UNIT 8 TEACHING FOR THINKING

Structure

8.1 Introduction
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8.1 INTRODUCTION

A teacher’s task in the class room is not limited to the teaching of a subject or developing knowledge, skills and understandings among students. Merely teaching facts does not helps students to achieve their potential. Education should enable the students to think and solve problems. It should also enable them to understand the underlying meanings instead of memorizing facts for grades. As teachers, therefore, it is our duty to ensure that students think and reason on their own in a critical, creative and intelligent manner. With this goal in view, this unit will help you to foster a comprehensive view of two different forms and modes of thinking to sharpen your students’ thinking and to enable them to think critically and creatively.

8.2 OBJECTIVES

After going through this unit, you should be able to:

- distinguish between critical and creative thinking,
- state the relationship and differences between critical and creative thinking,
- describe the importance of critical and creative thinking,
- state the role of education vis-à-vis thinking,
- explain the shift or emphasis from the readymade product of knowledge to the process of acquiring knowledge in curriculum transaction.

8.3 MODES OF THINKING

This unit deals with fostering two different forms of thinking through instruction. They are critical and creative thinking. Critical thinking aims at simplification/generalization on the one hand and truth and accuracy on the other. It scrupulously adheres to establish cannons of logic. Logic is the science of thinking. It offers general rules for thinking. Knowledge of these rules for thinking helps us to verify whether our thinking in a particular instance is right. Mastery of these rules, assimilating them into the blood streams of our brain will ensure that our thinking does not go astray. The
process of critical thinking should be strictly according to the established
cannons of logic if it is to be valid. In critical thinking the road leading to truth
is already well laid out. Further, there is only one royal road — the road of
logic — to truth in critical thinking. And, truth is already waiting to be
discovered. Critical thinking is described in psychology as convergent
thinking, because anyone and everyone who wants to arrive at truth must
conform to the cannons of logic.

Creative thinking aims at novelty in the first instance rather than truth.
Because it aims at novelty, it necessarily has to be different from the
conventional modes of thinking. Hence, creative thinking is labeled in
psychology as divergent thinking. The outcome of creative thinking, however,
has to be validated only by critical thinking. Thus, critical thinking and
creative thinking are not anti-thetical but complementary to each other. Both
aim at truth. One lays the road, the other follows suit. Let us clarify this
concept with the help of a scientific discovery.

When Archimedes discovered the famous Archimedes' Principle he did so by
virtue of his creativity. As you know, the task assigned to Archimedes by the
King was to find out whether the goldsmith had used all the gold that he had
given him to make the crown or whether he had mixed some weight of baser
metal and stolen some of the gold. The crown was not to be melted for this.
Archimedes's mind was seized of the problem. He was wondering how he
could find an answer to what seemed an insoluble problem. As you know, he
found his body losing a part of its weight due to the buoyancy of the water in
the bathtub. Somehow it occurred to him in a flash that this apparent loss of
weight must be related to the volume of the body and its density. And, since
the density of gold is fixed and is related to its volume, the apparent loss of
weight of the mass of gold given by the King to the goldsmith for making the
crown should be equal to the apparent loss of weight of another piece of gold
equal in mass to that given by the King to the goldsmith if the goldsmith had
not mixed up other, baser metals. In other words, the crown and a piece of
gold equal in mass to that given by the King to the goldsmith should weigh
exactly the same both in air and in water.

This truth is obvious to us now, especially when it has been formulated as
being equal in weight in air and in water. But nobody had thought along these
lines before Archimedes. Hence, his thinking in the first instance, was
creative. When we teach Archimedes' Principle in class we take the student's
through the same steps of thinking. We draw their attention to the tight logic
underlying the steps. We demonstrate its truth by means of an experiment,
asking them to repeat the experiment and verify for themselves the truth of the
Principle. All these constitute critical thinking. Unfortunately, since the
syllabus is large, and it is the marks that students score in the examinations
that count, we just read out the principle, go through the motion of
demonstrating the experiment, ask students to do the same thing, and they
pass examinations with high scores. Perhaps they can reproduce the principle
in verbatim, and even mechanically repeat the experiment. But if we ask them
questions that involve the processes of thinking, most of the students would
not be able to explain. But it is only this ability to think reflectively and
critically that will stand the student in good stead, not the ability to repeat the
principle by rote, nor the ability to perform the experiment robot like, without
understanding it. It may be added here that it was the repeated discrepancy in
the experimental verification of the law of conservation of mass that led Einstein to reflect on it and arrive at his famous formula $E = mc^2$ which in turn led to the invention of the atom bomb.

