.

#### 2.5.1.1 Perceptual Blocks

Stereotyping or seeing what we expect to see is an extremely prevalent and effective perceptual block because it is difficult to see clearly if we are controlled by preconceptions. Members of ethnic minorities, women, the elderly, the handicapped and others have successfully demonstrated that social stereotypes can be wrong. For example, twenty years ago television newscasters tended to be male, and generally in printed material the male gender was used to cover both males and females. This is not the case today where we see women in many roles that were once considered the exclusive domain of men. Furthermore today there is a great desire to see people with handicaps of all types being more fully incorporated into the society and the workforce. Indeed the "alternative olympics" provides a very powerful antidote to the idea that people with physical handicaps cannot lead an active life.

Perceptual stereotyping can sometimes be useful because it does allow people to complete incomplete data but it can be a handicap to perceiving new combinations of data. It is also important to be able to isolate the problem since the problem owners may not be able to clearly perceive their problems. Adams (1987, p21) quotes the engineering example where a lot of effort went into the mechanical design of tomato pickers before someone decided that the real problem was the susceptibility of tomatoes to damage during picking. The solution to the problem was a new plant, with a tougher skinned, more accessible fruit.

Adams (1987, p24) notes that sometimes there can be an unconscious tendency to place mental constraints on a problem. An example given by Adams (1987, p24) concerns

drawing, without lifting the pen off the paper, a given number of lines through nine dots which are arranged in the form of a square as shown in Figure 3. It is quite possible to draw only one line through all nine dots but this puzzle is impossible to solve if the imaginary boundary (limit) enclosing the nine dots is not exceeded. Adams (1987, p25) has found that a surprising number of people will not exceed the imaginary boundary, for often this constraint is unconsciously in the mind of the problem solver, even though it is not in the definition of the problem at all. The overly strict limits are a block in the mind of the solver. One possible solution using four lines is shown in Figure 4.

Adams (1987, p31) notes that once we realize the existence of the limits we place around our own functioning, then we will no longer be hampered by them because limits are negotiable. For example, a request for a better design of door would probably result in a rectangular slab with hinges and a handle. On the other hand, a request for a better way to get through a wall releases one from the preconception of the rectangular slab that swings or slides and could produce curtains, mechanical shutters, rotating and folding mechanisms and so on. Similarly, restating the problem in terms of finding a better method of acoustical, visual or environmental isolation may result in a solution like a laminar air curtain which is used to keep heat in stores or out of freezers while permitting free passage.

Adams (1987, p33) also places importance in being able to see the problem from various viewpoints because most problems affect people other than the solver. He illustrates his point with the example of a property owner building a fence. He should consider the viewpoints of not only neighbours, the city council, visitors, garbage collection and passing motorists who can no longer see around the corner but also the needs of

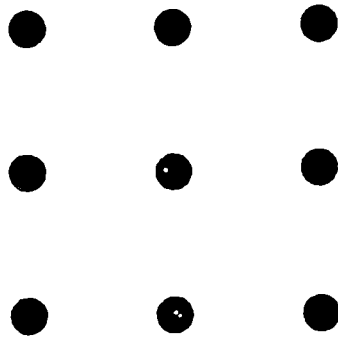


Figure 3. Draw no more than four straight lines (without lifting the pencil from the paper) which will pass through all nine dots.

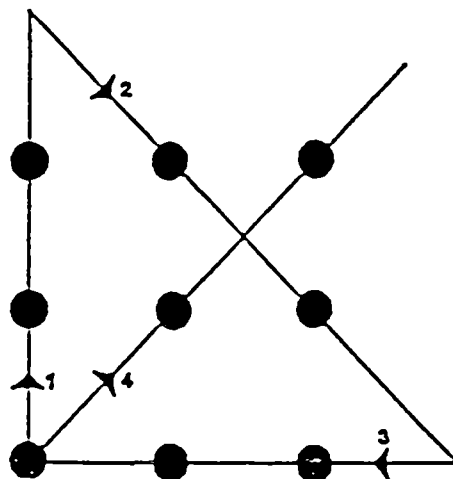


Figure 4. Four lines through the nine dots.

non-human participants such as the flowers and shrubs, which might die in the shade of the fence.

#### 2.5.1.2 Emotional Blocks

Emotional blocks may interfere with the freedom with which we explore and manipulate ideas, with our ability to conceptualize fluently and flexibly. Adams (1987, p42) believes that mankind creates for reasons of inner drive, whether it be for purposes of conflict resolution, self fulfilment, or even money. He believes that at least part of that creativity occurs in a part of the mind which is below the conscious level and that creativity flows best in the absence of neuroses. He says that the conscious mind can act as a control valve on creativity. Adams (1987, 42,43) lists the following six emotional blocks that can prevent us from thinking creatively.

1. Fear to make a mistake, to fail, to risk.
2. Inability to tolerate ambiguity; overriding desires for security, order; no appetite for chaos.
3. Preference for judging ideas, rather than generating them.
4. Inability to relax, incubate, and "sleep on it."
5. Lack of challenge (problem fails to engage interest) versus zeal (overmotivation to succeed quickly).
6. Inability to distinguish reality from fantasy.

Fear of taking a risk is a common emotional block since most people have grown up rewarded when they get the right answer and punished when they make a mistake. Adams (1987, p43) suggests that a good way of overcoming such a block is to realistically assess the possible negative consequences of such an idea. What are the catastrophic expectations? Adams (1987, p45) suggests that whenever someone is having difficulty in deciding to



push a creative idea, they should write a short (two page) catastrophic expectations report. In it they should detail as well as they can everything that would happen to them if everything went wrong. By making such information explicit and facing up to it, Adams says that the person will swap their analytical capability for their fear of failure.

Adams (1978, p45) also suggests that another emotional block to creativity can be a desire for stability and security. He believes that an ability to cope with ambiguity, misleading and ill fitting data, hazy and difficult to test concepts, opinions, values is also important. He also notes (1978, p46) that it is safer and easier to sit in judgement of ideas than it is to generate them. In creative problem solving however it is better to defer judgement until ideas have had time to mature, to develop and perhaps even lead to other ideas. It is possible that people who habitually judge ideas will often find that the habit will eventually exclude ideas from their own minds before they have had time to bear fruit.

#### 2.5.1.3 Cultural and Environmental Blocks

Cultural blocks are acquired by exposure to a given set of cultural patterns. Some examples of cultural blocks (in our western culture) quoted by Adams (1987, p53) are:

1. Taboos (see the example by Adams on the next page)
2. Fantasy and reflection (ie day dreaming) are a waste of time, or characterize lazy people,
3. Playfulness is for children only,
4. Problem-solving is a serious business and humour is out of place,
5. Reason, logic, numbers, utility, practicality are good; feelings, intuition, qualitative judgements, pleasure are bad,

6. Tradition is preferable to change,
7. Any problem can be solved by scientific thinking and lots of money.

Some examples of environmental blocks given by Adams(1987, p 53,54) are:

1. Lack of cooperation and trust among colleagues,
2. Autocratic boss who values only his own ideas; does not reward others,
3. Distractions, phone calls, easy intrusions,
4. Lack of support to bring ideas into action.

Adams (1987, p54) illustrates how taboos can limit solutions through the following example. Assume that a steel pipe is embedded in the concrete floor of a bare room with 100mm of the pipe protruding above the floor. The inside diameter of the pipe is 1.5mm larger than the diameter of a pingpong ball (35mm) that is resting gently at the bottom of the pipe. You are one of a group of six people in the room, along with the following objects:

- 30 meters of clothesline
- A carpenter's hammer
- A chisel
- A box of Wheaties
- A file
- A wire coat hanger
- A monkey wrench
- A light bulb

You are asked to list the possible ways that you can think of (in five minutes) to get the ball out of the tube, without damaging the ball, tube, or floor. Fluent thinkers will come up with lots of ideas, flexible thinkers will generate a wide variety of ideas. However it is unlikely that the group would have came up with the idea of urinating in the pipe. Adams (1987, p55) suggests that the reason for not thinking of this

solution is a cultural block, a taboo, because urinating is a closet activity in our society.

#### 2.5.1.4 Intellectual and Expressive Blocks

Intellectual blocks result in an inefficient choice of mental strategy for solving a problem, whereas expressive blocks can inhibit our vital ability to communicate ideas, not only to others, but also to ourself. Adams (1987, p71) gives the following blocks:

1. Solving the problem using an incorrect language (verbal, mathematical, visual) as in trying to solve a problem mathematically when it can be more easily accomplished visually.
2. Inflexible or inadequate use of intellectual problem solving strategies.
3. Lack of, or incorrect, information.
4. Inadequate language skill to express and record ideas (verbally, musically, visually, etc.).

One way suggested by Adams (1987, p80), of demonstrating expressive blocks for communicating ideas is to place a machine part or some other irregular three dimensioned shape that is unfamiliar to most people in a bag. Then to have someone place their hand in the bag, without looking at the object. The person is required to describe the object to some other people who are required to draw it. Adams (1987, p80) reports that the exercise is surprisingly difficult, especially if those drawing are not allowed to ask questions. He also notes that the presence of an audience also adds some interesting emotional blocks to the person with their hand in the bag. Adams (1987, p81) believes that this exercise demonstrates both the use of inadequate language skill to express an idea and the imprecision in our verbal expression. He notes that most engineering students and

engineers are not fond of drawing, this he attributes to drafting having a lower status than analysis.

#### 2.6.1 Blockbusters

The process of consciously identifying conceptual blocks to creative thinking takes one quite a distance towards overpowering them. In comparing Japanese and Western World style of conducting business meetings, De Bono (1990a, p44) notes that, at a typical Western style meeting, the participants tend to sit with their points of view and in many cases the conclusions they wish to see agreed upon. He says that the meeting then consists of arguing through these different points of view to see which one survives the criticism and which one attracts the most adherents. On the other hand De Bono says (1990a, p45) that in a typical Japanese style meeting, the participants sit down at a meeting without any preformed ideas in their heads. The purpose of the meeting is to listen and share information. According to De Bono (1990a, p46) the Japanese notion is that ideas emerge as seedlings and are then nurtured and allowed to grow into shape. In such a style of meeting, people's ideas are separated from their ego and this removes a prime source of the gladiatorial conflict often associated with Western style meetings.

De Bono (1978, p85,103) describes how we develop patterns (or habits, or engrams) of thought, through repetition, until we become unconsciously skilled in any given task or situation. An obvious example being that of learning to drive of a car. Initially it appears to be a complex sequence of procedures and yet once the task is mastered it becomes so automatic that there is little need for any conscious thinking. De Bono (1978, p90) notes that this can also apply to our automatic responses when we

are trying to be creative in our thinking. We can easily move along a main thought path from point A to B in our thinking without stopping to consider the possibility of diverting along a side road leading to C. De Bono (1978, p100) believes that we need specialized thinking techniques to prevent this "glide past" of alternative thought paths due to being constrained by dominant thought patterns. Some of the major techniques for breaking mental thinking blocks and fostering creative thinking will now be examined in sections 2.6 and 2.7.

#### 2.6.2 Six Thinking Hats

Talk about the wearing of hats for a specific purpose often occurs as part of our general conversation. Consider for example when we talk about putting on our thinking cap (or hat), or giving someone the dunce's hat when he or she makes a mistake, or the wearing of two hats at a meeting, say for example a teacher's hat and a trade union leader's hat. De Bono (1990a, p20) notes that people do not mind playing the fool so long as it is quite clear that they are just playing a role. They can even take pride in putting on a good performance and become a very foolish fool. That now becomes a measure of achievement and the ego can be the stage director. De Bono (1990a, p21) says that habitually negative people will often claim to be playing the role of devil's advocate when they want to be negative. This is meant to imply that they are not normally negative but are trying to be useful by playing a role well. De Bono (1990a, p22) combined the idea of playing character roles and wearing hats for specific tasks and, as a result, developed the six thinking hats approach. The main restriction on thinking is ego defence and De Bono (1990a, p29) claims that the value of the six thinking hats approach described below, is that it allows us to

think and say things that we could not otherwise think and say without risking our egos.

White hat: Often facts and figures are embedded in an argument. The facts are used for some purpose rather than being presented as facts and so they cannot be treated objectively when put forward as part of an argument. White hat thinking (De Bono 1990a, p31) is neutral and objective. Wearing the white hat means that at that point in time, the meeting is concerned with objective facts and figures. It provides the switch which says "Let us have the facts without any attached arguments, interpretations or bias". White hat thinking is a discipline in which the thinker strives to be more neutral and more objective in the presentation of information. In a meeting situation the leader or an individual could, for example, direct everyone to put on their white thinking hats and to consider why sales have been so low over the past year. Answers like "Because the salesmen are lazy" would not be an acceptable white hat reply. On the other hand a reply like "The market share of Australian manufacturers has fallen by 20 percent" would be an appropriate white hat answer.

Red hat: Red hat thinking is all about emotions and feelings and the non-rational aspects of thinking. The red hat provides a formal and defined channel for bringing these things out into the open as a legitimate part of the overall picture. De Bono (1990a, p56) says that if emotions and feelings are not permitted as inputs in the thinking process, they will lurk in the background and affect all the thinking in a hidden way. Emotions, feelings, hunches and intuitions are strong and real and red hat thinking acknowledges this. Thus whenever a person or a group of people are in red hat thinking mode it is permissible to say, "Don't ask me why. I just don't like this deal. It stinks." or "I have a hunch that this bit of land behind the church is going to be worth a

great deal in a few years time". De Bono (1990a, p61) says that red hat thinking encourages the search: "Just what are the emotions involved here?"

Black hat: This is the logical negative way of looking at things to express what is wrong with something. De Bono (1990a, p80) says that most thinkers will feel comfortable wearing a black thinking hat because of the Western World emphasis on argument and criticism. According to De Bono (1990a, p80,81) black hat thinking is always logical and negative but it is not emotional. Emotional negative (and positive) is the role of red hat thinking. With red hat thinking it is not necessary to give a reason for a negative feeling. However with black hat thinking, logical and relevant reasons must always be given. De Bono (1990a, p81) says that one of the great values of the six thinking hats idiom is to separate in this definite manner the emotional-negative from the logical-negative. Black hat reasons must stand on their own and be usable by anyone. They must be reasonable in print and not only when put forward in a persuasive manner by a strong character. Interestingly enough De Bono (1990a, p81) states that black hat thinking must be logical and truthful, but it does not have to be fair. The other side of the coin, the logical-positive side is presented under a different hat.

De Bono(1990a, p99) notes that constructing a railway is a complex feat of engineering and yet a simple concrete slab placed across the line can derail an express train. Placing that concrete slab is not a particularly skilled operation. Thus it is argued that destruction is always easier than construction and so it is with negativity in comparison to positive constructive thinking. According to De Bono, negative thinking is attractive because its achievement is immediate and complete. He says (1990a, p99) that proving someone wrong provides immediate satisfaction whereas offering a constructive idea does

not provide any achievement until someone likes the idea or you can show that it works.

Yellow hat: In attitude, the yellow hat is the exact opposite of the black hat. It is for positive thinking, for optimism, for constructive thinking and making things happen. De Bono (1990a, p110) states that we can choose to look at things in a positive way, we can choose to focus on those aspects of a situation that are positive and we can search for benefits. He sees positive thinking as a mixture of curiosity, pleasure, greed and the desire to make things happen. De Bono (1990a, p125) says that yellow hat thinking is more than just judgement and proposals, it is an attitude that moves ahead of a situation with positive hope. Yellow hat thinking sets out to glimpse possible benefits and values. As soon as there is a glimpse of these, exploration takes place in that direction. De Bono (1990a, p126) advocates that speculative thinking should always start off with the best possible scenario so that one can assess the maximum benefit from the idea. Thus if benefits are poor with the best possible scenario, then the idea is not worth pursuing. Yellow hat thinking is not directly concerned with creativity. The creative aspect of thinking is specifically covered by another hat. Yellow hat thinking is concerned with looking on the logical positive side and would state "That bottle is half full of whisky" rather than the black hat version, or indeed red hat version depending on intonation, which is "That bottle is half empty"

Green hat: The green thinking hat is specifically concerned with new ideas and new ways of looking at things. Green hat thinking is concerned with escaping from the old ideas in order to find better ones. Green hat thinking is concerned with change, it is a deliberate and focused effort in this direction. "Let us have some new ideas on this. Put on your green thinking hats."



The urge to do things in a better way should always be the background for green hat thinking according to De Bono (1990a, p136). The green hat allows us to switch into the creative role just as the red hat allows us to switch into the "feelings" role and the black hat into the negative role. De Bono believes that often there is more need for green hat thinking than for any other hat.

De Bono (1990a, p143) states that for most of our thinking, judgement of both yellow and black hat types is vital but for green hat thinking he says that we must replace judgement with movement. Movement is an active idiom, ideas are used for their movement value. The objective is to consider ideas for their forward effect, just like stepping stones are used to cross a river so provocations are used as stepping stones to move from one pattern to another. For De Bono (1990a, p144) provocation is necessary to cause movement from past patterns into new thought patterns. Thus we should look at ideas for their movement values, and not its judgement value. "Suppose we made hamburgers square. What movement could we get out of that idea?"