The difference between critical thinking and creative thinking has been summarized in Table 8.1:

**Table 8.1: Difference between Critical Thinking and Creative Thinking**

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Description</th>
<th>Critical Thinking</th>
<th>Creative Thinking</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Scope</td>
<td>Selective</td>
<td>Generative</td>
</tr>
<tr>
<td>2.</td>
<td>Aim</td>
<td>Rightness</td>
<td>Richness</td>
</tr>
<tr>
<td>3.</td>
<td>Direction</td>
<td>Specific and singular</td>
<td>Non-specific, roving</td>
</tr>
<tr>
<td>4.</td>
<td>Nature</td>
<td>Continuous, tight,</td>
<td>Can be discrete, jerky</td>
</tr>
<tr>
<td></td>
<td></td>
<td>sequential</td>
<td>and jumping</td>
</tr>
<tr>
<td>5.</td>
<td>Condition</td>
<td>Have to be correct in every step</td>
<td>Not necessary to be correct at every step</td>
</tr>
<tr>
<td>6.</td>
<td>Negative</td>
<td>Negative used for blocking certain pathways</td>
<td>No negatives</td>
</tr>
<tr>
<td>7.</td>
<td>Status of concepts &amp; categories</td>
<td>Fixed</td>
<td>Not fixed</td>
</tr>
<tr>
<td>8.</td>
<td>Path</td>
<td>Follows most likely paths</td>
<td>Follows least likely ones</td>
</tr>
<tr>
<td>9.</td>
<td>Nature of the goal</td>
<td>Finite and</td>
<td>Probabilistic</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Definite</td>
<td></td>
</tr>
</tbody>
</table>

**Check Your Progress 1**

**Notes:**

a) Write your answers in the space given below.

b) Compare your answers with these given in the text.

1. Fill in the blanks with appropriate words in the following sentences.

   i) Creative thinking aims at ......................... in the first instance rather than truth.

   ii) Creative thinking is labeled in Psychology as ............... thinking.

   iii) Critical thinking is described in Psychology as ............... thinking.

   iv) Creative thinking and critical thinking are not anti-thetical but ................... to each other.
8.4 CRITICAL THINKING

Most of us do think well, but we do not know how we think. It is akin to children who learn bicycle riding without knowing the principles that keep a bicycle moving without falling on either side. For that matter, we wonder whether even performers of feats on bicycles in a circus know the principles that enable them to do what seems like a miracle.

You might agree that one who knows how a bicycle keeps moving is all the better for his knowledge than one who can ride a bicycle but cannot explain how it keeps from falling. Even illiterate people can think accurately and take correct decisions but most of them may not be able to explain how they arrived at the decisions. Knowledge of this "how" of thinking prevents the mind straying into wrong tracks. The essence of education consists in providing a hedge against this straying of the mind.

Many shortcomings can be traced to the failure of our education to develop the capacity for critical thinking among students. Why have we failed here?

There can be two important reasons for this. While ancient Indian education was moral, contemporary education is amoral. Certainly, it is not immoral. But it does not explicitly aim at inculcating values in the students. The socio-political environment has unleashed greed instead of promoting legitimate ambition. Ambition, backed by industry is desirable. Greed is an insatiable search for short-cuts to big money. The failure to distinguish between legitimate ambition and avarice is a failure to apply critical thinking to the stream of one's own inner experience. This is what has been called viveka, that is, discrimination in ancient Indian tradition. It connotes the ability to distinguish between right and wrong, and good and bad in the outer as well as inner worlds. We will not pursue this moral dimension further at this juncture.

Secondly, our education is examination-oriented. Its backwash effect is to oblige teachers to fill up the minds of students with ready-made knowledge, a relatively easy job, without developing in them the process by which this knowledge was arrived at by the scientists in the original instance. Real teaching consists in enabling the student discover by, and for himself, through the very thought process by which, say, Newton, discovered the law of universal gravitation. Actually the curriculum is meant to be a "runway" for the student's mind to take off, not a dead-end. This is where the teacher plays a very crucial and significant role.

We can certainly communicate more, but not fully. For that matter, even when you meet your students face-to-face in a classroom, you can do more than through TV. But you are not sure whether you can exhaustively communicate the insights you have into the structure of scientific thought processes because they are rooted at the nonverbal level.

The process of critical thinking can be reduced to three basic operations, namely,

- classification,
- identifying cause and effect relationships and
- identifying functional relationships.
These are explained below:

i) Classification: This is the first step in any science. It is also the first mental operation a growing child tries to master by observing similarities and differences, and trying to group similar phenomena together into a meaningful and manageable number of classes. It is an atemporal if not an instantaneous process. Perception of time is not involved in classification unlike in cause and effect relationship. As you know, there is always an interval of time, however short it may be, between a cause and its effect.

Unfortunately, we teach readymade schema of classification, that is, the product of classification rather than the process and the skill of classification. Actually readymade schema will be of little use to most of the students but mastery of the skill of classification will stand them in good stead till the end of their lives. But teaching and testing readymade schema is easier. Teaching the skill of classification and testing it are challenging. With a huge syllabus and limited time available for teaching a large number of students in a class with uneven ability level, we remain contented with teaching readymade schema. But that is of little use, even a waste of time, for the teacher and the students. They just help the students escape from the lower class to the higher class, year-after-year, and the teacher to make an apology – through the prevailing, convenient mode of testing – of having taught the subject, the husk instead of the grain, that is, the cognitive process involved in understanding the subject. How should we teach a subject for mastering the process and the skill of classification, instead of passing the content centred test? The former is real teaching while, the latter is mere coaching.

The two lesson plans given in Table 8.2 presented parallel to each other, must bring home the difference between real teaching and mere coaching.