De Bono (1990a, p149) coined the word Po, representing the term Provocative Operation, as a symbolic indicator to indicate an idea that was being put forward as a provocation and for its movement value. It also represents a sort of green hat approach to thinking and can be used in similar situations. For example Po cars should have square wheels or Po a polluting factory should be downstream of itself. According to DeBono (1990a, p150) this last provocation lead to the idea of legislating that any factory built alongside a river must have its water input downstream of its own output. In this way the factory would be the first to sample its own pollution. De Bono (1990a, p154) cautions of the danger learnt in mathematics of only one right answer to a question and encourages us to first of all come up with

the obvious answers to a problem and then to wear a green hat to seek alternative choices.

Blue hat: Wearing the blue hat represents being in control of the other hats, rather like a conductor of an orchestra who calls up the violins first and then perhaps the wind section. When wearing the blue hat we can lay out a plan for thinking with details of what should be happening in a defined sequence. De Bono (1990a, p173) compares a blue hat thinking plan with a computer program which directs the actions which the computer is required to perform. One possible blue hat fixed structure for a sequence of thinking operations that has been suggested by De Bono (1990a, p181) has the acronym PISCO. First a problem or situation is considered in terms of what is its Purpose; next all relevant information is Input; then generate Solutions; then examine the solutions and make a Choice; and finally the choice is put into Operation. The blue hat can also be used to focus thinking by asking questions. In resolving disputes De Bono (1990a, p182) suggests that blue hat should map out areas of Agreement, then areas of Disagreement and finally areas of Irrelevance (ADI) as a way of making progress. Another method suggested by De Bono (1990a, p12) is to identify the Plus points of a choices, then the Minus points and finally any Interesting points (PMI).

Normally the chairperson of a meeting has an automatic blue hat function but it is possible for other people to be assigned a specific role or for them to assume a blue hat role. For example "My blue hat thinking tells me that we should define this point as a key problem, then we should attempt to tackle this problem either now or later." Or also "I am sorry, that is clearly black hat thinking and out of order at this point."

The value of the six thinking hats is that it unscrambles thinking so that a thinker is able to use one thinking mode at a time instead of trying to do everything at once. De Bono (1990a, p199) gives the analogy of colour printing in which each colour is printed separately and in the end they all come together. The six thinking hats approach is designed to switch thinking away from the normal argument style to one of map making. This makes thinking a two stage process. The first is to make the map and the second is to choose a route on the map. If the map is good enough, then the best route will often become obvious. De Bono (1990a, p199) believes that a major strength of using the six thinking hats approach lies in its artificiality. It provides a formal and convenient way of requesting a certain type of thinking either of oneself or of others. The six thinking hats approach establishes rules for the game of thinking and a thinker can take pride in play acting each of the thinking roles.

#### 2.6.3 Lateral thinking

De Bono (1990a, p140) invented the term lateral thinking to distinguish between the thinking used for generating new ideas and the vertical or serial thinking that is used in logical processes. Lateral thinking is concerned with changing concepts and perceptions (these are said to be historically determined organizations or patterns of experience). Lateral thinking is about changing existing patterns of thought and it is often used as a synonym for creative thinking. Table 2 lists some of the techniques developed by De Bono to develop creative thinking skills. Some other formalised strategies will now be examined whereby ideas and egos

**TABLE 2**  
**STRATEGIES FOR IMPROVING PLANNING AND DECISION MAKING**  
(De Bono 1978, p128-137)

**Plus, Minus, Interesting (PMI)** A list is made of the plus, minus and interesting points in a problem being considered. This is especially useful in a group where each member is required to think of one point from each category. Decisions often becomes much clearer after a group PMI session.

**Consider All Factors (CAF)** When you have to choose or make a decision, there are always many factors to consider. CAF simply notes all possible factors so that none are left out of consideration. For example do a CAF on the factors to consider in buying a new house, or a second hand car.

**Consequences and Sequences (C&S)** In thinking about an action, it is important to think of all the consequences. What happens if the world runs out of oil, you won a million dollars, animals could speak, or you went blind.

**Alternatives, Possibilities, Choices (APC)** Often there are more alternatives in taking a decision than first comes to mind. Sometimes the obvious choice is not the best one. What alternatives do you have if your best friend is a thief? Your find \$20 note what choices do you have?

**Other Points of View (OPV)** People look at the same situation from different and personal points of view. Everyone thinks differently.

**Agreement, Disagreement, Irrelevant (ADI)** Often when faced with a conflict between two apparently opposing points of view it is possible to make progress by identifying the areas of agreement and those which are irrelevant.

can be separated, and the dominance of existing thought patterns can be reduced sufficiently to permit new ideas to germinate and grow.

#### 2.6.3.1 Brainstorming

De Bono (1990b, p131) says that brainstorming provides a special setting which encourages the application of the principles and techniques of lateral thinking while providing a holiday from the rigidity of vertical thinking. He states that the main features of a brainstorming session are cross stimulation, suspension of judgement and a formalized setting. There is no ideal size for a brainstorming session but De Bono (1990b, p134) notes that less than six can degenerate into an argument and above fifteen will make it more difficult for everyone to get an opportunity to contribute. A chairperson is appointed to the task of guiding the session without in any way controlling or directing it see Table 3.

De Bono (1990b, p136) says that a brainstorming session of twenty minutes would be sufficient in most cases and forty five minutes should be regarded as an outside limit. He suggests that a ten minute warm up period dealing with a simple problem, can also be useful prior to the actual session. After the main session is over the participants will continue to have ideas on the subject. These can be collected by asking each participant to send in a list of further ideas.

No evaluation is made during the brainstorming session because it would tend to kill the spontaneity and convert the session into one of critical analysis. De Bono (1990b, p137) says that evaluation should be carried out later, by either the same group or another group, even if

**TABLE 3**  
**DUTIES OF CHAIRPERSON OF A BRAINSTORMING SESSION**  
(De Bono 1990b, p134-136)

The duties of a chairperson are:

1. Preventing any evaluation of criticism of the ideas given.
2. Ensuring that not everyone speaks at once and encouraging those who have been prevented from airing their ideas by more dominant speakers.
3. Ensuring that the notetaker has got an idea down.
4. Filling in gaps by offering suggestions.
5. Suggesting different ways of tackling the problem and the use of different lateral thinking techniques for trying to generate different ways of looking at the problem. (eg. "let's try turning this thing upside down.")
6. Defining the central problem and keep pulling people back to it. This is a difficult task since apparently irrelevant flights of fancy may be very generative and one does not want to restrict people to the obvious view of the problem.
7. Ending the session either at the end of a set time or if the session seems to be flagging.
8. Organizing the evaluation session and listing of ideas.

the problem was not a real one. It is the evaluation exercise that makes a worthwhile activity of what would otherwise be a frivolous exercise. The evaluation exercise should pick out ideas which are directly useful and extract from ideas that are wrong or ridiculous the functional kernel of the idea which may be generalized in a useful way. At the end of the evaluation session there should be three lists consisting of ideas of immediate usefulness, areas for further exploration and new approaches to the problem. De Bono (1990b, p138) notes that the evaluation session is not just a mechanical sorting process but one where creative effort is required to extract usefulness from ideas before they are discarded.

#### 2.6.3.2 Synectics

Adams (1987, p137) notes that synectics is more complex than brainstorming because it allows criticism and a higher level of technical expertise. In the synectics process, the group works with a client who has a problem, giving the client ample opportunity to provide input to the group. The client originally states the problem and selects ideas from those presented. The ideas may be generated through metaphors (Joyce & Weil, 1986, p167) using personal analogies, direct analogies, or compressed conflict that is, pairs of ideas that are in conflict say for example friendly foe or shyly aggressive. Joyce & Weil (1986, p169) show how the synectic process can be used to generate a new solution to a problem and this is reproduced in Table 4.

Other strategies to generate initial ideas or "springboards", that have been suggested by Nolan (1989, p45-56), for synectic sessions include word association, excursions, paradoxes, doodling and writing sentences.

**TABLE 4**  
**THE SYNECTIC PROCESS FOR CREATING SOMETHING NEW**  
(Joyce & Weil, 1986, p169)

Phase one (Description of present condition): The leader has the group describe the problem or situation as they see it now.

Phase two (Direct Analogy): Members of the group suggest direct analogies, select one, and explore it further.

Phase three (Personal Analogy): Group members "become" the analogy selected in phase two.

Phase four (Compressed conflict): The group take their descriptions from phase two and three, suggest several compressed conflicts, and choose one.

Phase five (Direct Analogy): The group generates direct analogies based on the compressed conflict choice from previous phase and select one.

Phase six (Re-examination of the original task): The leader gets the group to move back to the original task or problem and fit the last analogy as a possible solution to the problem.



One example of the excursion techniques is to have a career excursion where one looks at the problem through the eyes of someone from a different career perhaps a deep sea diver or a ballet dancer. Other examples include a street excursion where one walks along the street generally looking around until some particular sight catches one's eye and then one starts to make connections between that object and the problem. The technique of writing sentences involves taking a random word and writing sentences containing that word for a period of ten minutes, then use some of the sentences to trigger absurd solutions to the problem and finally develop them into more practical solutions.

One particularly interesting feature of the synectics process is that the leader does not contribute to the problem solution. The leader of a synectics group role is restricted to that of being a facilitator and a recorder. This reduces the opportunity for a leader to satisfy ego at the expense of process.

Adams (1987, p139) notes that in synectics fewer ideas are produced than in brainstorming. One of the traits that a synectics leader must acquire is the ability to deal gracefully with group members whose ideas are not selected. An interesting technique incorporated into synectics sessions is the use of an approach to evaluation in which negative statements must be preceded by at least two positive statements. The positives serve to give the group continual indication of the desires of the client and maintain a psychological atmosphere which is conducive to creativity. Adams (1987, p139) notes that the criticism or negative should be couched as a reservation rather than an overall no-vote and it can immediately be made the problem for the next round. In this way strong criticism can be accommodated without inhibiting conceptualization.

## 2.7 Visual thinking

Visual thinking is not an exclusive reserve for artists, according to McKim (1980, p8), but is used by a wide range of people including chess players, engineers to design circuits, chemists to construct molecular models, architects to coordinate function and beauty, gardeners to create beautiful landscapes and interior decorators for decorating room. McKim identifies three types of visual imagery that are probably contained in visual thinking:

1. Perceptual imagery which is the way we see and record images in our brains.
2. Mental imagery whereby something is imagined in the mind's eye, especially when we dream.
3. Graphic imagery which includes drawing, sketching, doodling, painting and so forth.

McKim (1980, p9) notes that visual thinkers appear to utilize seeing, imagining and drawing in a fluid and dynamic way, moving from one kind of imagery to another. For example, they will see a problem from several angles and perhaps even choose to solve it in the direct context of seeing. Once they have a suitable visual understanding of the problem, they imagine alternative solutions. They sketch their ideas as they think of them so that they can be compared and evaluated later. They will continue cycling between perceptual, inner and graphic images, until the problem is solved.

The internal imagery of the mind's eye has played a central role in the thought processes of many creative individuals. In rare thinkers, this inner imagery is extremely clear. McKim (1980, p10) quotes the example of Nikola Tesla, the technological genius whose inventions included the fluorescent light and the A-C generator, as someone who could project before his eyes a picture of an as not yet invented machine that was complete in every

detail. To Tesla these pictures were more vivid than a blueprint. Tesla's inner imagery was so like perceptual imagery that he was able to build his complex inventions without drawings. Tesla also claimed to be able to test his devices in his mind's eye "by having them run for weeks, after which he would examine them thoroughly for signs of wear."

Adams (1987, p89) cites the following example of Friedrich Kekule, the chemist who discovered the structure of the benzene ring.

I turned to the fire and dozed. Again the atoms were gambolling before my eyes. This time the smaller groups kept modestly in the background. My mental eye, rendered more acute by repeated visions of this kind, could now distinguish larger structures, of manifold conformation; long rows, sometimes more closely fitted together; all twining and twisting in snakelike motion. But look! What was that? One of the snakes seized hold of its own tail, and the form whirled mockingly before my eyes. As if by a flash of lightning, I awoke.

The result of the dream was Kekule's brilliant insight that organic compounds such as benzene were closed rings rather than open structures.

Herrmann (1990, p196) notes that Albert Einstein dreamed of himself riding on a beam of light as a prelude to conceiving the theory of relativity. Apparently Einstein considered his gift for fantasy to be much more important to his thinking repertoire than the more rational and organized modes of thought. Herrmann (1990, p190) believes that for Einstein, the acquisition of knowledge, facts, data and statistics was simply preparation for the intuitive process from which his epochal ideas emerged.

McKim (1980, p29) believes that visual thinking can be taught, but suggests that as a prelude we should stop unteaching it. By this he is referring to a preference among adults for the teaching of the three R's in schools

which carries with it a perception that art is a frill, a non essential, whereas language is considered to be a must. He believes that we should consider both to be essential for wholesome mental development. He notes that art allows for harmless individual self expression, a learning which the three R's may not permit. Instead the three R's tend to give the essential training in conforming mental activity which children need in order to become communicative and cooperative social beings.

Adams (1987, p89) suggests that we can learn to see better perceptually through a conscious effort, by for example engaging in activities which require us to reproduce things that we have seen. Making sketches of friends, family, pets, home and neighbourhood will serve to raise our level of seeing our immediate environment. Attending a drawing class can be another way to improve our seeing ability.

Adams (1987, p90) notes that the ability to imagine visually is complex, because it depends not only upon our ability to form images, but also upon the supply of pertinent imagery that is stored in our minds. However he believes that we can improve our visual imaging by devoting effort to it and making it a high priority item in problem solving. Adams (1987, p90) suggests that exercises like the following in Table 5 will help to develop our ability to control and manipulate visual imagery.

Adams (1978, p92) divides graphical imagery into drawings which are done to communicate to others such as an architects concept sketch of a proposed building and those which are to communicate with ourselves such as idea sketches. The first type of drawing (communicative) receives a good bit of attention educationally and the ability to make such drawings can be acquired through formal classes. Adams (1987, p94)

TABLE 5  
IMAGINE (Adams, 1987, p90)

Imagine the following:

1. A pot of water coming to a boil and boiling over
2. A Boeing 747 being towed from the terminal, taxiing to the runway, waiting for a couple of other planes, and then taking off.
3. A running cow changing slowly into a galloping race horse.
4. An old person you know well changing back into a teenager
5. A speeding car colliding with a giant feather pillow
6. The image in (5) in reverse.

considers the second type of drawing (thinking sketches) to receive far less emphasis, even though it is an important adjunct to visual thinking. He advises that people wanting to develop their visual thinking skills should buy a cheap notebook of a size that can be conveniently carried around and a pencil or fibre tipped pen. He recommends that drawings should be made in the note book over the following few weeks while trying to conceptualize or solve a problem. The game Pictionary can be a good exercise in visualizing and communicating ideas since it involves seeing the object in our mind's eye and the need to communicate the essential features of the object.

Mindmapping is a useful sketching method to creating a graphical imagery of the relationship between various aspects in a problem. It was invented by Tony Buzan in the 1970's as a note taking technique where the relationships between facts and ideas can be displayed. The strength of mindmapping is because it is non linear, quick, flexible, non judgemental, and it can be used to encourage creative thinking and the generating of many ideas. Buzan (1993, p77-136) describes the techniques

and applications of mindmapping and a summary of the techniques is presented in Table 6.

Mindmapping is effective because it is a whole brain process that expands as well as focuses our thinking and it is logical as well as imaginative. Mindmapping is a way of developing a picture that enables a lot of information to be conveyed in a small space. Links and connections between ideas can be seen clearly and so it is a powerful tool for communicating ideas. An example of a mindmap is presented in Figure 5.

TABLE 6  
CREATING MINDMAPS  
(after Buzan, 1993, p77-136)

1. Start the mindmap by writing the main topic in the centre of a large (A3) blank piece of paper turned sideways. Add a sketch; then draw a box around the subject title.
2. Think about what main factors, ideas, concepts, or components are directly related to the topic. Quickly jot them down on a piece of scrap paper, then print the most important ones on lines as main branches off the central title.
3. Now concentrate on one of these headings or main ideas. Identify the factors or issues related to this particular idea. Additional branches lines and details are then added using key words, not phrases, so that the map can be kept uncluttered. Printing in capital letters is recommended, even subtopics.
4. Repeat the process for each of the main ideas. During the process, associations and ideas will not always come to mind in an orderly arrangement. These can be easily incorporated into the map at the most appropriate place.
5. The idea is to recall everything your mind thinks of around the central idea. Do not worry about organisation as a final organisation can be accomplished at the end of the exercise.
6. The use of colours and symbols throughout the mindmap will help stimulate the right hemisphere of the brain.