<table>
<thead>
<tr>
<th>Teaching Ready Made Product of Thinking</th>
<th>Teaching the Process of Thinking</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Objective</strong></td>
<td>Teacher Content Pupil Evaluation</td>
</tr>
<tr>
<td>Ask the student to answer the question: What are the things we study about in Chemistry?</td>
<td>Describes: Chemistry is the study of elements mixtures and compounds</td>
</tr>
<tr>
<td><strong>Ready Made Product of Thinking</strong></td>
<td>Name the various kinds of things we find around us.</td>
</tr>
<tr>
<td><strong>Teaching the Process of Thinking</strong></td>
<td>Can you exhaustively name all the things around us?</td>
</tr>
<tr>
<td>Should we or should we not learn about things around us for living well?</td>
<td>Is puzzled</td>
</tr>
<tr>
<td>Teaching Learning Strategies</td>
<td>Thinking</td>
</tr>
<tr>
<td>-----------------------------</td>
<td>---------</td>
</tr>
<tr>
<td><strong>How can we know what we should know about and what we need not?</strong> For example, How can we know whether a particular substance is a poison or a nourishment?</td>
<td><strong>Is puzzled?!</strong></td>
</tr>
<tr>
<td><strong>How did he do it?</strong></td>
<td></td>
</tr>
<tr>
<td>Yes, somebody studies, leaves notes behind, which accumulate</td>
<td><strong>We can take up things which look alike, feel alike or sound alike as the case may be and study one or a few of them.</strong></td>
</tr>
<tr>
<td>But even then we can never exhaustively study all the things around us. Can we?</td>
<td>From a study of a small number of things we get to know the properties of a large number of things</td>
</tr>
<tr>
<td><strong>Then, what do we do?</strong></td>
<td></td>
</tr>
<tr>
<td>Yes, you are right. But what is the advantage of this approach?</td>
<td></td>
</tr>
<tr>
<td><strong>We club together those which are similar.</strong></td>
<td></td>
</tr>
<tr>
<td>Can anybody tell me what such clubbing similar things together is called?</td>
<td><strong>Classification</strong></td>
</tr>
<tr>
<td>Yes, when we are confronted with a large number of different kinds of things, the best way to deal with them is to group similar things</td>
<td></td>
</tr>
</tbody>
</table>
together—that is classify them.

Now, can you tell me how the numbers in the arithmetic progression-1,2,3,4,5,6,... are classified in the first instance?

Can anyone tell me how pupils in a class are first classified?

You will study in Botany how plants are classified; in Zoology how animals are classified.

Almost any and every subject begins with classification of the phenomenon of its domain.

You may remember you listed some of the things around us. Can you recollect them?

There are many ways of classifying these. Can you try? Well, it is good you remember classification of things in terms of the state they are in. This is one way.

But does it sound right to classify cats and dogs as solid? How else can we classify the items in this list?

Recall of Classification of numbers

Odd numbers and even numbers

As boys and girls.

Dog, table, cat, water, sand, air, butter ghee petrol, iron.

Solids liquids and gas

No

Living things and non-living things
Fine, that’s right—because living things have a set of properties distinct from those of non-living things. This classification will help us understand the things around us better, more economically in terms of memory space in our brain.

Now, can you tell me how appropriate classification must help us?

Now, sort out the list

Now, Chemistry is concerned with what is “inside” each of these things—that is, the ultimate stuff of which things are made.

From this point all things in the universe have been classified into three major groups:

Elements, Mixtures and Compounds. Anything and Everything found anywhere in the universe should fall within anyone and only one of these three categories.
Tfids, this classification is at once very clear and comprehensive—nay, exhaustive. So, it is quite sound and useful.

Can you tell me two criteria for a sound scheme of classification?

Now, what is an element? What is a mixture? What is a compound? What is a given thing?

A mixture consists of two or more kinds of stuff which have however lost their original properties.

Clarity and comprehensiveness are key in Chemistry teaching for Thinking.

An example of an element is iron; an example of a mixture is air, which consists of oxygen and nitrogen. While oxygen makes things burn fast and nitrogen puts out fire, air keeps things burning.

An element consists of only one kind of stuff. A mixture consists of two or more kinds of stuff. A compound consists of two or more kinds of stuff which have however lost their original properties.

The criterion by which we decide whether a given thing is an element, mixture or compound is the categorisation of phenomenon in the first instance and the spelling out of the basis on which an item is to be judged to belong to the category that determine whether a particular scheme of classification is sound or not.
Water is an example of a compound; it consists of hydrogen and oxygen.

While hydrogen itself would burn, and oxygen would help things burn faster, water would neither itself burn nor help other things burn. Thus both the elements—hydrogen and oxygen have lost their respective original properties when they became the compound ‘water’.

We have seen how we can teach the *process of classification* rather than the readymade schema of classification — the *product* of the mental exercises of those who originally arrived at this schema of classification.