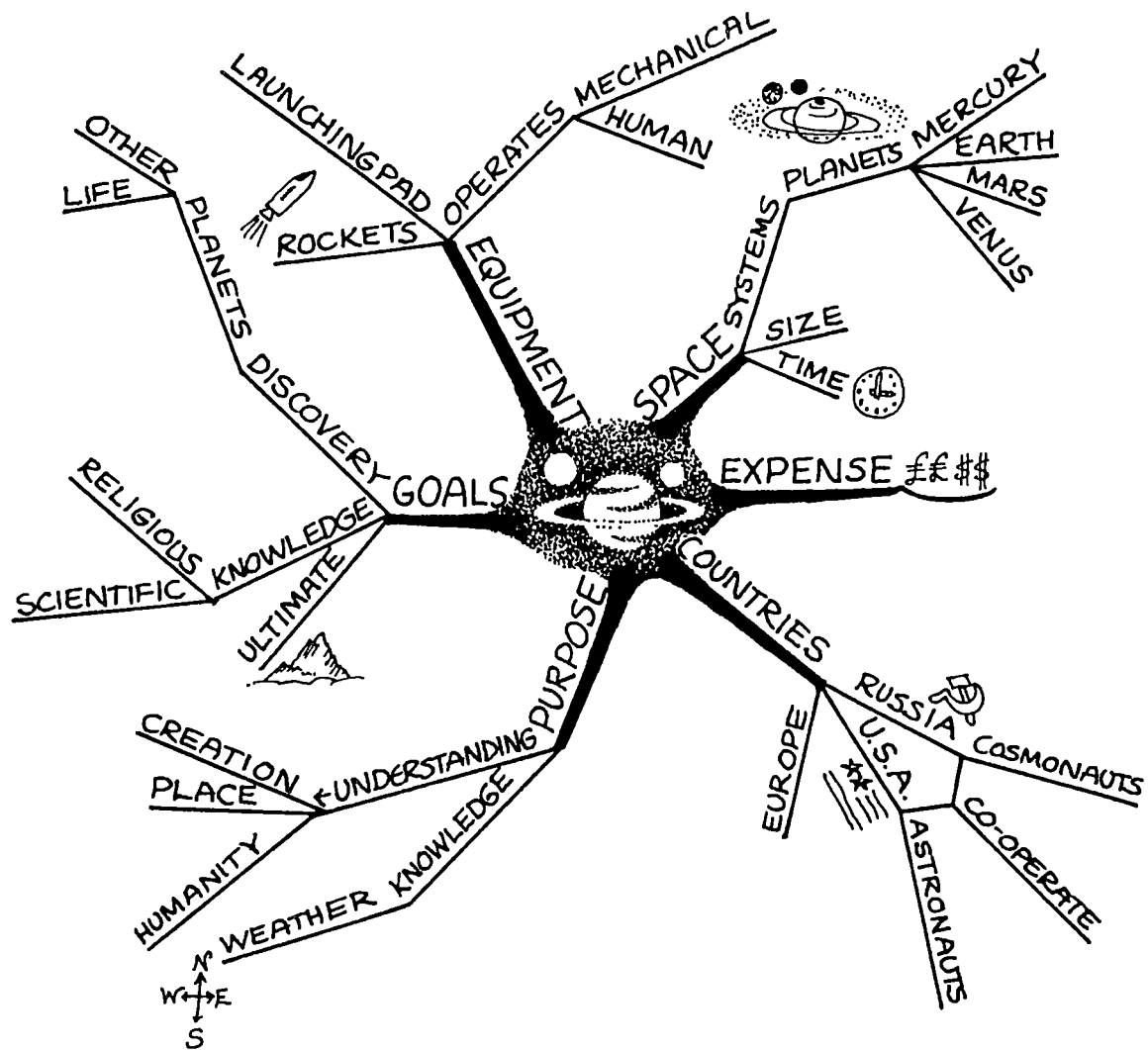


Figure 5. Example of a Mindmap for a Talk on Space Travel. (Buzan, 1993, p94)



## 2.8 EXPERIENTIAL LEARNING

To Kolb (1993, p143) learning is the process whereby knowledge is created through the transformation of experience. He believes that learning is best conceived as a process, rather than in terms of outcomes and so Kolb sees learning as a continuous process grounded in experience. Kolb (1984, p20-38) suggests that people perceive (how we take things in) and process (how we make things a part of us) new information differently. Some people perceive by feeling their way through a new experience (concrete experience) and others perceive by thinking (abstract conceptualization) about the new experience. The perceiving function can be represented by a line signifying a continuum with the words concrete experience and abstract conceptualization at the opposite ends of a line. The manner in which any individual perceives a new experience would be found somewhere on this continuum. In processing new information, some people watch (reflective observation) while others become actively involved (active experimentation). Again, a line can be used to represent a continuum with reflective observation and active experimentation at opposite ends. Kolb (1984, p42) put these two elements of learning together and identified four different types of learning style types as shown in figure 6.

Kolb (1984, p77,78) defines the four types of learning styles as follows:

- 1 A convergent learning style relies primarily on the dominant learning abilities of abstract conceptualization and active experimentation. The greatest strength of this approach lies in problem solving, decision making and the practical application of ideas. People with this style of learning prefer dealing with technical tasks and problems rather than social and interpersonal issues.

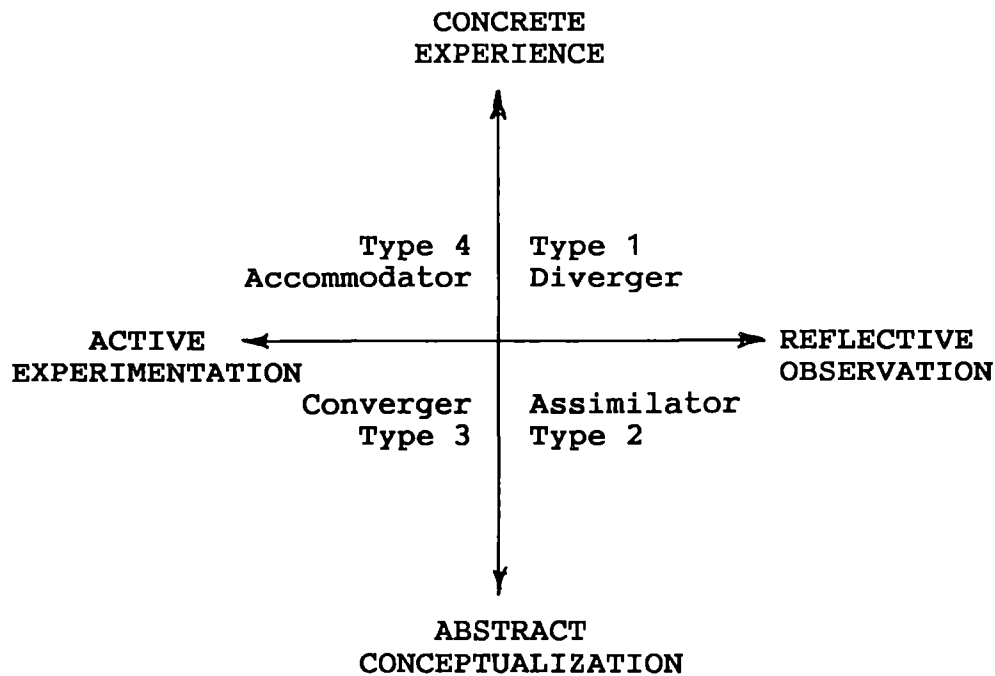


Figure 6. The Experiential Learning Styles Model  
(Kolb, 1984, P40)

- 2 A divergent learning style has the opposite learning strengths from convergence, emphasizing concrete experience and reflective observation. The greatest strength of this orientation lies in imaginative ability and awareness of meaning and values. The primary adaptive ability of divergence is to view concrete situations from many perspectives and to organize many relationships into a meaningful whole. The emphasis in this orientation is on adaption by observation rather than action. People with this style of learning are better in situations which call for the generation of alternative ideas, such as brain storming sessions. They are interested in people and tend to be imaginative and feeling orientated.
  
- 3 In an assimilation learning style, the dominant learning abilities are abstract conceptualization and reflective observation. The greatest strength of this orientation lies in inductive reasoning and the

ability to create theoretical models which assimilate disparate observations into an integrated explanation. This orientation focuses less on people and more concerned with ideas and abstract concepts. It is more important for this type of thinker that the theory is logically sound and precise than for the ideas to have practical values.

- 4 An accommodating learning style emphasizes concrete experience and active experimentation. The greatest strength of this orientation lies in doing things, in carrying out plans and tasks and getting involved in new experiences. The emphasis in this orientation is on opportunity seeking, risk taking and action. People with this style of learning tend to solve problems in an intuitive trial and error manner, relying heavily on other people for information rather than their own analytical ability. They are at ease with people but they can be seen as pushy and impatient.

McCarthy (1987) developed the 4MAT learning system based mainly on the Kolb learning style research and the left and right brain research of Sperry (1973). McCarthy proposed that all four learning styles should be used in a learning situation, with each style valued equally. As a result students will be comfortable some of the time and stretched to think in different ways at other times. For effective teaching, instructors should use all segments of the cycle in the 4MAT system even though they themselves may have a preferences for particular modes. The 4MAT learning system is based on the premise that learning will best occur by sequentially passing through the four learning abilities as shown in Figure 7. The cycle moves from concrete experience at A, to reflective observation to abstract conceptualization, to active experimentation, and then back to concrete experience at H.

Left Mode: Lineal, sequential

Right Mode: Global

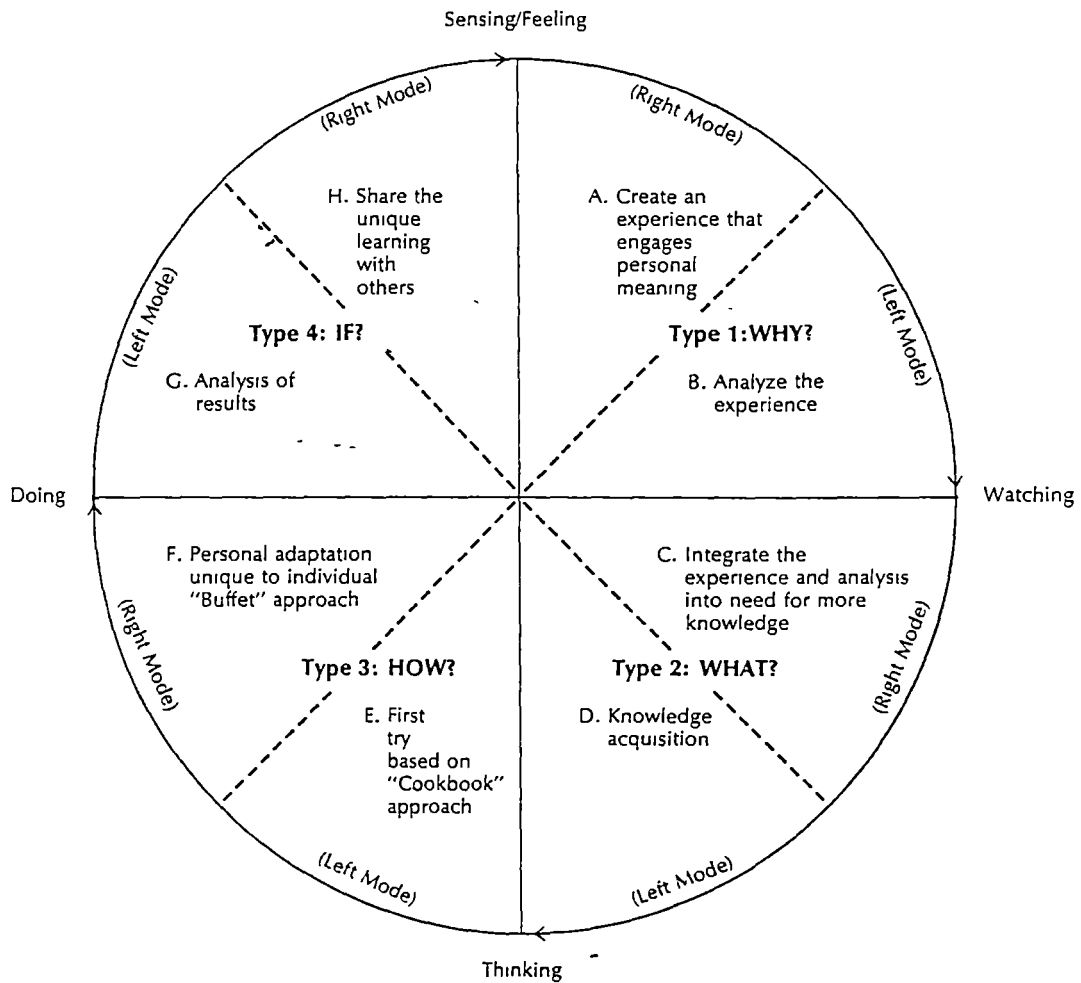


Figure 7. The 4MAT Cycle of Learning.  
McCarthy (1987)

## 2.9 Summary

The literature reviewed suggests that most people have the potential to be creative thinkers but that, through our experiences in life and our society's cultural values, we have evolved patterns of thinking which currently limits us from utilizing our full potential. It would appear from the literature that creative thinking skills can be taught and a variety of strategies to foster creative thinking have been explored.

The work of Kolb and McCarthy on experiential learning styles emphasises the need to provide variety in the learning experiences of the students. The process used to develop a curriculum to foster creative thinking skills among engineering students, is described in the next chapter.

## CHAPTER 3

### CURRICULUM DEVELOPMENT

#### 3.1 CURRICULUM MODELS

The format used in producing the written curriculum document presented on pages 66 to 68, was the one suggested by Brady (1983, p70) in which he recommended that the curriculum elements should be in the following order: objectives, content, method and evaluation. The order does not however reflect the actual sequence in which the curriculum was developed. Brady (1983, p73) states that curriculum development models are simply a convenient way of relating the curriculum elements during the development stage. In fact an eclectic approach was taken to the development of the curriculum rather than adopting a single model. Tyler's (1949) Objectives model (Figure 8) was used as a starting point. However the Interaction Model (see Figure 9) of

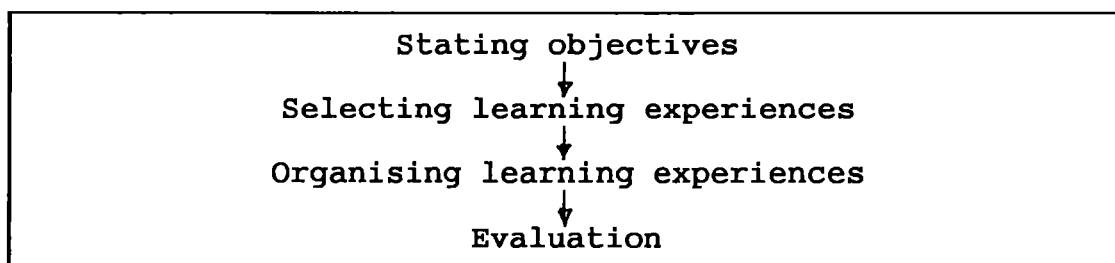


Figure 8. Tyler's Curriculum Objectives Model  
(Brady 1983, p58)

Taba (1962, p425) would define more closely the actual process used during the development of the topic outlines. Various starting points were used when devising activities for each topic, with learning experiences being sometimes selected before objectives. Evaluation was considered to be a continuous part of the development process and not something to be confined solely to the conclusion of the curriculum. Thus discussions with colleagues were used as the basis of an

on going process of evaluation. The Interaction Model permitted a more flexible and creative approach than the Objectives Model.

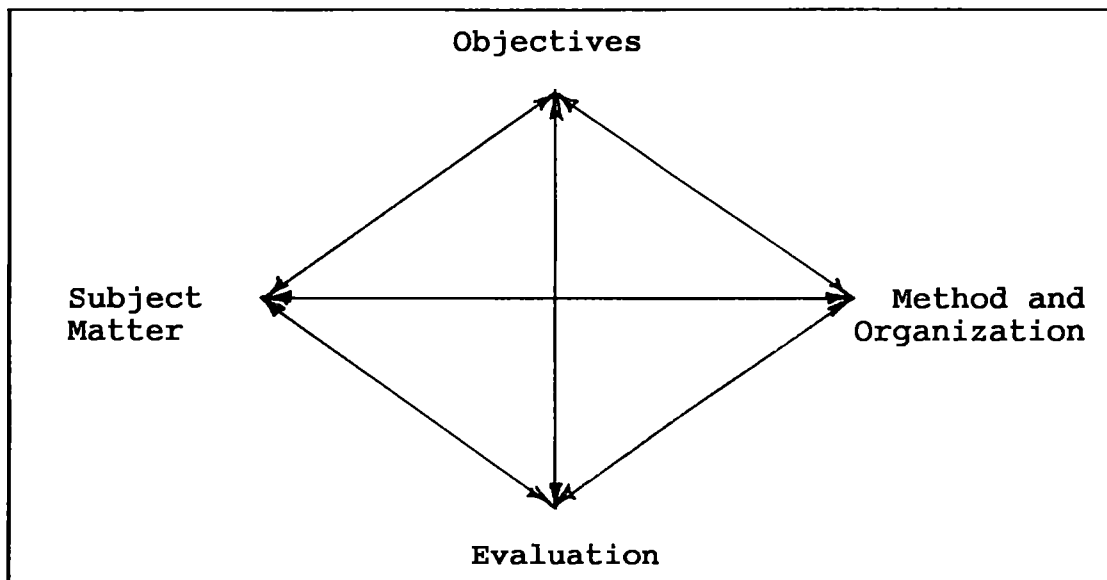


Figure 9. Curriculum Interaction Model (Taba 1962, p425)

### 3.2 CURRICULUM OBJECTIVES

Wiles and Bondi (1984, p96) warn that the need to write clear, precise objective statements may cause curriculum developers to choose simple objectives that require little thinking on the part of students. Taba (1962, p204) advises that objectives should be realistic and should only include what can be translated into curriculum and classroom experience. She believes that objectives are often developmental in nature, representing roads to travel rather than terminal points. Eisner (1979, p103) classifies objectives into instructional (behavioural) and expressive objectives. Expressive objectives are not prescriptive but are designed to provide a fertile field for personal experiencing. Expressive objectives

are generated from activities (perhaps a visit to an engineering factory) that are engaged in, to court surprise, to cultivate discovery, and to find new forms of experience.