Now, carry out an exercise about your own beliefs. You know that some of your beliefs are valid and would stand the scrutiny of scientific method. The scientific method consists of objective, empirical verification of claims about generalizations. An example for a scientifically verifiable belief is that when hydrogen which itself burns, and oxygen which supports burning, will always result in water which neither burns nor supports burning. Some of our beliefs are plain superstitions. An example for a plain superstition is that if a cat crosses our path when we set out, we will meet with failure. There are some others that we can neither dismiss as invalid nor accept as valid. Belief in God, or the doctrine of rebirth are examples of this category.

Close the rest of this page and try to give names of these three categories of beliefs on the analogy of the three categories of education in relation to morals that we have discussed above.

| Table 8.3: For Exercise in the Classification of Beliefs |
|-----------------------------------------|-----------------|----------------|
| **Rational**                           | **Irrational**  | **A rational** |
| e.g., law of gravitation               | e.g., omens     | Faith in God   |

Now ask your students to carry out the exercise. Let them become aware of the three kinds of beliefs though they may not be able to get rid of irrational
beliefs, particularly the behaviour patterns that stem from irrational beliefs, overnight.

Let us take another example. Aristotle declared that when two balls of different mass are dropped from the same height, the heavier one would strike the ground first. This was proved wrong by Galileo who demonstrated centuries later by his famous Pisa Tower experiment that both the balls would strike the ground simultaneously. Was Aristotle’s belief rational, irrational or arational? Give reason for your classification. Pose this question to your students, get the range of their answers, scrutinize them and have a debate in the class. Such a debate would sharpen the students’ thinking.

ii) Cause and effect relationships: The next important mode of critical thinking is verification of cause and effect relationships. Cause and effect relationships are pivotal ones in the scientific enterprise. They are sequential to classification. Usually, cause and effect relationships are explored between categories that have been arrived at in the earlier phase of classification. As we have seen earlier, there is invariably a time interval, sometimes so short as to appear instantaneous and at other times extending to months and years. When the interval is short like putting on the switch and the lamp beginning to burn almost immediately it is easy to identify the cause. The longer the interval, the more difficult to do so.

An example for a cause and effect relationship is a law of dreaming. Sigmund Freud states that every dream has as its cause a day residue. A day residue, to put it simply, is an undigested experience we had during the course of the previous day. This law of Freud has been verified often by many people. Of course, there is a problem in the causal analysis of dreams: in case we are not able to trace and dig out the day residue of a dream, Freud and Freudians would not admit that this particular instance did not have a day residue as a cause but we evince resistance to unearthing it because it is often unpleasant to recollect. In other words, they will say that this dream also did have a day residue but the dreamer could not just recollect it.

The critical challenge consists in identifying and isolating the precise cause from among a multiplicity of antecedents. We have found, for example, that those who become blindly devoted to a cult figure either had a miraculous escape from a dangerous situation after they prayed to the figure at the suggestion of a close friend or relative who was already a blind devotee, or they had been strongly influenced from their early unsuspecting childhood to grow up devoted to the cult figure. It is quite unlikely that all their prayers to the cult figure on all subsequent occasions were fulfilled. In other words, praying to the cult figure has been just one of the so many antecedents, like thundershowers from the sky, the blooming of a mushroom in his backyard, the birth of a calf to a neighbour’s cow, the visit of our prime minister to a foreign country etc. If prayer to a cult figure could always fulfill the wishes of anyone and everyone, all human beings — including myself — would have by now become total and blind devotees of that figure. It is quite likely that many were not. Still, they would like to feel they are living in the shelter and protection of a figure, prayer to whom would always and forever fulfill their desires. The slender, untenable basis of this faith is that prayer to the figure was followed by satisfactory resolution of a dangerous predicament once upon a time just once, or a few times, in their lives.
Fortunately, rules of logic that can easily help us guard against succumbing to such uncritical and irrational behaviour have been discovered more than two thousand years ago. These are called rules relating to conditional propositions which can be of two forms:

- If x, then y; x, therefore, y. e.g., If it rains, the road will become wet. It rains; therefore, the road must be wet.

- If x, then y. Not y; therefore not x. e.g., If it rains, the road will become wet. The road is not wet. Therefore, it has not rained.

Now, you can readily see that if it rains the road will become wet. There is no way by which we can prevent the road from getting wet when it rains. You will also readily see that if the road is not wet there could not have been rains at all.

The first rule is: Affirm the antecedent and thereby affirm the consequence. The second rule is: Deny the consequence and thereby deny the antecedent.

The first rule is called modus ponens and the second one modus tollens.

The scientific method consists in applying both the rules repeatedly to a particular cause and effect relationship and finding that both the rules hold good in an interlocking way every time they are applied.

It is said that a priest was trying to convert an atheist into a believer in God. The atheist was taken to a hall that had scores and scores of portraits of men who were caught in a shipwreck, but prayed to God and survived. The atheist was told these are portraits of men who prayed to God and survived. The atheist is said to have quipped, “Where are the portraits of those who were drowned in spite of praying to God?”

In this instance the priest had applied the first rule but partially:

Affirm the antecedent and thereby affirm the consequence:

If you pray to God in a life threatening situation, God will save you.

The men in the portraits had prayed to God and had been saved.

So, if you pray to God, God will save you too.

The atheist was pointing out to the incompleteness in the argument:

There were passengers in the ship who prayed to God and yet did not survive.

Of course, the atheist was too astute a psychologist to ask for portraits of those who did not pray and still reached the shores safely because – we believe so, anyway — seldom would a person, facing the risk of imminent death, stand on prestige and refrain from praying to God! We mostly would not mind praying for a miraculous rescue in such a situation and we suspect that most of you who read this piece too would not mind!
But sound and complete education must empower the individual to face the world as it is, for what it is without flight into the shelter of a false faith, like a frightened toddler rushing to his/her mother’s apron, hoping for miracles. The world obeys certain unalterable laws and it is impossible for individuals to change them arbitrarily. Of course, this does not mean “miracles” like the computer cannot be invented. These apparent miracles too obey the unalterable laws of the world in a roundabout way. If we believe in the depths of our minds that we can defy these laws of the world, then we have not been taught how we should think critically and, to that extent, our education is not sound and complete.

It is possible to develop such psychological self-sufficiency that would prevent a person from succumbing to promises of miraculous solutions to personal problems in return for blind faith and total surrender. Buddha during the forty five years of his mission, wanted to promote precisely such an attitude of psychological self-sufficiency. Once, one of his disciples produced from thin air a begging bowl to demonstrate to the audience the power of Buddhism to perform miracles, and thereby to convert them. Buddha took the bowl from the disciple, threw it on the ground, trampled upon it and crushed it. He did not want to propagate this way of life which had as its foundation the inexorable laws of nature and eradication of desire as the goal.

The story of prayer and shipwreck is not yet complete. There might have been passengers, like children, who did not pray and yet were brought ashore to safety by other passengers. This part of the argument would be formulated as:

If you do not pray to God while in jeopardy, you will not survive.

The priest who wanted to prove that prayer brings survival should have got the portraits of all the passengers who travelled in the ship, counted them, sorted into those who prayed and survived, and those who did not pray and did not survive, and further demonstrated that the number of those who prayed and survived, and those who did not pray and were drowned, together add up to the number of passengers who boarded the ship. This tallying is necessary to prove that there was none who did not pray but survived, and all who did not pray were drowned.

Furthermore, this has to be repeated as many times as possible, if we want to arrive at a law that states: “Prayer to God will always ensure survival in shipwrecks”. Yes, we are not justified in extending it to cases of engine failure in aircrafts! That will require another set of field studies about aircraft accidents.

When we want to teach our students about thinking — rigorous, logical thinking — that will be fool-proof, we have to teach them both these rules of thinking, and further point out that both must be proved in an interlocking way and repeatedly.

iii) **Functional relationships:** Functional relationships are usually quantifications of cause and effect relationships. The law of expansion of linear objects on heating that ‘the increase in length is directly proportional to the increase in temperature’ is a simple functional relationship between two variables. The law relating to the length of the simple pendulum and its period of oscillation that the square of the period of oscillation is directly
proportional to its length is another instance of a direct relationship between one variable, namely, length of the pendulum, and a function, namely, the square of the period of oscillation. This mathematical function may be a square, cube, logarithm or even a more complicated one. This is a direct relationship. That is, when one of the variables increases, the other variable or a function like the square or cube or logarithm of it will also increase.

There are again, inverse functional relationships like that between pressure and volume in a gas in Boyle’s law. According to Boyle’s law, the pressure of a given mass of gas at constant temperature is inversely proportional to its volume. That is, if the volume is decreased the pressure will increase.

When teaching these functional relationships our focus should shift from the concrete variables to the nature of the abstract relationship between them. How to ensure that the student grasps the formal thought process underlying the generation of such laws in the first instance, besides the concrete content or product of the thought process? It is simple.

After teaching a particular law, say, the law relating to stress and strain in elastic substances, ask the students to repeat the law, first in terms of the names of the variables, then in terms of symbols and equation, and finally the nature of the formal relationship between the variables.

- What are the variables related by this law?
- Are the variables found to be related to them or has some function of one of the variables been found to be related?
- What is the nature of the relationship between the variables – directly proportional or inversely proportional?

We have presented some examples of the process of formulating laws of functional relationships. You can collect more examples of such relationships from the subjects you are teaching.

Shifting of emphasis from content to the process of formulating laws of functional relationships is explained with the help of some topics in Table 8.4.
In the foregoing section on teaching critical thinking we have discussed the skills of classification, understanding of the cause and effect relationships—the rules of logic that will safeguard us against going wrong, and functional relationships in terms of quantified measures of the variables involved. All these are well structured domains for thinking. Next, we will go on to creative thinking which necessarily has to be exercised in ill structured domains. Of course, we should not forget that all the well structured domains of today were ill structured ones before some great scientist discovered the underlying structure behind them, doing so not by critical thinking but based on creative thinking.
Check Your Progress 2

Notes: a) Write your answer in the space given below.

b) Compare your answers with those given in the text.