Many undergraduate design curricula include some aspects of creative thinking as a part of the design process. This approach can often result in a compartmentalization of skills such that creativity is linked into something that only designers do. A guiding philosophy for this unit was that students should see creative thinking as something anyone can use at home, work or play as a natural complement to logical thinking skills.

The unit aim, which was evolved through discussions with colleagues and also in reference to the I.E.Aus (1993, p18-20) document on National Competency Standards for Engineers, is as follows:

To expose engineering students to alternative thinking styles and help students to understand their own learning preferences, give them a greater appreciation of their strengths and weakness and so prepare them for life-long learning.

This unit aim was expanded into five objectives which formed the basis for developing the curriculum content into six topic areas. A set of sub-objectives was then developed for each of these topic areas. In general, each objective also specifies a behaviour which can act as an indicator that the objective has been achieved. However, in the context of a creative thinking skills curriculum, it is considered desirable also to include some expressive objectives, with a view to providing a fertile field for personal experience.



### 3.3 CURRICULUM CONTENT

According to Bruner (1965, p11) the teaching of new curricula is concerned with giving students an understanding of the fundamental structure of whatever subjects we choose to teach. To learn structure is to learn how things are related (Bruner 1965, p7). An obvious example of this would be when children learn the structure of a sentence. They are able to generate many other sentences with different content but modelled on the structure of the original sentence. The process of learning may often be more important than mere subject knowledge. For example, in subject areas like electronics and computing, the pace of development is such that knowledge gained five to ten years ago may be obsolete.

Discussions with colleagues and a review of design curricula indicated that activities like brainstorming and synectics traditionally comprise a major component of the creative thinking skills that are taught to engineering undergraduates. Visual thinking skills like visual brainstorming or imagining do not seem to be specifically taught. This is surprising since some very noteworthy innovators like Einstein and Tesla had very highly developed abilities of imagining. Tesla's (1980, p10) ability to test machines in his mind's eye, by having them run for several weeks and then examine them for wear would seem to be well worth cultivating in engineers. Visual thinking skills are considered to be an integral part of creative thinking and so they form an important part of this curriculum content.

Edward De Bono (1990b) invented the term lateral thinking to distinguish it from the more usual vertical or serial type of thinking. The term lateral thinking has become synonymous with creative thinking. A range of De Bono's lateral thinking techniques has also been included in the curriculum content. The ability to generate ideas is

central to the process of creative thinking but it is also important to be able to evaluate such ideas. De Bono's PMI (Pluses, Minuses, Interesting) is one particular example of a suitable technique that has been included in the content.

De Bono's (1990a) six thinking hats is an excellent strategy for running meetings. A major strength of the method is that it separates out feelings and bias and permits them to be declared without any loss of face. Ideas and egos are separated and hence entrenched positions do not develop. Six thinking hats is an important strategy for working in group situations and has been included in the content.

The final component of the curriculum is called creative designing. Its purpose is to provide a framework for the students to apply the knowledge and skills gained in the specific topics by finding a conceptual solution to a given problem.

### 3.4 LEARNING EXPERIENCES

Rogers (1989, p127) acknowledges that a traditional lecture can be a neat and convenient way of presenting information. However she suggests that case studies, role play, simulation and games should be used whenever possible because they are all ways of involving students in experiencing the knowledge they are required to learn. This view is also shared by Hook (1990, p251-256) who advocates that non-convergent learning styles should be introduced into the engineering curriculum in an attempt to nurture a more balanced learning profile along the lines of the 4MAT Cycle of Learning (McCarthy, 1987). He believes that the traditional learning experiences for engineering undergraduates produces convergent thinkers who find difficulty in moving into management roles.

Hook (1990, p255) advocates the use of student-centred tutorials, prior reading, simulation, role playing, debating, inter-group exercises, structured discussion sessions, selected assignments, guest lecturers, essay type questions and dissertations as being ways of enhancing students' learning experiences.

The basic philosophy of Kolb and McCarthy's four learning styles has played a major part in selecting the learning experiences for this curriculum. The learning experiences of the unit have been selected to facilitate the integration of theory with practice. This is in keeping with the recommendations of Brady (1983, p118) in which he states that learning is active rather than passive and that students should be involved actively. He also notes that learners react in different ways to the same learning situation. A large component in the delivery of this curriculum is based around practical experiences in which students can explore, practice and evaluate the different thinking styles. This includes working individually as well as in small groups of four to six. Lectures will be used to deliver some of the curriculum material but they will typically be around twenty minutes duration. Lectures will be supported by simulation and role play activities in techniques of problem solving and the communicating of ideas to others. Students will be required to solve practical problems through in-class and out of class assignments.

For this curriculum a class size of twenty students is considered to be ideal in facilitating good learning experiences and a class size of thirty should be regarded as an absolute maximum. Likewise the classroom used for the delivery of this unit should be one that encourages a good learning environment. It should be reasonably spacious, tables and chairs should be easy to move around, it should have a friendly feel to it, carpeted and it should be easy to display students' work.

### 3.5 ASSESSMENT OF STUDENT LEARNING

Assessment is an integral part of an Engineering Degree Course because it is used by a Board of Examiners to determine whether a student has satisfactorily completed a unit of study and may progress on to the next stage. Such assessment will often be used to determine the grade of honours with which a student will graduate when they have completed their course of study. Subjects central to the nature of the course such as mathematics, mechanics, dynamics, thermofluids, etc, are used in determining honours gradings and so the assessment is required to classify a student's performance into grades of distinction, credit, pass and fail. When subjects have been included in the course to enrich and widen the perspective of students, then the assessment of student performance is generally on a satisfactory or unsatisfactory (ie pass/fail) basis. This curriculum on creativity would be included in the latter category and so it is necessary to establish a set of criteria defining the nature of a satisfactory performance.

Brady (1983, p131) provides the following questions to allow a distinction to be made between assessment and evaluation.

#### Assessment:

- . Were there changes in students?
- . What were these changes?
- . How great or small were these changes?
- . Were these differences in performance between the classes or grades?
- . What was the extent of these differences?

#### Evaluation:

- . Were all the changes in student behaviour desirable?
- . Were the learning experiences suitable?
- . Which methods were the most effective?
- . Which content was the most effective?
- . Did the learning experiences produce desirable behaviours?

It can be seen that assessment is a prerequisite to evaluation because assessment is used to provide the information that enables evaluation to take place. Evaluation is concerned with judging the nature and extent of change in students and using that knowledge to change the curriculum if necessary. Evaluation according to Brady (1983, p132) is of two types, namely summative evaluation and formative evaluation:

Summative evaluation is used at the end of a course to give a final indication of a student's progress. It involves a judgement about the student, the teacher or even the effectiveness of the curriculum. It is an appraisal of the extent to which the outcomes of a course have been achieved.

Formative evaluation is used throughout both the development and the teaching of a curriculum, so that appropriate revisions can be made to it. Formative evaluation helps the teacher to ascertain areas of learning difficulty as a basis for further teaching. Feedback to students is the basis of formative evaluation, and feedback should be designed to assist the students to determine in which areas they need to improve their abilities.

Items have been provided which can be used for formative and summative purposes. Formal formative and summative assessment has been incorporated in the curriculum through five assessed exercises during the progression of the curriculum delivery. Although these assessments are essentially summative in nature, students will gain a degree of formative assessment when their assignments are returned. This information will assist them when applying that part of the topic to the design project. Three of these are individual assignments and two are group exercises. Each student will also experience some degree of informal formative self-evaluation during the various role plays and learning exercises that form part of the learning experiences.

For a curriculum seeking to develop creative thinking skills, it was considered that a traditional two or

three hour written exam would not be the best way of encouraging students to develop their skills. This view is shared by Taba (1962, p316) who believes that evaluation procedures should be consistent with the objectives of the curriculum. She believes that the way of evaluating what is learned will dictate the way in which the learning takes place and illustrates this point by saying;

If a thoughtful reorganization of knowledge is stressed in the classroom, but the testing and grading are confined to the mastery of facts, the latter learning is reinforced. If creativity and thinking are stressed in evaluating student progress, factual cramming is less likely to be the order of the day.

(Taba, 1962, p316)

It was considered a project would enable students to demonstrate how well they had assimilated and could apply the information gained. However it was felt that a project based assessment required more than a two or three hour slot at the end of the unit. Students should have time to digest a problem, reflect on its many facets, incubate solutions and select the most promising one for further development. Thus it is envisaged that the project will be undertaken in parallel with the rest of the curriculum delivery.

The curriculum topic creative designing will not only provide summative evaluation of a student's progress but it will also permit a degree of formative evaluation through discussions with the project supervisor and peers. This topic is a group exercise and as such it could be argued that it is difficult to separate out the individual contribution of each student. This has been recognised as a possibility but the experience to be gained through the interaction of group members with their different perceptions of the problem was considered to be a very important part of the learning experience. Some redress has been built into the project assessment

scheme, through an entirely subjective assessment component called "overall individual effort" which is worth ten percent of the total project mark.

Brady (1983, p132) recommends that teachers should undertake some diagnosis of the readiness of students and their particular abilities prior to implementing the curriculum. To this end a questionnaire was prepared, and is presented in Chapter 4 on pages 71 to 74 as part of the course material, to help students gain an insight into their own preferred learning and thinking styles. The questionnaire is not designed as an instrument to give a quantitative assessment of a student's thinking and learning style. Rather it is designed to promote awareness of alternative thinkings and learning styles and in so doing, to assist a student in becoming aware of their own preferences. This questionnaire is to be given to every student at the commencement of the curriculum delivery. It will also be given again at the completion of the unit so that they can make a comparison and determine what changes have occurred to their thinking skills.

### 3.6 EVALUATION OF CURRICULUM

Wiles and Bondi (1979, p249) state that the general purpose of evaluation is to improve the educational program by facilitating judgements about its effectiveness based on evidence. They detail the following specific purposes:

- 1.To make explicit the rationale of the instructional program as a basis for deciding which aspects of the program should be evaluated for effectiveness and what types of data should be gathered.
- 2.To collect data upon which judgements about effectiveness can be formulated.

- 3.To analyse data and draw conclusions.
- 4.To make decisions which are based on the data.
- 5.To implement the decisions to improve the instructional program.

It can be readily deduced from the foregoing statements that evaluation is not an end in itself but a process to assist in improving the curriculum. It is not possible at this stage to evaluate any of the curriculum components based on actual teaching situations, because it has not yet been offered to students. A trial run of the curriculum is being planned on a voluntary basis to a limited number of student during 1994 to provide an opportunity for assessing the effectiveness of the curriculum.

To date evaluation of the curriculum developed has taken place in two ways:

1. Informal formative evaluation has taken place during the development of this curriculum through discussions with colleagues.
2. A formal review of the curriculum as developed was made by nine professional colleagues in the field of education. Six were from my place of employment and comprised one engineering undergraduate student, one engineering graduate student, two colleagues on the engineering academic staff, the Associate Director of Engineering and the Associate Director of Business Studies. The three other colleagues were from the School of Engineering in the University of Tasmania, at Launceston, one of them being the Head of Department.

Each of the nine people was given a copy of the curriculum, for reading and reviewing. They were given the evaluation form contained in Appendix A and which was



based on the criteria format suggested by Brady (1983, p193,194). All nine were asked to answer the fifteen questions given and to comment on the curriculum as they thought appropriate.

All nine curriculum reviewers were very supportive of the curriculum on creative thinking skills. They all believed that it was important to develop the creative thinking skills of engineering undergraduates. Some concern was expressed regarding the length of the curriculum because it was felt that one thirty hour unit might not be sufficient to redress a perceived imbalance in the thinking skills of engineering undergraduates. This concern was acknowledged and it is envisaged that additional curricula would be developed for second, third and fourth year students. The curriculum title was changed to reflect that it was intended to provide an introduction rather than an all-embracing coverage of creative thinking. Another suggestion was that perhaps the curriculum should be aimed at second year students who would have developed a better understanding of engineering. On reflection however, the lack of engineering theory and practice was not considered to outweigh the benefits of introducing first year students to creative thinking skills before they became conditioned in patterns of left brain thinking. It is envisaged that for second, third and fourth year students, additional creative thinking skills curricula will be developed to built on their acquired engineering knowledge.

The curriculum evaluation form addressed the four areas of objectives, content, teaching methods and evaluation (assessment). The distribution of the reviewers' replies are also given in Appendix A. It can be seen that reviewers consider the objectives to be clearly stated, worth achieving and relevant to engineers. The objectives were acknowledged to be attainable although

interestingly enough none of the reviewers considered them to be easily attainable.

In general the reviewers considered the curriculum content to be of interest to students, clearly sequenced, sufficient to achieve the objectives and that it exposed the students to a significant range of thinking skills. There was agreement that the learning experiences involved the students and that they would help the students to assimilate the thinking skills. The variety of teaching methods was acknowledged and the consensus of opinion was that the learning experiences were sufficient to achieve the objectives. One reviewer believed that the learning experiences were not sufficient to achieve the objectives but included a comment which indicated that the reviewer believed the unit time was not sufficient. This comment lends support to the need for additional creative thinking curricula.

The reviewers considered that the evaluation (or more correctly assessment) procedures were sufficient to indicate if the learning objectives had been attained, that there was some variety in the evaluation procedures and that they would enhance the learning procedures.

All the reviewers were very positive about the curriculum and the underlying philosophy of promoting whole brain thinking among engineering undergraduates, a few even requested a copy of the completed work. Some reviewers made suggestions to improve both the curriculum and the teaching material and these have been incorporated into the curriculum and associated teaching material as appropriate.

### 3.7 Summary

In this chapter a description has been given of the process by which a curriculum in creative thinking was

developed. The actual process was iterative in nature and the comments of colleagues were feedback into the curriculum design process as part of continuous development. A curriculum for creative thinking skills has been developed and although it has not yet been presented to students, it has been evaluated by nine colleagues in education. The written curriculum is presented in the next chapter.

## CHAPTER 4

### THE CURRICULUM

#### 4.1 INTRODUCTION

This chapter contains the written curriculum that was developed according to the methodology described in the previous chapter. Topic outlines together with a representative sample of associated teaching material are presented for each topic to illustrate the intended methods of curriculum delivery. Information is also included about student assignments, the assessment procedures to be used. Many of the samples of teaching material, presented in the exhibits in this chapter, are based on the books referenced in chapter 2. For clarity of presentation, references to the source of origin have not been included in the exhibits which are only intended to illustrate delivery modes of the subject content. Readers, who wish to gain further information about any of the topic areas presented in the exhibits, are encouraged to read the appropriate books referenced in chapter 2.

#### 4.2 THE CURRICULUM

The contents of the curriculum are contained in Exhibit 4.1. The curriculum as presented is suitable for inclusion in a Bachelor of Engineering Course Submission Document. Such a document is the main component of the evidence submitted to a course accrediting body like the Institution of Engineers Australia when it is assessing whether or not the course is of a suitable standard for professional engineers.

UNIT NAME:	AN INTRODUCTION TO CREATIVE THINKING SKILLS
UNIT LEVEL:	B.Eng. First Year
CONTACT HOURS:	one(1) hour per week for fifteen(15) weeks or five(5) sessions of three(3) hours in one(1) week.
PRE-REQUISITES:	There are no pre-requisites for this unit.
UNIT AIM:	To expose engineering undergraduate students to alternative thinking styles, and help students to understand their own learning preferences, give them a greater appreciation of their strengths and weakness and so prepare them for life long learning.
OBJECTIVES:	On completion of this unit students should be able to:
	<ol style="list-style-type: none"> <li>1. Know their own preferred thinking style and be able to adopt strategies to help develop a more holistic approach to solving problems.</li> <li>2. Solve problems in a logical and planned approach, using basic engineering principles and making appropriate assumptions.</li> <li>3. Use creative problem solving to generate new ideas and innovative solutions for a given need or problem.</li> <li>4. Understand how barriers to creative thinking can occur and develop strategies to minimise them.</li> <li>5. Lead, or be a part of, a group of people who are working together, using creative, flexible thinking to find and implement new ideas to the solution of a problem.</li> </ol>

Exhibit 4.1. The Curriculum.

#### CONTENT:

1. Thinking and learning styles. Kolb learning styles quadrant, comparison of logical and creative thinking. Engrams as the patterns of thoughts. The four Quadrant Brain model of thinking preferences.
2. Visual thinking, visual brainstorming, visual communication of ideas, Visualizing as an aid to memory, Imagining and mindmaps.
3. Creative thinking, barriers to creative thinking. De Bono's lateral thinking, brain storming and synectics.
4. Creative decision making. De Bono's PMI (Pluses, Minuses, Interesting), ADI (Agreement, Disagreement, Irrelevant), CAF(Consider All Factors) and APC (Alternatives, Possibilities and Choices).
5. Creative Teamwork, group dynamics and communications. De Bono's six thinking hats.
6. Creative Designing, integration of the unit ideas through finding a conceptual solution to a given design problem.

#### LEARNING EXPERIENCES:

The unit integrates theory with practice. As far as possible this unit will be based around practical experiences in which students can explore, practice and evaluate the different thinking styles. This will include working individually as well as in groups.