1. After carefully studying the table, answer the following questions. Write your answer in the space provided.
   i) How many laws have we studied so far? ( )
   ii) How many of them have direct proportionality as their core? ( )
   iii) How many of them have inverse proportionality as their core? ( )
   iv) How many of them are in terms of the variables themselves? ( )
   v) How many of them are in terms of a function of a variable? ( )
   vi) What are the different kinds of functions we have seen so far (e.g., square, logarithm, cube etc.)? ( )

2. Define critical thinking.

........................................................................
........................................................................

3. Give two reasons why our education system has failed to develop the capacity for critical thinking among students.

........................................................................
........................................................................

4. Name three basic operations of the process of critical thinking.

........................................................................
........................................................................

8.5 CREATIVE THINKING

Now, can we foster creative thinking among all our students? Can creative thinking be taught at all? Can we teach creative thinking to all the students – the bright, the average and the below average? Are there methods for teaching creative thinking? Does not creative thinking get reduced to conventional thinking if and when it is reduced to a method or even set of methods? These are indeed difficult questions to answer. Certainly, teaching creative thinking is a much more difficult task than teaching conventional thinking. Just as creative
thinking itself cannot be reduced to formulae, the teaching of creative thinking too cannot be reduced to a set of neat and tidy pedagogical methodologies. Rabindranath Tagore’s observation in this regard is worth recalling here, “There can be laboratories to train botanists but there can be none for making poets”. Rabindranath Tagore, who won the Nobel Prize for Literature, could not produce another nobel laureate in literature; nor has the institution he founded achieved it so far. After all, Tagore himself had said that there can be no laboratory to train poets. But creative thinking is slightly different from artistic or literary creativity. Creative thinking is involved in every scientific discovery. Every scientific discovery that is awarded the Nobel Prize each year is the outcome of unparallelled scientific creativity. And, some Nobel Laureates in science have not only won the prize themselves but have trained and inspired their research students to aim at a standard of excellence that enabled them to win the prize. Rutherford, for example, not only won the prize himself, eight of his students emulated him.

Psychologists have addressed, and are still addressing, this challenge of understanding creativity and of fostering it. They (psychologists) have identified three dimensions in creativity: the person, the process and the product. They have listed the traits of a creative personality, tried to track the intrapsychic processes involved in creativity and also study why and how a creative product commands the attention and admiration of persons other than the one who produced it.

Though all three are inextricably linked, we will confine ourselves here to the process of creative thinking since we are concerned with such a process in classroom curriculum transaction. Though our aim is to promote creative thinking, we have to do it within the constraints of the prescribed curriculum. Hence, this section on creative thinking has necessarily to be an assortment of methods and techniques rather than an elaborate and systematic lesson plan for teaching classification that we saw in the previous section.

Some of the ways to promote creative thinking are:

- to ask students to raise questions instead of requiring them to answer questions we pose,
- to ask students to observe the everyday world around them and raise questions about it,
- to ask them to identify suitable problems where they can apply their knowledge,
- to adopt the discovery model of teaching wherever this is possible, offering successive clues to the answer,
- to orient them to lateral thinking.

These strategies for promoting creative thinking overlap. Let us discuss three strategies to foster creative thinking among the students. These are:

- Teaching for questioning
- Discovery method of teaching, and
- Lateral thinking
We shall discuss each of these strategies with the help of suitable examples.

(i) **Teaching for questioning:** A stunning example for catalyzing creative thinking is *reversing the usual mode of mathematical thinking they exercise* by asking the students in the elementary class to find all the sums that will lead to a particular answer:

(a) Write down all the subtraction sums with all single digit numbers for which the answer is 6.

(b) How many such sums can you write?

E.g., \((9 - 3) = (8 - 2) = (7 - 1) = 6\); three sums.

Answering this question of identifying all the questions of subtraction that have as their answer the number 6, as you can readily see, is an ill-structured problem for the elementary school students. Most probably, most of them will start with any one of the three sums arbitrarily and write them in a haphazard way. Ask the students who write it in a haphazard way to arrange them in a meaningful sequence.

E.g., \((9 - 3) = (8 - 2) = (7 - 1) = 6\) or the other way:

\[(7 - 1) = (8 - 2) = (9 - 3) = 6\]

Now, ask them to find out the number of sums they can write within the same condition of single digit numbers for which the answer is 5. Ask them to count the number of sums they could write in this instance. They will find four such sums. Ask them to compare the number of sums they could write when the answer is 6, and when it is 5. And ask them if they can tell you straight away, that is, without writing out all the possible sums, the number of sums for which the answer will be 2. Ask them how they arrived at the answer. When they are able to answer this second order question they have been able to discover an underlying structure \((N = 9 - x)\) where \(N\) is the number of possible sums, \(x\) is the number given and 9 the highest single digit number.

Another strategy is to *make the students question everything that* will bring under scrutiny many things we take for granted. This involves observation of phenomena around us:

For example, all human beings who took bath before Archimedes experienced their bodies becoming lighter when they entered a tub, tank or river. But none of them questioned why their bodies thus seemed to lose weight, nor how much weight was lost. Archimedes was prompted to ask this question (perhaps, he did it only implicitly and because of the problem entrusted to him by his king).