Maximum class size should be limited to 25 and the small group sizes to 4/5 to facilitate good learning experiences. The class will be divided into groups and given a common problem during the initial session. This problem will then act as a vehicle for the students to implement the skills acquired over the unit. At the end of the unit, each group will be required to provide an original solution to the given problem.

Lectures will be supported by simulation and role play activities in techniques of problem solving and the communicating of ideas to others. Students will be

Exhibit 4.1 cont. The Curriculum.

expected to solve practical problems through in-class and out-of-class assignments. Some of this work will be in the form of wall displays for peer group assessment.

All students will be expected to participate in a small group role play presentation of a problem solving technique.

**ASSESSMENT:**

Conceptual design group report.  
Three individual assignments.  
Two small group assignments.

**SET TEXTBOOK:**

Von Oech, R. (1990), A Whack on the Side of the Head: How You Can Be More Creative, Thorsons Publishing Group, England.

**RECOMMENDED READING:**

Buzan, T. (1993), Use your Head, BBC Books, London.

De Bono, E. (1990), Six Thinking Hats, Penguin Books, London.

De Bono, E. (1990), Lateral Thinking, Penguin Books, London.

Friedman, R. (1991), Problem Solving For Engineers and Scientists: A Creative Approach, Van Nostrand, Reinhold.

Herrmann, N. (1990), The Creative Brain, Brain Books, North Carolina.

Lumsdaine, E. and Lumsdaine, M. (1993), Creative Problem Solving: Thinking Skills for a Changing World, College Custom Series Mc Graw Hill, New York.

Nierenberg, G.I. (1986), The Art of Creative Thinking, Simon & Schuster Inc., New York.

Nolan, V. (1987), The Innovator's Handbook: The Skills of Innovative Management, Problem Solving, Communication and Teamwork, Sphere Books Limited, England.

Exhibit 4.1 cont. The Curriculum.

The time allowed for the delivery of the curriculum was chosen as fifteen hours so that the unit can be time-tabled as one hour per week for fifteen weeks or five sessions of three hours in one week. The latter curriculum delivery would be useful if the curriculum was to be offered prior to first year B.Eng studies or if the curriculum was to be offered as a short course for practising engineers.

The curriculum content is divided into six topic areas which are thinking and learning styles, visual thinking, creative thinking, creative decision making, creative teamwork and creative designing. Each of these six topics are in turn described in more detail as topic outlines in sections 4.3 to 4.8. In each section, the topic objectives are stated and an outline is given of how that topic will be presented to students. Sample teaching material is also included to illustrate how the content is to be presented to the students.

#### 4.3 TOPIC OUTLINE FOR THINKING AND LEARNING STYLES

An outline is given in exhibit 4.2 for teaching the topic thinking and learning styles. A questionnaire on preferred thinking and learning styles, see exhibit 4.3, has been prepared for distribution to students when the group first meets. The questionnaire is intended to foster an awareness of the range of ways in which people think and learn. It is also designed to help students identify their present thinking and learning preferences rather than give them an absolute measurement of these quantities. A general class discussion of the student responses to the questionnaire will also provide a natural introduction to the Kolb Learning Styles Quadrant. Students should have some knowledge about the work of Kolb, since not only will it help them to be



**TOPIC: THINKING AND LEARNING STYLES**  
(Three hours)

**Topic Objectives:**

To appreciate the variety of ways that we use to perceive new information, and the ways in which we process that information, as evidenced by being able to apply information to familiar situations.

To develop an awareness of personal thinking and learning styles, as evidenced through self assessment of preferred thinking and learning styles.

To know the essential features of creative thinking and be able to compare them to logical thinking as evidenced by being able to produce a comparative list.

**Outline of Topic Delivery**

1. Get students to complete questionnaire on Preferred Learning and Thinking Styles, see Exhibit 4.3.  
Discuss with students their responses.  
(Total time 30 mins)
2. Introduce the Kolb Learning styles quadrant and let students reflect on how it relates to them.  
(Total time 20 mins)
3. Get students to do exercise on thinking, and discuss answers, see Exhibit 4.4. (Total time 25 mins)
4. Introduce the human brain structure, engrams as patterns of thought, and the Herrmann four quadrant brain model. (Total time 25 mins)
5. Get students to produce a list on the qualities of logical and creative thinking, first as individuals, then in small groups. Class discussion of the lists and compare with those given on the overhead transparency, see Exhibit 4.5. (Total time 25 mins)
6. Talk on some limitations of logical thinking and how it can be complimented by creative thinking.  
(Total time 20 mins)

**Exhibit 4.2. Topic outline for Thinking and Learning Styles.**

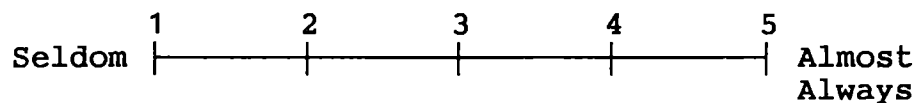
**PREFERRED LEARNING AND THINKING STYLES**  
(Time 15 mins)

Researchers have identified that people perceive (how we take things in) and process (how we make things a part of us) new information differently. The following questions will help you gain information about your own preferred thinking and learning styles.

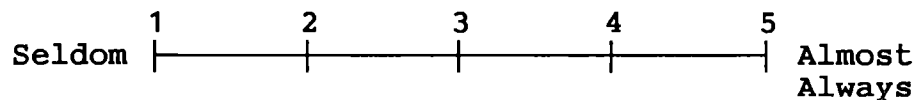
For each of the statements below place a circle at one of the five positions that best identifies your place on the scale.

1) When listening to someone do you tend to say

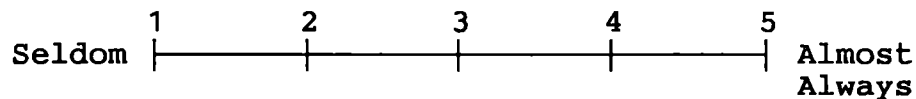
a) I THINK I understand what you are saying



b) I SEE what you mean

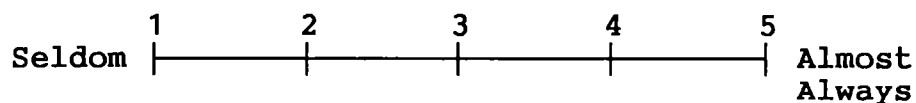


c) I FEEL what you say makes sense.

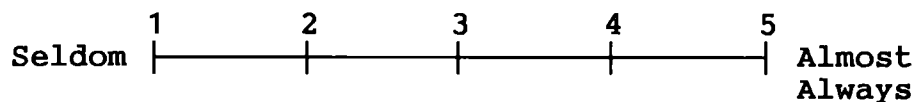


2) When someone speaks to you in confidence do you concentrate on

a) The words



b) Their facial expression



c) The way you sense they are feeling

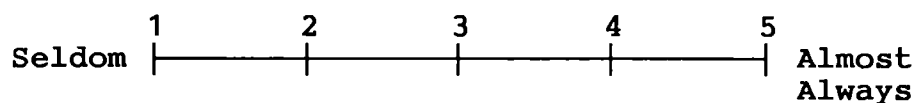


Exhibit 4.3. Sample of teaching material developed to support the topic on thinking and learning styles.

3) When you have just received a piece of information do you respond by saying

a) Oh yes that SOUNDS right

Seldom | 1 | 2 | 3 | 4 | 5 | Almost  
Always

b) Oh yes I SEE what you mean

Seldom | 1 | 2 | 3 | 4 | 5 | Almost  
Always

c) Oh I FEEL that makes sense

Seldom | 1 | 2 | 3 | 4 | 5 | Almost  
Always

4) Place a circle on one of the following statements which best describes you. When you are not making yourself clear to someone, do you most often know because

a) You can hear it from what they say

b) You can see it from the look on their face

c) You sense it because they seem to feel unsure.

5) In perceiving new learning situations, do you prefer to focus on concepts (logic and ideas), or do you prefer to be involved in experiences (dealing with situations in an intuitive and personal way).

Concepts | | | | | Experience  
Always Mainly Both Mainly Always

6) In processing and understanding new information, do you prefer to reflect and observe, or do you tend to look for practical meanings with an emphasis on doing or experimenting.

Observe | | | | | Experiment  
Always Mainly Both Mainly Always

Exhibit 4.3 cont. Sample of teaching material developed to support the topic on thinking and learning styles.

7) Please rank the following words in an order (1, 2, 3..., where 1 is best) that best describes your preferred method of handling new learning situations. You can give equal ranking to any or all of the words.

- ☐ feeling
- ☐ doing
- ☐ thinking
- ☐ watching

8) Please rank the following words in an order (1, 2, 3..., where 1 is best) that best describes your response when someone is giving you a new piece of information. You can give equal ranking to any or all of the words.

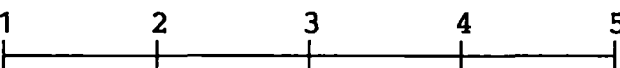
- ☐ Why?
- ☐ What?
- ☐ How does it work?
- ☐ If?

9) Please rank the following learning experiences in an order (1, 2, 3..., where 1 is best) that you believe is the most effective way for you to learn new information. You can give equal ranking to any or all of the words.

- ☐ Lectures
- ☐ Laboratory
- ☐ Small group assignments
- ☐ Projects (Design and make, etc)

10) I feel a step by step method is best for problem solving

Strongly Agree    1                  2                  3                  4                  5    Strongly Disagree



11) Daydreaming has provided the impetus for the solutions of many of my more important problems

Strongly Agree    1                  2                  3                  4                  5    Strongly Disagree

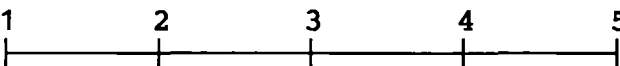


Exhibit 4.3 cont. Sample of teaching material developed to support the topic on thinking and learning styles.

12) Thorough planning and organization of time are mandatory for solving difficult problems

Strongly Agree | 1 | 2 | 3 | 4 | 5 | Strongly Disagree

13) I rely on hunches and the feeling of "rightness" or "wrongness" when moving towards the solution of a problem

Strongly Agree | 1 | 2 | 3 | 4 | 5 | Strongly Disagree

14) Please rank the following words in an order (1, 2, 3..., where 1 is best) that best describes your strength in the activity. You can give equal ranking to any or all of the words.

<input type="checkbox"/> analytical	<input type="checkbox"/> innovation
<input type="checkbox"/> people skills	<input type="checkbox"/> creative aspects
<input type="checkbox"/> planning	<input type="checkbox"/> administrative

15) Please rank the following words in an order (1, 2, 3..., where 1 is best) that best describes the way you see yourself.

<input type="checkbox"/> logical	<input type="checkbox"/> emotional
<input type="checkbox"/> creative	<input type="checkbox"/> spatial
<input type="checkbox"/> critical	<input type="checkbox"/> intuitive
<input type="checkbox"/> sequential	<input type="checkbox"/> artistic
<input type="checkbox"/> detailed	<input type="checkbox"/> controlled
<input type="checkbox"/> analytical	<input type="checkbox"/> holistic

Exhibit 4.3 cont. Sample of teaching material developed to support the topic on thinking and learning styles.

aware of their own learning preferences but it will be of value in their professional careers when instructing colleagues.

Exhibit 4.4 contains an exercise for students to do that will require them to use analytical thinking for the first question and more creative thinking for the rest. This exercise is intended to be a lead into the concepts of right and left brain thinking and the work of Ned Herrmann. Students will be required to work individually and as a group using exhibit 4.5 to arrive at a definition of creativity. This will lead into looking at how creative thinking can be used to complement logical thinking.

#### 4.4 TOPIC OUTLINE FOR VISUAL THINKING

Visual thinking is something which engineers generally tend to use in a fairly limited manner. Therefore in developing this topic, a deliberate attempt was made to expose students to as wide a range as possible of visual thinking skills. The topic outline, which is presented in exhibit 4.6, begins with an exercise based on pictionary. Pictionary is an ideal game for developing our skills at communicating visually because one has a limited time in which to characterise some object by sketching a few lines. The time limit ensures that someone with a lack of drawing skills can compete those who have good drawing skills. Exhibit 4.7 outlines an exercise that is the engineering version of the game pictionary. This is used to lead into a more general examination of the ways in which ideas can be communicated to someone else visually. Television commercials being one obvious example, but the use of cartoons and word pictures such as analogies and metaphors will also be covered.

### FLEXIBILITY IN THINKING

(Time 20 mins)

Research indicates that we use different parts of our mind for solving different types of problems. The following questions will encourage you to experience some of these different thinking modes as you seek to obtain the solutions.

1. Each of three friends - Mr Carpenter, Mr Mason and Mr Painter - is engaged in a different occupation. By a strange coincidence one is a carpenter, one is a mason and one is a painter; but their names do not necessarily match their trades. Assuming that only one of the following four statements is true can you work out who does what?

Mr. Carpenter is not a painter  
Mr. Mason is not a carpenter  
Mr. Carpenter is a carpenter  
Mr Mason is not a painter

2. An eccentric old king wants to give his throne to one of his two sons. He decides that a horse race will be run and the son who owns the slowest horse will become king. The sons, each fearing that the other will cheat by having his horse run less fast than it is capable, ask the court fool for his advice. With only two words the fool tells them how to make sure that the race will be fair. What are the two words?

3. Can you think of a way in which you put a sheet of newspaper on the floor so that when two people stand face to face on it, they won't be able to touch one another? Cutting or tearing the paper is not allowed. Neither is tying up the people or preventing them from moving.

4. The Roman numeral for 9 shown below can be turned into a 6 by adding only a single line. Suggest two possible solutions to the problem.

IX

5. A man and his son were driving along a highway one day when their car was involved in a very serious accident. The man was killed and the boy rushed to hospital. The surgeon looked at the boy and said I cannot operate on this boy because he is my son. Can you explain how this is feasible?

6. A man builds a house with four sides, a rectangular structure each side having a southern exposure. A bear comes wandering by. What colour is the bear?

Exhibit 4.4. Sample of teaching material developed to support the topic on thinking and learning styles.

**QUALITIES OF LOGICAL AND CREATIVE THINKING**  
(Time 25 mins)

Thinking is an essential part of the way we live our daily lives. Sometimes we use logical thinking while on other occasions we need to use creative thinking. In this exercise you are required to list the qualities that you think characterise logical and creative thinking. Then share your list with other members of your group. Finally compare your combined list with those shown on the overhead transparency.

LOGICAL THINKING IS .....

My List	Group/OHT List

Exhibit 4.5. Sample of teaching material developed to support the topic on thinking and learning styles.



CREATIVE THINKING IS .....

My List

Group/OHT List

Exhibit 4.5 cont. Sample of teaching material developed to support the topic on thinking and learning styles.

**TOPIC: VISUAL THINKING**  
(Three hours)

**Topic Objectives:**

To understand the power of persuasion behind visual images as evidenced by being able to identify what images adverts are linking to their product.

To be able to think visually and communicate ideas visually as evidenced through sketches and mindmaps.

To understand and apply the power of visual images as a memory tool as demonstrated by using visual association to remember lists of objects.

To think visually as a way of creative thinking as demonstrated through creating a personal logo.

**Outline of Topic Delivery**

1. Students play engineering pictictionary as detailed in Exhibit 4.7. Finish with a brief discussion about communicating ideas visually. (Total time 25 mins)
2. Selling ideas using the power of visualization in analogies, metaphors, cartoons, TV commercials. (Total time 15 mins)
3. Visual Brainstorming. Thirty circles exercise, see Exhibit 4.8. (Total time 10 mins)
4. Exercise to sketch three houses, see Exhibit 4.9, leading into a discussion about the right and left brain thinking that was required while drawing each of the houses. (Total time 15 mins)
5. Brief discussion about the use of pictures to convey ideas. Exercise to draw a cartoon to illustrate the main idea contained in a short article. (Total time 30 mins)
6. Give out imagining exercise for students to do for next lesson. Discuss imagining exercise at next lesson, see Exhibit 4.10. (Total time 10 mins)
7. Introduce the construction of mindmaps and get students to develop a mindmap of the course so far. (Total time 25 mins)
8. Lecture on memory, how it works and the power of visualization to improve memory. The use of visual association techniques to aid memory. (25 mins)

Exhibit 4.6 Topic outline for Visual Thinking.

**ENGINEERING Pictionary**  
(Time 25 mins)

Sketching is a way of visually communicating an idea between one person and another. For example most people would rather have a map of how to find their destination than to try and remember a whole series of instructions. This exercise is designed to develop our awareness on the importance of being able to distil the visual essence of an object before we try and communicate to others. This is a part of the skill of a cartoonist who with a few exaggerated lines can capture some essence of leading social and political figures.

1. The class is to be divided into groups of four, six or eight people. Each group is further subdivided into teams of two. One person will initially do the sketching and the other is to try and name the object being sketched. Each group should arrange themselves in teams around a table.
2. One of the people in the group designated as a sketcher should select a card from the box and note the name of the object that is to be drawn. The card is passed to each of the other sketchers in turn so that all sketchers know what they are to draw.
3. The game begins when every one in the group is ready. The sketchers have three minutes to draw the object named on the card and their team member tries to guess the name of the object during this time. The round finishes at the end of three minutes or when someone guesses the name of the object.
4. In the next round the roles are reversed. The person who was previously sketching is required to do the guessing and the one who was guessing will do the sketching. The alternating of sketching and guessing roles continues during each round of the game. The winning team in each group will be the one that has correctly identified the most number of objects after eighteen minutes.
5. Take five minutes to discuss within your group the ease or difficulty with which you were able to sketch or name the objects.