All human beings who lived before Sir Isaac Newton took for granted that an apple would always fall down. As you know, Newton asked *why it should fall downwards* and thereby discovered the law of universal gravitation.
Similarly, Sir C.V. Raman discovered the famous phenomenon named after him by such questioning. The question that he raised was “Why are the sea and the sky blue, while water and air which fill them respectively are colourless?”

There is a subject called *erotetic logic* (not erotic logic, please remember!). As you know, ordinary logic is the logic of statements or assertive sentences. An example for thought process following ordinary logic, it is also called Aristotelian logic, is:

*All men are mortal.*
*Socrates is a man.*
*Therefore, Socrates is mortal.*

The third statement is a *valid* inference from the first two statements.

Just as the nature of ordinary logic empowers us to draw an inference about Socrates through the term “therefore”, once we have on hand the first two statements, erotetic logic has a sequence of interrogative pronouns i.e., terms with which questions can be formed once the prior questions have been raised and answered positively.

A simple set chain of such of questions along with an illustration is given in Table. 8.5.

**Table 8.5: An Example of Logical Questioning**

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Question</th>
<th>Illustration</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Whether something exists?</td>
<td>Whether a distinct disease called AIDS exists?</td>
</tr>
<tr>
<td>2.</td>
<td>Whether any particular patient brought into the hospital has instantiated it?</td>
<td>Yes</td>
</tr>
<tr>
<td>3.</td>
<td>What is the medical/pathological definition of AIDS? (The definition should be so formulated as to distinguish it from similar diseases).</td>
<td>Acquired Immuno Deficiency Syndrome. That is, it reduces resistance of the body to any and every disease.</td>
</tr>
<tr>
<td>4.</td>
<td>What is the character/ description — i.e., syndrome - set of symptoms - of AIDS?</td>
<td>Appearance of rashes, diarrhoea etc.,</td>
</tr>
<tr>
<td>5.</td>
<td>What is the function (in this instance, the prognosis) of AIDS? (That is, what will happen to the body and mind of an AIDS patient?)</td>
<td>Slow death; spread to others who have sexual contact with the patient, etc.,</td>
</tr>
</tbody>
</table>
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Ask your students to study whether these questions are answered in the lessons say, in Chemistry or Botany and also to identify the sequence in which they are taken up for discussion. They will discover that it is so. Then ask them to apply it to any new phenomenon like “electronic pollution”, find the answers and prepare an essay from them.

Of course, once these questions are applied in sequence to a hitherto unknown phenomenon, the answers for them are found and organized, it is no longer a question of creative thinking. An episode of critical thinking must result in something that is new and also true.

(ii) **Discovery model of teaching:** This model consists in enabling the students to discover on their own, major discoveries made by scientists. Details of this model are available in Bruce Joyce and Marsha Weil’s book titled “Models of Teaching”. The model usually involves providing the run up in terms of concepts or models. For example, we can enable the students in a class to discover Newton’s Law of Universal Gravitation on their own by sheer demonstration and nonverbal suggestions as follows:

Repeatedly throw a ball or any object (unbreakable, of course!) and ask the students what is happening. Ask the class to raise as many questions as possible about the phenomenon. At least one would ask,” Why does the object fall downward towards the ground?”

Now, ask the class to attempt to answer it. It is unlikely that anyone will be able to answer. Then bring a piece of iron and a magnet and take the magnet close to the piece of iron. The iron will move towards and stick to the magnet. Ask the students why the piece of iron always moves towards the magnet. At least one student will be able to say that the magnet *attracts* the piece of iron. Now, ask why the object falls towards the ground. Almost all the students will answer that the earth attracts the object.

We have a wonderful example for the discovery model of teaching in the episode in the life of Buddha in which a woman – a poor widow – was bereaved. Her only son, her hope and solace for life, had died. She heard about the greatness of Buddha and brought the dead body of her child to him and prayed to him to revive her child. As you know, Buddha was preaching through the length and breadth of North India his three doctrines of *anicca*, *anatta* and *dukha*. That is, life is insubstantial, impermanent and miserable. He was asking people to recognize this fundamental nature and give up all worldly desires.

When the woman approached him with the prayer to revive her son, Buddha told a lie. He said he would revive her child. He put forward a condition: that she should get some mustard seeds and a little buttermilk from any house in the town. The woman rushed ahead. Buddha asked her to wait and put another condition that she should collect these things from a household in which nobody had died. As the story goes, the woman went into the town, and from door to door, stating her plight and begging for mustard seed and buttermilk. Many kind hearted people were only too ready to help. But when she put forward the condition, they laughed at her and asked how she could be so naïve as to look for a household where nobody had died. Suddenly, the truth dawned on her.
Similarly, the episode in which Dhronacharya brings home to Duryodhan that he did not excel in archery as Arjuna did, just because he was lacking in concentration, is an example *par excellence* of the discovery model of teaching. Earlier, Duryodhan had complained to his teacher that he was partial to Arjuna, and that is why Arjuna excelled him in archery. The acharya did not deny, nor argue with Duryodhan. Instead he asked Duryodhan to aim at a small bird sitting on the top branch of a tree. When he said he had, the teacher asked him whether he sighted the bird. Duryodhan replied in the affirmative. Then the teacher asked him whether he saw the leaves surrounding the bird. The disciple replied, “Yes, of course”. The teacher asked him whether he saw the branch, the trunk and the root of the tree. Duryodhan replied to all these in the positive. Then he asked Duryodhan to step aside and observe. Duryodhan now asked Arjuna to take his bow and arrow and aim at the same bird. The acharya said,

“Arjuna, do you see the bird?”