Exhibit 4.7. Sample of teaching material developed to support the topic on visual thinking.

The term brainstorming is fairly familiar to a lot of professional people, including engineers, even though the word is often used inappropriately to describe a group of people coming up with some ideas during the course of a meeting. However the visual brainstorming exercise given in exhibit 4.8, is an excellent alternative to verbal brainstorming because it will also help foster right brain visual thinking.

The sketching exercises in exhibit 4.9 are to help students experience what it feels like to be working in right hand brain thinking mode. This will help them to recognise other occasions when their left brain shuts down and so assist them in working out their own strategies for thinking creatively, perhaps when washing dishes or gardening.

The exercise contained in Exhibit 4.10 on imagining is something that does not come easy to predominantly left brain thinker, it requires a lot of time and perseverance and for this reason it is intended as a home exercise rather than a class exercise. Students will also be introduced to the use of mindmaps as a way of pictorially expressing the relationship between primary and secondary ideas in any particular topic or problem. In the final part of this topic of visual thinking students will also be introduced to the use of visual association techniques as a way of improving memory.

## VISUAL BRAINSTORMING

Brainstorming is an idea generating activity that can be performed individually or in a group. Although brainstorming is usually verbal, it can take other forms, a dancer can brainstorm directly through dancing, a composer can brainstorm musically and a visual thinker can brainstorm visually. Visual brainstorming is a basic strategy for exploratory graphic ideation and should be used whenever thinking has become stale.

The two basic principles of visual brainstorming are:

1. Defer judgement until the session is over.
2. Reach for quantity. Take a problem of interest to you and generate a series of thumb-nail idea-sketches on that problem. Set a quantity goal (say 30 idea sketches in 60 minutes). Also keep a tally of every time you find yourself judging an idea while brainstorming.

The following exercise will enable you to evaluate how fluently and flexibly you currently generate and express ideas.

1. On a large piece of blank paper, draw 30 freehand circles, each approximately 25mm and 50mm apart.
2. In 5 minutes, draw a few sketchy details into or around each circle to make it an identifiable image (such as the planet Venus, a soccer ball, or a teapot). Work rapidly; fill one circle every 10 seconds and you will complete all 30 in 5 minutes.
3. How fluent in graphic ideation were you? Did you complete all 30 circles? How flexible were you? Did you fall into ruts (such as drawing four faces) or did you represent a variety of ideas? Repeated practice in generating a large number of varied ideas on a given theme in a short time period (say five minutes) will improve your ability in this important skill.

Exhibit 4.8. Sample of teaching material developed to support the topic on visual thinking.

## DOUBLE BRAIN

Sketching is an aid to our thinking and it is a help for developing visual ideas worth communicating. Sketching is basically a right hemisphere function. The purpose of these exercises is to help us to become conscious of our thoughts as we sketch and to help us to experience a shift from our dominant left hemisphere mode to our sub dominant right hemisphere mode.

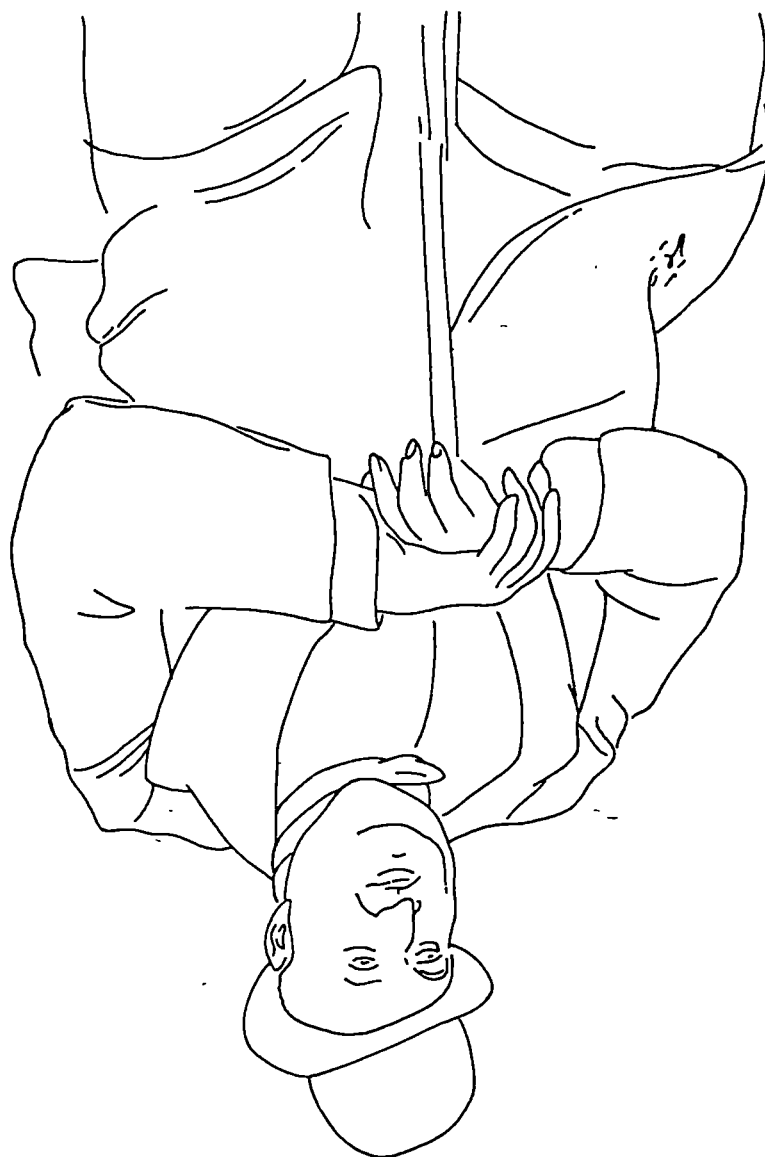
1. In 30 seconds, sketch a house.
2. Take two minutes to sketch a house that you see from a window or in a picture.
3. Take three minutes to sketch your dream house.
4. Draw the face of your best friend.
5. Take five minutes to discuss with another person how each of the sketching exercises differed in the type of thinking you had to do to carry out the assignment. Which one was the easiest for you to do?

The following exercise is to be undertaken in a quiet place where no one will interrupt you and allow yourself about twenty minutes to complete the exercise. On the next page is a line drawing by Picasso and the image is upside down. You are required to make a copy of the upside down image. You will copy the Picasso just as you see it and so your drawing will also be done upside down.

Look at the upside down drawing for about one minute, paying attention to the angles, shapes and how the lines come together. Place the drawing you are copying from in front of you and above the page you are copying onto. When you start your drawing, begin at the top and copy each line, moving from line to adjacent line, putting it all together like a jigsaw puzzle. Notice once you become involved with the drawing how absorbing the process becomes.

When you have finished, turn you drawing the right way up and compare it with the original.

Exhibit 4.9. Sample of teaching material developed to support the topic on visual thinking.



Remember to keep this page so that the sketch is upside down while you are making your copy. Do not turn the picture round and look at it normally until you have completed making your upside down copy.

Exhibit 4.9 cont. Sample of teaching material developed to support the topic on visual thinking.

#### 4.5 TOPIC OUTLINE FOR CREATIVE THINKING

It can be seen from exhibit 4.11 that the main areas covered within the topic creative thinking is to identify the mental blocks that inhibit creative thinking and to look at how the use of lateral thinking, brain storming and synectics can facilitate creative thinking. Exhibit 4.12 is an exercise to encourage students to develop their own definition of creative thinking. Exhibit 4.13 is to support a lecture on mental thinking blocks and the need to keep an open mind. It also provides students with a check list to help them identify any inflexible thinking patterns that they may be using. An exercise in the use of brainstorming is given in exhibit 4.14. The final part of this topic is for students to learn how creative thinking skills can be fostered through the use of synectics. Through a short exercise they will be able to experience the use of idea generation techniques like "I wish" springboards, word association, excursions, analogies and paradoxes as part of the synectic process.



## IMAGINING

Visual imagining ability is complex, since it depends not only upon our ability to form images, but also upon the supply of pertinent imagery which is stored in the mind. However experts in this area suggest that our visual imagining ability can be improved by practice and making it a higher priority item when problem solving.

Find some quiet spot at home where you will not be disturbed as you do this exercise. Note during each exercise, the clarity of your image and your ability to manipulate it. Do not give up after the first attempt, as with any skill, ability comes with practice.

Imagine the following:

1. A pot of water coming to a boil and boiling over.
2. A Boeing 747 being towed from the terminal, taxiing to the runway, waiting for a couple of other planes, and then taking off.
3. A running cow changing slowly into a galloping race horse.
4. An old person you know well changing back into a teenager.
5. A speeding car colliding with a giant feather pillow.
6. The imagine (5) in reverse.

Exhibit 4.10. Sample of teaching material developed to support the topic on visual thinking.

**TOPIC: CREATIVE THINKING**  
(Three hours)

**Topic Objectives:**

To distinguish between creative and logical thinking as demonstrated by being able to list aspects of both.

To increase awareness of how internal thinking patterns can be a block to creative thinking as evidenced by through applying a check list to identify mental blocks.

To know the principles of De Bono's Lateral Thinking techniques and applying them to familiar situations.

To know and apply strategies for using creative thinking to generate ideas both in groups and as an individual as demonstrated through participating in brainstorming type exercises.

**Outline of Topic Delivery**

1. Get students to do creativity questionnaire and have a open discussion on the answers. Generate a definition of creative thinking. See Exhibit 4.12.  
(Total time 15 mins)
2. Introduce the idea of mental conceptual blocks to finding a solution to a problem. Discuss perceptual blocks, emotional blocks, cultural and expressive blocks. Provide a strategy to identify dominant thoughts, crucial factors, polarising tendencies, boundaries and assumptions, see Exhibit 4.13.  
(Total time 35 mins)
3. Introduction to De Bono's Lateral thinking techniques.  
(Total time 25 mins)
4. Introduction to brainstorming as an ideas generation technique. Brainstorming exercise, see Exhibit 4.14  
(Total time 35 mins)
5. Introduction to synectics as another way of generating ideas. The use of "I wish" springboards, word association, career excursion, direct analogy, personal analogy, and paradox.  
(Total time 40 mins)

Exhibit 4.11. Topic outline for Creative Thinking.

### FACTS AND MYTHS ABOUT CREATIVITY

Complete the following quiz, circling true (T) or false (F) for each statement.

- |                                                                   |   |   |
|-------------------------------------------------------------------|---|---|
| 1. To be creative means imagining something completely new.       | T | F |
| 2. Only an expert knows enough to create something meaningful.    | T | F |
| 3. Only a gifted few minority are creative.                       | T | F |
| 4. Creative people are weird or insane.                           | T | F |
| 5. If you really have creative talent, someone will discover you. | T | F |
| 6. Ideas are like magic: you do not have to work for them.        | T | F |
| 7. Creative thinking is nice but impractical.                     | T | F |
| 8. Creativity means complexity or high technology.                | T | F |
| 9. The best ways and inventions have already been found.          | T | F |
| 10. Only people with a high I.Q. can be creative.                 | T | F |
| 11. Only men are creative geniuses.                               | T | F |
| 12. People under 40 are too young to be creative.                 | T | F |

In the space below write down your definition for creative thinking.

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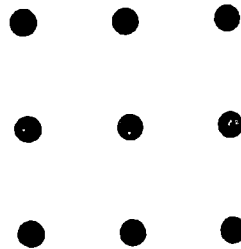
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Exhibit 4.12. Sample of teaching material developed to support the topic on Creative Thinking.

### KEEP AN OPEN MIND

The techniques and skills of creative thinking can be learned. Techniques are merely the formal setting that encourages the use of creative thinking. Skill in creative thinking, like any other skill, comes with the practise of techniques.



In the above figure draw no more than four straight lines (without lifting your pencil from the paper) which will pass through all nine dots.

(5 mins)

Can you solve the above problem using three lines or even one line?

It is important to develop an attitude of awareness about the dangers of being trapped by a fixed way of looking at things and of accepting the confines of an existing concept. There is a need to be able to recognise the dangers of arrogance in thinking and awareness that adequacy does not prevent the introduction of a better idea.

The following set of questions will help you keep an open mind and look beyond a first response to any given situation. Practiced, they will help foster creative thinking by allowing you to break out of some current thinking patterns. Think of the last major disagreement that you had with someone (parent, colleague, partner or friend) and use the chart to identify what dominant thoughts, crucial factors, polarising tendencies, boundaries and assumptions were involved.

Exhibit 4.13. Sample of teaching material developed to support the topic on Creative Thinking.

Dominant thoughts organise the approach to a problem in the same way that a dominant person organises a group. Sometimes the idea is specifically stated, but normally there is only a general awareness of it. What are the dominant thoughts about the current problem by you, by your group?

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Crucial factors are usually taken for granted. No one voices them in the open and so they are very difficult to establish and note. What are the apparently small insignificant details that are stopping big decisions about the current problem?

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Polarising tendencies are either/or situations. They need to be discovered, noted and removed from the mind because they will exclude intermediate options. Write down the either/or situations which relate to the current problem.

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Boundaries are the limitations on the thought process beyond which the thinker cannot go. They must be identified and removed from the thought process. What are the limits beyond which you think you cannot go?

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Assumptions are needed to start the thinking process. They are the material that is fed in to help ideas grow. They should be noted because they can easily become boundary conditions. State all your assumptions on the subject, however shaming they may be.

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Exhibit 4.13. Sample of teaching material developed to support the topic on Creative Thinking.

## BRAINSTORMING (35 mins)

Verbal brainstorming or classical brainstorming was developed in 1938 by Alex Osborn. It is a group method of creative idea generation. The ideal group size for a verbal brainstorming session is from six to nine people. Larger group sizes can result in a reduced contribution of ideas from quieter team members while smaller group sizes can easily become forums for the arguing points of view. It is important to set a time limit for the session, twenty minutes is usually sufficient and forty five minutes should be regarded as an outside maximum.

People frequently mistake committee discussions or meetings with brainstorming. These undirected repetitive, critical or routine discussions of problems and old solutions have little to do with brainstorming. Brainstorming requires careful mental preparation, including a problem briefing and a creative thinking warm up. Although it is a creative freewheeling activity, definite rules and procedures are followed.

### Rules of Brainstorming

1. Generate as many ideas as possible. Quantity counts! Don't give long explanations along with your ideas, just toss them out using key words only. Be brief. Ideas do not have to be completely new. It is perfectly fine to "pinch" or expand or "hitchhike" or build on other people's ideas. The more ideas you generate individually or collectively, the better the chance that an innovative solution will be found.
2. Wild ideas are encouraged. This point cannot be over-emphasized; the more odd, weird, wild, impossible, crazy ideas are generated, the better are the chances of coming up with a truly original solution in the end. The only limit here is to avoid words and ideas that could be hurtful or offensive to your team members, because the stress that is caused will inhibit creative thinking in addition to undermining team spirit.
3. Do not judge ideas. Do not put down ideas or the people who express them (including yourself). Humour, favourable comments, laughter, and applause are all permitted. There is no such a thing as a dumb idea. There is also no such a thing as a right and wrong answer in brainstorming. Brainstorming is a deferred judgement activity. Idea evaluation and critical judgement comes later in the creative problem solving process.

Exhibit 4.14. Sample of teaching material developed to support the topic on Creative Thinking.

The best way to learn how to brainstorm is by doing it and the following exercise should help to consolidate the key ideas.

1. Divide into groups of seven or eight and select one person to be the facilitator and another to be the note taker for the group.
2. The facilitator will select a problem definition card from the box and brief the group on the problem's background. The facilitator will then get the note taker to write down a problem definition statement.
3. The facilitator will review the three rules of brainstorming and explain the "housekeeping procedures" that will be used regarding the collecting and writing down of ideas.
4. The group is given five minutes to find twenty different uses for a building brick (or pencil, newspaper, ruler, or paper clip). This acts as a warm up exercise to stimulate creative thinking.
5. A time limit of fifteen minutes is set and the group members are invited to start sharing ideas about the main problem. They can begin by bringing out the obvious, well known ideas, these have to be purged first before the mind will be able to bring out some really new creative ideas. "This is known as load dumping."
6. If the flow of ideas slows down then the facilitator can encourage the process by throwing out an outrageous idea to serve as stepping stone. Or the group can have generate a list of wishful thoughts by asking what if questions.
7. The facilitator gives a three minute warning when the time limit is coming up. When the process is completed, the facilitator should thank the group members for their participation.
8. As a group discuss the strengths and weaknesses of brainstorming as a process to generate ideas.

Exhibit 4.14 cont. Sample of teaching material developed to support the topic on Creative Thinking.

#### 4.6 TOPIC OUTLINE FOR CREATIVE DECISION MAKING

In this topic two decision making models are to be presented to students, together with some of De Bono's strategies for developing options and evaluating suggestions. The topic outline is given in Exhibit 4.15 and some exercises are presented in exhibit 4.16 that will be used to help students apply the techniques.