“Yes sir, I do”

“Do you see the leaves around the bird”

“No, sir”

Duryodhan was dumbfounded. He understood instantly, without even a word of reproach from the teacher, that he was lacking in concentration, the *sine qua non* for success in archery.

Yes, the discovery model of teaching best teaches psychological truths about one’s own shortcomings and misperceptions. They are as new for the individual as scientific discoveries are for the entire human race.

(iii) Lateral thinking: Edward de Bono who originated the concept of lateral thinking says that it is made of a set of specific techniques that promote creative problem solving. The first technique is generation of alternative ways of looking at the same phenomenon or problem. For example, hitherto physicists and chemists found that when experiments were performed to prove that a law was true in every instance of its verification, the readings were *not* constant. They attributed the variation to the fallibility and inaccuracy of the human beings who undertook the exercise. It never occurred to them to question that the laws might not be true up to the infinite decimal place. In other words, the world is not as ordered a place, as we want it to be. This strand of thinking which has been gathering momentum since the sixties has given rise to *chaos theory*. Though it originated in the physical sciences, it finds wide application in almost every domain including Sociology, Economics, Politics and Psychology. *Chaos* theory is in stark contrast to *systems theory* which gained currency from World War II onwards. As a great thinker said, “The opposite of a great truth is also true”!

One of the shortcomings of our education are that it structures *all* minds to look at things unidimensionally. And there is an inherent tendency in the human mind to look at a thing the same way as it did on earlier occasions. This is called *Einstellung Effect*. Only those who see things differently can become creative thinkers. But creativity should not degenerate into eccentricity, or
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worse, into insanity. The dividing line between the two is very thin. This is the challenge for the teacher.

A second, related technique is *challenging assumptions*. Galileo, for example, challenged many of the perceived assumptions of his times. The first one is the speed of balls of different mass falling towards the ground. We have already seen this earlier. The second one is the belief based on common sense that the pendulum that has longer amplitude will take more time per oscillation. The third is the assumption that time and space are independent which Albert Einstein challenged.

The third technique – if it is a technique at all is the concept of “PO” which Edward deBono offers as the opposite of “NO”. “PO” does not certainly mean “YES”. It clears the space and makes psychological way for the search for alternatives. It is refreezing a sterile mindset.

### Check Your Progress 3

**Notes:**

a) Write your answer in the space given below.

b) Compare your answers with those given in the text.

1. List three strategies for fostering creative thinking among students.

   ........................................................................

   ........................................................................

2. Give an example for discovery model of teaching from the subject you are teaching in your school.

   ........................................................................

   ........................................................................

3. Complete the following sentences with suitable words:

   a) Psychologist have identified three dimensions in creativity: the person, the process and the ............... 

   b) There is an inherent tendency in the human mind to look at a thing the same way it did on earlier occasions. This is called ..........effect.

   c) Chaos theory is in stark contrast to ............. theory.

### 8.6 LET US SUM UP

This unit deals with fostering two different forms of thinking through instruction, that is, critical thinking and creative thinking. Critical thinking is described as convergent thinking in Psychology. It aims at simplification/generalizations, and truth and accuracy. Anyone who wants to arrive at the truth must follow the established cannons of truth. Creative thinking is also
labelled as divergent thinking in psychology. It aims at novelty in the first instance rather than truth. Therefore, it is different from conventional modes of thinking. Both are complementary to each other and not anti-thetical.

The difference between critical thinking and creative thinking lies with respect to their aim, scope, nature, direction, status of concepts and categories, path, etc.

Students have not been able to develop the capacity for critical thinking due to two reasons. First, contemporary education system does not explicitly aim at inculcating values in students. Secondly, our education system is examination-oriented. It does not enable the students to discover by themselves and for themselves.

The process of critical thinking comprises of three basic operations, namely, classification, identifying cause and effect relationships, and identifying functional relationships.

Teaching creative thinking is more difficult than teaching conventional thinking. Just as creative thinking itself cannot be reduced to formulae, the teaching of creative thinking too cannot be reduced to a set of neat and tidy pedagogical methodologies.

Psychologists have described three dimensions in creativity, viz the person, the process and the product. They have listed traits of a creative personality. They have also tried to study why and how a creative product commands attention and admiration of individuals. Process of creative thinking aims at promoting creative thinking.

Three main strategies to foster creative thinking among students are: teaching for questioning, discovery method of teaching and lateral thinking.

### 8.7 UNIT-END EXERCISES

1. What is the difference between creative and critical thinking?
2. What makes one a creative thinker?
3. What is an assumption?
4. What can you do in your classroom to help your students develop insight?
5. Describe discovery model of teaching.
6. What does De Bono teach?

### 8.8 SUGGESTED READINGS