#### 4.7 TOPIC OUTLINE FOR CREATIVE TEAMWORK

It can be seen, from the topic outline given in exhibit 4.17, that this topic is centred around De Bono's six thinking hats technique. The six thinking hats was considered to a significantly useful strategy that students should become familiar with it because team work is an important part of the functioning of a professional engineer. Indeed even if in later life students do not formally run a six thinking hats style meeting, they will still be able to ascribe hat colours to colleagues members describing their dominant thinking preferences. This is helpful because they then seek to ensure that ideas receive balanced consideration before any decisions are reached. The purpose of the exercise given in exhibit 4.18 is to illustrate the benefits of team solutions to problem solving. This will provide a lead into discussing the dangers of "group think" and how it can be counter productive to creative thinking. A second exercise, which is given in exhibit 4.19, is intended to provide students with an opportunity to apply the six thinking hats technique.



**TOPIC CREATIVE DECISION MAKING**  
(Two hours)

**Topic Objectives:**

To know and apply a decision making model as demonstrated through the use of PISCO or DCDEI.

To have strategies for obtaining the factors that are relevant when making choices between a range of options as demonstrated through the use of techniques like De Bono's CAF and APC.

To have strategies for selecting one solution from a range of solutions to a problem as evidenced through the use of PMI or an advantage/disadvantage matrix.

**Outline of Topic Delivery**

1. Exercise to get students to develop their own sequence for decision making. (Total time 15 mins)
2. Introduction to two models for decision making. These are PISCO (Purpose, Input, Solution, Choice, Operation) and DCDEI (Define objectives, Collect information, Develop options, Evaluate and decide, Implement) (Total time 35 mins)
3. Exercise to demonstrate De Bono's Consider All Factors (CAF) technique, see Exhibit 4.16. (Total time 10 mins)
4. Exercise to demonstrate De Bono's Agreement, Disagreement, and Irrelevant (ADI) technique. (Total time 10 mins)
5. Exercise to demonstrate De Bono's Alternative, Possibilities and Choices (APC) technique, see Exhibit 4.16. (Total time 10 mins)
6. Exercise using De Bono's Pluses, Minuses and Interesting (PMI) techniques as an aid to decision making, see Exhibit 4.16. (Total time 10 mins)
7. Exercise to construct an advantage/disadvantage decision making matrix. (Total time 10 mins)

Exhibit 4.15. Topic outline for Creative Decision Making.

### ATTENTION DIRECTORS

Edward De Bono the inventor of the term lateral thinking, believes we all know that, before we make a decision, we should rationally develop a set of options, find out all the relevant information, look at the problem from many different angles and reach an informed and rational decision. He also asserts that knowing is different from doing and for that reason he has developed a number of what he calls "Attention Directors." He gives the analogy of a child crossing a road. Removed from the situation, the child knows very well, that a car travelling quickly along a street would seriously injure anyone who stepped out in front of it. However, De Bono notes that a child chasing a ball will often continue running across a road. Knowing is not the same as doing and so children are taught the rule to look right and left before crossing roads, as a way of directing their attention to checking for possible danger before crossing they road. De Bono makes the point that his attention directors are very simple rules, they are also very obvious rules, but he believes they are very important rules for fostering a creative approach to problem solving. The following exercises will provide experience using some of De Bono's "Attention Directors."

#### Consider All Factors (CAF)

When you have to choose or make a decision there are always many factors to consider. It is easy for some factors to escape notice and decisions which seemed right at the time may well turn out to be wrong. CAF is used to note all possible factors so that non are left out of consideration.

In a group 4/5 take ten minutes to do a CAF on one of the following:

- . buying a second hand car.
- . choosing where to go for a holiday.
- . going to live in another country.
- . buying a computer and printer.

Exhibit 4.16. Sample of teaching material developed to support the topic on Creative Decision Making.

### Alternatives, Possibilities, Choices (APC)

Often there are more alternatives in taking a decision than first thought. Sometimes the most obvious choice is not the best one.

In a group of 4/5 take ten minutes to find out what the choices would be, if one of the following situations has occurred:

- . you have won \$20,000
- . you have three months to live
- . your dog can talk
- . you can fly

### Pluses, Minuses, Interesting (PMI)

PMI can be used individually or with a group. In a group, everyone is invited in turn to state one positive point about the proposal under discussion, then everyone is invited to make one Minus point and finally they are asked to contribute one interesting point. PMI is a very powerful strategy for forcing us to think beyond being negative about someone else's idea and positive about our own idea.

In a group of 4/5 people take ten minutes to do a PMI on one of the following.

- . every worker should retire at 55 years of age.
- . mothers raising a family should be classified as civil servants and paid a salary by the government.
- . engineers should be retested in all their final year exam subjects every five years.
- . motorists should be given a driving test every year.

Exhibit 4.16 cont. Sample of teaching material developed to support the topic on Creative Decision Making.

**TOPIC: CREATIVE TEAMWORK**  
(Two hours)

**Topic Objectives:**

To understand the benefits of using groups to generate ideas as demonstrated through prioritizing a list of objects.

To be aware how "group-think" can hinder creative thinking and be able to describe situations where it has occurred.

To know and apply a technique for creatively developing and evaluating ideas in a group situation as demonstrated in the use of De Bono's six thinking hats.

**Outline of Topic Delivery**

1. Exercise on prioritizing list of components used by astronauts on moon, first as individuals, second with whole group and then comparing with NASA listing, see Exhibit 4.18. Lead into the benefits and disadvantages of team work including group think.  
(Total time 25 mins)
2. Introduction to De Bono's six thinking hats.  
(Total time 25 mins)
3. Exercise using six hats thinking. (See Exhibit 4.19)  
(Total time 50 mins)

Exhibit 17. Topic outline for Creative Teamwork.

**SURVIVAL PRIORITIES**  
(15 mins)

**Instructions**

You are part of a spaceship crew originally scheduled to rendezvous with a mother ship on the lighted surface of the moon. Due to mechanical difficulties, however, your ship was forced to land at a spot some 200 miles from the rendezvous point. During re-entry and landing, much of the equipment aboard was damaged and the captain was killed. Since survival depends on reaching the mother ship, the most critical items available must be chosen for the 200 mile trip. Below are listed, the 15 items left intact and undamaged after the landing. Your task is to rank them in terms of their importance in allowing your crew to reach the rendezvous point. Place the number 1 by the most important item, the number 2 by the second most important, and so on, through to number 15 the least important.

Your Ans	Group Ans	NASA Ans	
.....	.....	.....	Box of matches
.....	.....	.....	Food concentrate
.....	.....	.....	20 metres of nylon rope
.....	.....	.....	Parachute silk
.....	.....	.....	Portable heating unit
.....	.....	.....	Two .45 calibre pistols
.....	.....	.....	One case dehydrated milk powder
.....	.....	.....	Two 40 kg tanks of oxygen
.....	.....	.....	Stellar map (of the moon's constellation)
.....	.....	.....	Life Raft
.....	.....	.....	Magnetic Compass
.....	.....	.....	25 litres of water
.....	.....	.....	Signal flares
.....	.....	.....	First aid kit containing injection needles
.....	.....	.....	Solar powered F.M receiver-transmitter

Exhibit 4.18. Sample of teaching material developed to support the topic on Creative Teamwork.

**SIX THINKING HATS**  
(Total time 50 mins)

The class is to divide up into two major groups and go into two separate class rooms to do this exercise. Each group will then sub divide into group A and group B and do a short role play based on the topic specified below. Each sub group will have five minutes to collect their thoughts and to designate someone to play the role of blue hat. Subgroup A will then have fifteen minutes to demonstrate De Bono's six thinking hats being applied to their topic while subgroup B watches. It will then be subgroup B turn to role play their topic while subgroup A watches. Comments on the two role plays are to be shared within each major group at the end of the exercise.

The topic for each sub group is as follows:

A A country which uses a lot of nuclear material during various processes has offered the Australian government a one thousand million dollar contract for the disposal of the nuclear waste somewhere in Australia. Accepting the contract would mean the creation of 500 new jobs directly with the potential for 800 infrastructure jobs (retailers etc). There is a strong environmental lobby group that is opposed to Australia being used as a nuclear waste dump. You are the engineering consultants who have been asked to advise the government as to whether they should accept or refuse the contract. What is your advice?

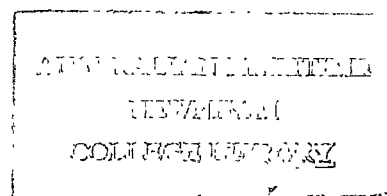
B You are the senior administrator for a hospital and the leading surgeon has referred the following problem to you for your decision about a life and death matter. Five patients are in a hospital ward suffering from a terminal but curable disease. The hospital has enough resources to save only one patient, and the others will almost certainly die although every effort will be made to ensure they are as comfortable as possible. Your decision is required as to which one should be selected for the life saving treatment. What is your choice? The known facts are as follows:

- 1 Mary is sixty years of age. Her husband Bill has just retired and they are planning to have a world cruise and then build their dream house.
- 2 Donald is twenty two years of age. He is a pleasant, outward going sportsman who has already represented his country many times in his sport.

Exhibit 4.19. Sample of teaching material developed to support the topic on Creative Teamwork.

- 3 Sarah is twenty eight years of age. She is married to Bruce, and is three months pregnant with their first child.
- 4 John is forty five years of age. He is married to Bev and they have three children. He is an outstanding academic, with a Nobel prize in his field.
- 5 Carol is fourteen years of age. Already she is a brilliant pianist and has written a major symphony which has been played by leading orchestras around the world.

Exhibit 4.19. Sample of teaching material developed to support the topic on Creative Teamwork.



#### 4.8 TOPIC OUTLINE FOR CREATIVE DESIGNING

The topic on creative designing is not intended to have any formal lecture time because the subject is intended to act as a vehicle for students to put into practice all the techniques learnt during the curriculum delivery. Two hours have been set aside for routine housework of allocating the design assignments, critiques of student wall displays, and general consultations by groups with the project supervisor. The topic outline is presented in exhibit 4.20.



**TOPIC: CREATIVE DESIGNING**  
(Two hours class contact time)

**Topic Objectives:**

To develop skills in working in small groups as demonstrated by obtaining a solution to a set problem.

To develop skills in creative thinking as evidenced by the development of a wide range of feasible and impractical solutions.

To develop skills in decision making as evidenced by the choice made for a preferred solution from a wide range of solutions.

To develop skills in the communication of engineering concepts as demonstrated through a design report.

To be a vehicle for integrating the skills and ideas developed in this unit.

**The topic will be undertaken as follows:**

1. Students will be formed into arbitrary groups of four or five people at the beginning of the unit.
2. Each group will select one design problem from the list and prepare a conceptual solution. Each group will be expected to develop a variety of alternative solutions to their problem and to present a wall display of three solutions for peer group critique. Each group will be expected to select one design solution and to develop that solution for submission as a report.
3. The group solution is to be submitted as a formal report and should detail each of the steps that has been taken in arriving at the solution. The report should demonstrate how the principles of creative thinking have been applied in arriving at a solution.
4. The report should be of a professional standard with reference and bibliography sections. The report should be dated. A title page should clearly identify the project and the group members submitting it.
5. The report should clearly demonstrate each step towards the solution and be illustrated with sketches and drawings as appropriate. A report of at least ten A4 pages is envisaged.

Exhibit 4.20. Topic outline for Creative Designing.

#### 4.9 ASSESSMENT OF STUDENT LEARNING

Student learning will be assessed through three individual assignment exercises, two group assignments and one group report of a solution to a given design problem as outlined in Exhibits 21a and 22a. The five assignments and the group report will carry a maximum of 100 marks each. Assessment of the individual assignments and the report will be made using the assessment sheets contained in Exhibits 21b and 22b respectively. Each student will be given a copy of the relevant sheet with each assessed exercise.

Each student will be allocated a mark at the completion of the unit which will be calculated as follows:

1. The total assignment marks will be divided by five to give an average assignment mark out of one hundred.
2. The average assignment mark will be added to the group report mark to give a unit total mark out of two hundred.
3. The unit total mark will be divided by two to give a unit assessment mark out of one hundred.
4. Students who have achieved a unit assessment mark of fifty or more will be deemed to have satisfactorily demonstrated their learning of the curriculum content and will be given a grade of pass for the unit.
5. Students who have obtained less than fifty marks will be deemed to have demonstrated unsatisfactory ability in their learning of the curriculum content and they will be given a grade of fail for the unit.

### Individual Assessed Exercises

Thinking and Learning: Using your knowledge about Kolb's learning styles quadrant and Herrmann's four quadrant brain model, describe your ideal methods for helping undergraduate students to learn engineering

Visual Thinking: Create a personal logo

Creative Thinking: Create five metaphors or similes that you feel best describe the meaning of life. Write them down in the style, "Life is ....." and then followed by a brief expansion of the metaphor.

### Group Assessed Exercises

Creative Decision making: You are the managing director of a small engineering company of 80 employees. The financial director has advised you that 20 employees must be made redundant. Identify what options are available to you concerning how you will deal with the employees who are to be made redundant.

Creative Teamwork: Imagine that you are in the plumbing business and you want to design and sell a better bath tub. What features would you include?

Exhibit 4.21a. Individual and group assignments.

ASSIGNMENT ASSESSMENT	Student..... Assignment..... ..... Lecturer.....
<p>The following criteria will be used in allocating marks to the assignments that are required to be submitted for assessment.</p>	
<p>Demonstrated an understanding of topic concepts. (max 20 marks).....</p> <p>Covered all required aspects of topic. (max 15 marks).....</p> <p>Demonstrated original thinking. (max 15 marks).....</p> <p>Application of creative thinking to exercise. (max 40 marks).....</p> <p>Legible, clean presentation (max 10 marks).....</p>	
<p>COMMENTS:</p>	

**Exhibit 4.21b. Assessment Sheet for Individual and Group Assignments.**

### List of Conceptual Design Problems

You must select one of the following topics.

1. Design a foot powered concrete mixer.
2. Design a system for producing initialled toast. It may be an attachment to suit existing toasters or it may be a new and separate unit. It must produce any initials requested.
3. Design a device which when thrown from a dingy on a lake, will descend to a predetermined (and adjustable) depth, collect a 0.5 litre sample of water and return it to the surface where it will remain until collected. The unit will not remain attached to the boat. Drift of the unit is not a problem and need not be considered in the solution.
4. Design a water powered egg timer giving a variable time between three and ten minutes.
5. Design a vehicle that is powered only by a standard building brick. The vehicle should be capable of passing through a framework 500mm high as it starts. There are no other design requirements.
6. Design a cheap "post pack" that will maintain medical drugs/specimens at approximately 0°C for 72 hours during postage.
7. Design an attachment for a domestic mower to convert it to a composteur and a fertiliser spreader.
8. Design a mechanism which allows for a shell collector to walk along the beach scooping sand samples to a depth of 150mm seeking shells. The device should separate shells from the sand. The device should be able to be transported and operated by one person.

Exhibit 4.22a. List of Concept Design Projects

<p>CREATIVE DESIGNING</p> <p>REPORT EVALUATION</p>	<p>Student.....</p> <p>Assignment.....</p> <p>.....</p> <p>Lecturer.....</p>
<p>The following criteria will be used in allocating marks to the Creative Designing group report which is required to be submitted for assessment.</p>	
<p>Demonstrates original thinking. (max 30 marks).....</p> <p>The proposed solution is feasible. (max 10 marks).....</p> <p>Application of creative thinking to exercise. (max 35 marks).....</p> <p>Legible, clean presentation grammatical and easy to follow (max 10 marks).....</p> <p>Overall individual effort. (max 15 marks).....</p>	
<p>COMMENTS:</p>	

Exhibit 4.22b. Assessment Sheet for Concept Design Project.

## CHAPTER 5

### CONCLUSIONS AND RECOMMENDATIONS

#### 5.1 Conclusions

The aim of this dissertation was to develop an introductory curriculum on creative thinking skills for first year engineering students studying on a Bachelor of Engineering degree course. This aim has been achieved and a curriculum has been designed that will encourage students to develop whole brain thinking skills. The curriculum will help prepare students to be more innovative in their future engineering careers. In addition to producing the written curriculum which is given in Exhibit 4.1, topic outlines and a variety of teaching materials have also been produced to illustrate how the curriculum should be delivered to students.

The curriculum has been reviewed by nine colleagues and it has been subject to very favourable comments. Some concern was expressed that the fifteen hours allocated to this curriculum might be insufficient for teaching creative thinking skills. This concern was acknowledged and it is envisaged that further curricula on creative thinking would be produced when this introductory curriculum had been trialled with first year students. The comments of the curriculum evaluators have been incorporated into the curriculum given in Exhibit 4.1.

#### 5.2 Recommendations

In practice it is possible that the curriculum as planned may be different from the curriculum as that delivered to students. This loss of fidelity may occur through a number of unforeseen events, perhaps the perspective of creative thinking of the lecturer delivering the course may be different from the author of the curriculum.

Furthermore, in chapter 3 section 4, it was stated that a class size of twenty students is considered to be ideal and thirty should be considered to be a maximum, however it may be that timetabling requirements dictate a class size in excess of thirty students. Also priorities in the allocation of classrooms may mean that the room used for curriculum delivery may have an environment that inhibits creative thinking instead of encouraging it. It is also possible that some of the times allocated in the curriculum for activities may vary. It is recommended that the curriculum as detailed in exhibit 4.1 should be trialled to a group of volunteer students as a further part of the formative evaluation process of this curriculum before it is formally implemented. With the volunteer group it would be useful to run two small groups rather than one large group and to involve other teaching colleagues in delivering the curriculum. In addition to enhancing the formative evaluation process this would also increase the awareness about creative thinking skills among colleagues.

Successful translation of a planned curriculum into classroom practice on a long term basis, requires the programme to be monitored closely and built upon through an ongoing, consistent and planned follow-up process. Formative and summative evaluation of the curriculum would be essential along with continually developing knowledge about creative thinking skills among the lecturers involved in the teaching process and maintaining their awareness of alternative strategies to enhance the learning process. It would also be essential to implement an evaluation process that assessed how effective the programme was in regard to the development of students' creative thinking skills.



## BIBLIOGRAPHY

- Adair, J. (1985), Effective Decision Making, Pan Books, London.
- Adams, J.L. (1987), Conceptual Blockbusting; A Guide to Better Ideas, Penguin, London.
- Anderson, D.C. (1981), Evaluating Curriculum Proposals, Croom Helm, London.
- Anderson, S.B, Ball, S., Murphy, T.R. & Associates (1975), Encyclopedia of Educational Evaluation, Jossey Bass, San Francisco.
- Bloom, B.S. (1956), Taxonomy of Educational Objectives, The Classification of Educational Goals - Handbook 1: Cognitive Domain, David McKay Co., New York.
- Borich, G.D. (1974), Evaluating Educational Programs And Products, Educational Technology Publications, New Jersey.
- Botkin, J. W., Elmandjra, M. & Matilza, M. (1979), No Limits To Learning: Bridging the Human Gap, Pergamon Press, England.
- Boud, D. & Feletti, G. (1991), The Challenge of Problem Based Learning, Kogan Page, London.
- Brady, L. (1983), Curriculum Development In Australia, Prentice-Hall of Australia, Sydney.
- Bruner, J.S. (1965), The Process of Education, Havard University Press, Cambridge, Mass.
- Bruner, J.S. (1966), Towards a theory of Instruction, Harvard University Press, Cambridge, Mass.
- Buzan, T. (1993), Use Your Head, BBC Books, London.
- Cohen, D. & Simpson, G. (1976), Destination Debatable - On Education Objectives, Ashton Scholastic, Sydney.
- Dalton, J. (1986), Adventures in Thinking, Thomas Nelson Australia.
- Dalton, T.H. (1988), The Challenge of Curriculum Innovation, Falmer Press, London.
- Davis, E. (1981), Teachers As Curriculum Evaluators, Allen & Unwin, Sydney.
- De Bono, E. (1978), Teaching Thinking, Penguin, London.

- De Bono, E. (1990a), Six Thinking Hats, Penguin, London.
- De Bono, E. (1990b), Lateral Thinking, Penguin, London.
- Dixon, J.R. (1966), Design Engineering; Inventiveness, Analysis and Decision Making, Mc Graw-Hill, New York.
- Eisner, E.E. (1979), The Educational Imagination: On the Design and Evaluation of School Programs, Macmillan, New York.
- Edwards, B.E. (1979), Drawing on the Right Side of the Brain; A Course in Creativity and Artistic Confidence, J.P. Tarcher Inc., Los Angeles.
- Egan, K. & Nadaner, D. (1988), Imagination and Education, Teachers College Press, Columbia University, New York.
- Fisher, R. (1990), Teaching Children to Think, Basil Blackwell, Oxford.
- Gallant, R.A. (1980), Memory; How it Works, Four Winds Press, New York.
- Gregory, S. A. (1972), Creativity and Innovation in Engineering, Butterworths, London.
- Hammond, R.L. 1973, "Evaluation At Local Level", In Worthen and Sanders, Educational Evaluation: Theory And Practice, pp 157-69, Wadsworth, California.
- Henry, J. & Walker, D. (1991), Managing Innovation, Sage, London.
- Herrmann, N. (1990), The Creative Brain, Brain Books, North Carolina.
- Hergenhahn, B.R. (1976), An Introduction to The Theories of Learning, Prentice-Hall, New Jersey.
- Holt, J. (1964), How Children Fail, Pitman, New York.
- Hook, M.H. (1990), "Learning Styles: Mismatching for a Balanced Profile", Australasian Association for Engineering Educators, 2nd Annual Conference Proceedings, Melbourne.
- Hunkins, F.P. (1980), Curriculum Development; Program Improvement, Merrill, Columbus Ohio.
- Institution of Engineers Australia (1993), National Competency Standards For Professional Engineers (Stages 1 and 2), Pub I.E.Aus, ACT.
- Joyce, B. & Weil, M. (1986), Models of Teaching, Prentice Hall International, New Jersey.

- Kemp, B. (1979), "Specific Objectives: The Curriculum Panacea?", The Leader 1, pp 26-31.
- Kolb, D.A. (1984), Experiential Learning: Experiences in the Source of Learning and Development, Prentice Hall, New Jersey.
- Kolb, D.A. (1993), "The Process of Experiential Learning". In Thorpe, M., Edwards, R., Hansom, A., Culture and Process of Adult Learning, Routledge, London.
- Khun, T.S. (1970), The Structure of Scientific Revolutions, University of Chicago, Chicago.
- Lovell, R.B. (1980), Adult Learning, Croom Helm, London.
- Lumsdaine, E. (1993), Creative Problem Solving, College Custom Series McGraw Hill, New York.
- Marsh, C. & Stanfford, K. (1988), Curriculum Practices And Issues, McGraw-Hill, Sydney.
- McCarthy, B. (1982), "Improving Staff Development Through CBAM and 4MAT", In Educational Leadership, Vol. 40, No. 1, pp 20-27.
- McKim, R.H., (1980), Experiences In Visual Thinking, Brooks/Cole Pub. Co., California.
- Metfessel, N. S. & Michael, W. B. (1967), "A Paradigm Involving Multiple Criterion Measures For The Evaluation Of The Effectiveness Of School Programs", Educational and Psychological Measurement, No. 27, pp 931-943.
- Nickerson, R. S., Perkins, D.N. & Smith, E. E. (1985) The Teachning of Thinking, Lawrence Earlbraum Associates, New Jersey.
- Nierenberg. G.I. (1982), The Art of Creative Thinking, Simon & Schuster Inc, New York.
- Nolan, V. (1989), The Innovators Handbook; The Skills of Innovative Management, Sphere Books/Penguin Group, London.
- Peters, R.S. (1965), "Education as Initiation" In Archambault, R.S. Philosophical Analysis and Education, Routledge and Kogan Page, London.
- Peters, T. (1987), Thriving on Chaos; Handbook for a Management Revolution, Pan Books, London.
- Poole, M. (1980), Creativity Across the Curriculum, Allen & Unwin, Sydney.
- Popham, W.J. (1975), Educational Evaluation, Prentice-Hall, New Jersey.

- Print, M. (1993), Curriculum Development and Design, Allen & Unwin, Sydney.
- Robinson, F.G., Ross, J.A. & White, F. (1985) Curriculum Development for Effective Instruction, OISE Press, Toronto.
- Rogers, J. (1989), Adults Learning, Open University Press, Milton Keynes.
- Rust, J. & Golombok, S. (1989), Modern Psychometrics; The Science of Psychological Assessment, Routledge, London.
- Tyler, R.W. (1949), Basic Principles of Curriculum and Instruction, Chicago University Press, Chicago.
- Scriven, M. (1991), Evaluation Thesaurus, Newberry Park, California.
- Skinner, B.F. (1953), Science and Human Behaviour, Macmillan, New York.
- Sperry, R.W. (1973), "Lateral Specialization of Cerebral Function in Surgically Separated Hemispheres," In McGuigan, F.J. & Schoonover, R.A., The Psychophysiology of Thinking, Academic Press, New York.
- Taba, H. (1962), Curriculum Development; Theory and Practice, Harcourt Brace, New York.
- Thorpe, M., Edwards, R. & Hansom, A. (1993), Culture and Process of Adult Learning, Routledge, London.
- Wiles, J. & Bondi, J.C. (1984), Curriculum Development; A Guide to Practice, Merrill, Columbus Ohio.
- Woditsch, G.A. & Schmittroth, J. (1991) The Thoughtful Teacher's Guide to Thinking Skills, Lawrence Erlbaum Associates, New Jersey.
- Wolf, R.M. (1990), Evaluation in Education, Praeger, New York.
- Worthen, B.R. & White, K.R. (1987), Evaluating Educational and Social Programs, Kluwer Nijhoff, Holland.
- Von Oech, R. (1990), A Whack on the Side of the Head, Thorsons Ltd., England.

**APPENDIX A**  
**Evaluation of Curriculum**

Dear

The subject of my Master of Education dissertation has been to produce "A Curriculum for Developing Creative Thinking Skills in Engineering Students." Evaluation is an important part of the process of curriculum development and I am inviting you to participate in the evaluation of my curriculum using the form attached to this letter.

If you are happy to take part in the evaluation then I would like you to read through the information provided which for the moment has been labeled Appendices A to H. When you have read through the information, would you please answer the questions contained in the evaluation form according to your professional judgement. Please feel free to annotate with your comments any part of the information provided.

I emphasise that your participation is voluntary, however I will be most grateful for your cooperation.

Thank you

Norman Lawrence.

Attachments to this letter

Appendix A. Creative Thinking Skills Curriculum  
Appendix B. Curriculum Topic Outlines  
Appendix C. Teaching Material for Topic on  
Thinking and Learning Styles  
Appendix D. Teaching Material for Topic on  
Visual Thinking  
Appendix E. Teaching Material for Topic on  
Creative Thinking  
Appendix F. Teaching Material for Topic on  
Creative Decision Making  
Appendix G. Teaching Material for Topic on  
Creative Teamwork  
Appendix H. Evaluation of Student Learning  
Appendix I. Evaluation of Curriculum (Part of this  
letter)

EVALUATION OF CURRICULUM  
FOR CREATIVE THINKING SKILLS  
(Based on Brady 1983, p193)

1) Are the objectives clearly stated?

Very Clear |-----| Not very Clear

2) Are the objectives worth achieving?

Worth Achieving |-----| Not worth Achieving

3) Are the objectives relevant to engineers?

Very Relevant |-----| Not very Relevant

4) Are the objectives attainable?

Easily Attainable |-----| Not Attainable

5) Is the content of interest to students?

Great Interest |-----| No Interest

6) Is there a clear sequencing of the content?

Very Clear |-----| Not Very Clear

7) Is the content sufficient to achieve the objectives?

Very Sufficient |-----| Not Sufficient

8) Does the content expose the students to a significant range of thinking skills?

Very Significant |-----| Not Significant

9) Is there a variety of teaching methods?

Great Variety |-----| No Variety

10) Are the learning experiences sufficient to achieve the objectives?

Not Sufficient |-----| Very Sufficient

11) Do the methods involve students in the learning process?

Not At All |-----| Very High Involvement

12) Will the learning experiences help students to assimilate the thinking skills?

Not at All Helpful |-----| Very Helpful

13) Are the evaluation procedures sufficient to achieve the objectives?

Very Sufficient |-----| Not Sufficient

14) Is there a variety of evaluation procedures?

Great Variety |-----| No Variety

15) Will the evaluation procedures enhance the learning experience?

Greatly Enhance |-----| No Enhancement

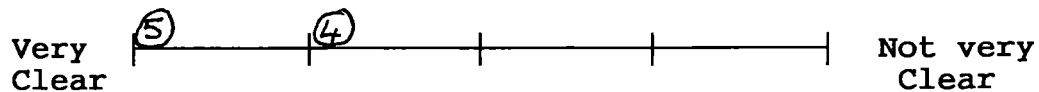
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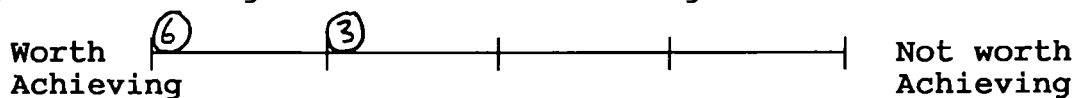
# REPLIES FROM CURRICULUM REVIEWERS ON THEIR EVALUATION OF A CURRICULUM FOR CREATIVE THINKING SKILLS

There were nine reviewers and the numbers in circles beside a possible answer indicate the number of reviewers giving that particular reply.

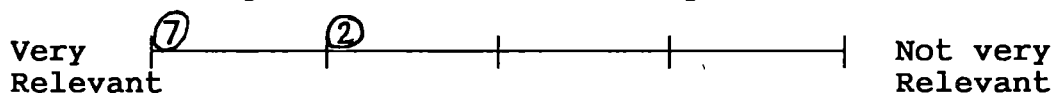
1) Are the objectives clearly stated?



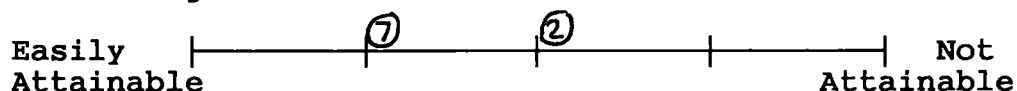
2) Are the objectives worth achieving?



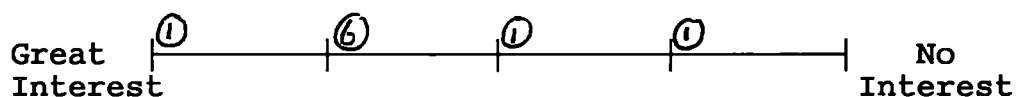
3) Are the objectives relevant to engineers?



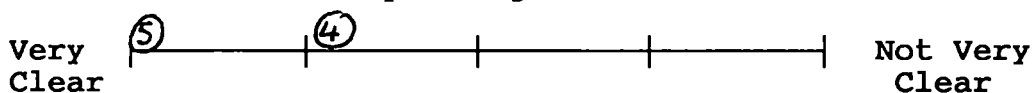
4) Are the objectives attainable?



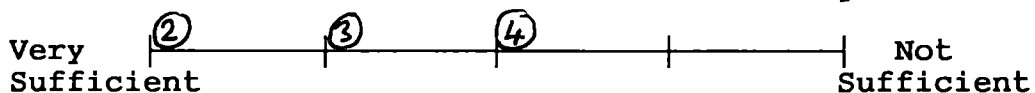
5) Is the content of interest to students?



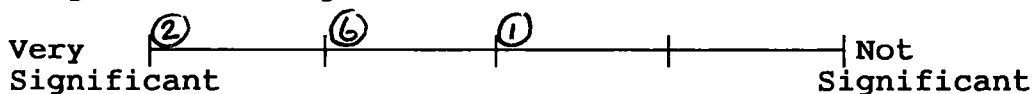
6) Is there a clear sequencing of the content?



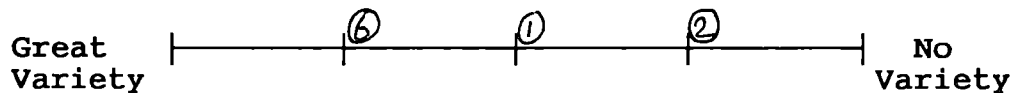
7) Is the content sufficient to achieve the objectives?



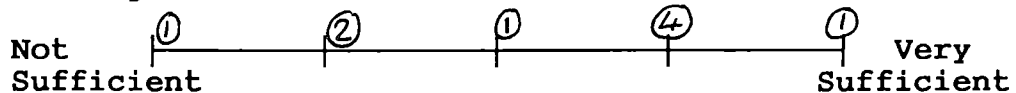
8) Does the content expose the students to a significant range of thinking skills?



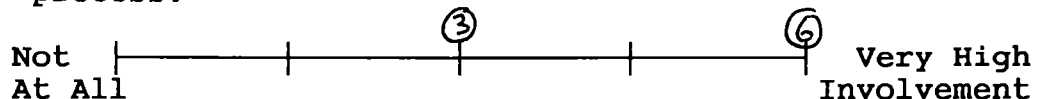
9) Is there a variety of teaching methods?



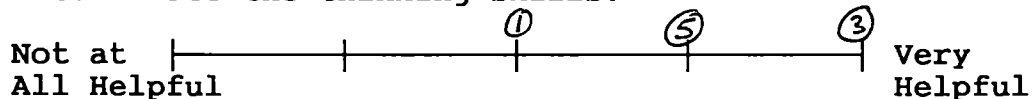
10) Are the learning experiences sufficient to achieve the objectives?



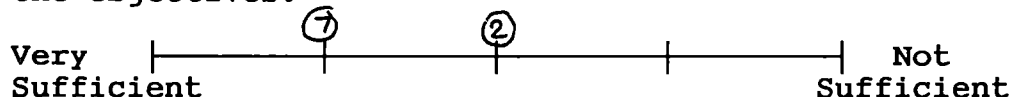
11) Do the methods involve students in the learning process?



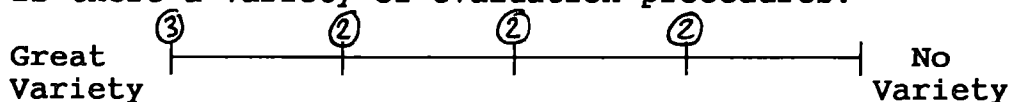
12) Will the learning experiences help students to assimilate the thinking skills?



13) Are the evaluation procedures sufficient to achieve the objectives?



14) Is there a variety of evaluation procedures?



15) Will the evaluation procedures enhance the learning experience?

