DOCUMENT RESUME

ED 214 848 SO 013 983

AUTHOR Smith, Gary R.
TITLE Skills for the Future.
INSTITUTION Denver Univ., Colo. Center for Teaching International Relations.
PUB DATE Sep 79
NOTE 78p.; Sponsored by the Graduate School of International Studies and the School of Education.
AVAILABLE FROM Center for Teaching International Relations, University of Denver, Denver, CO 80208 ($7.95 plus postage and handling).

EDRS PRICE MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS Creative Thinking; *Futures (of Society); Interdisciplinary Approach; Intermediate Grades; Learning Activities; Mathematical Concepts; Mathematics Education; Problem Solving; Secondary Education; *Skill Development; *Social Studies; Teaching Guides

ABSTRACT

This publication contains two miniunits to help students in grades 7-12 build skills for the future. The exercises can also be adapted for use in grades 4-6. Each of the miniunits contains several exercises to build specific skills. Miniunit One, "The Arithmetic of Growth," deals with two concepts--exponential growth and doubling time. These two concepts were singled out as appropriate skills for students to develop because they bring into focus the enormous numbers involved in the future of the growth of energy demand and technology. Students are first given a five-question pretest to determine their understanding of the arithmetic of exponential growth. A simple exercise helps them see the relationship between a million and a billion. Other exercises include having students draw a line graph of exponential growth and having them do some compound interest problems. Miniunit Two, "Lateral Thinking for Creative Problem-Solving," attempts to present concrete ways to enhance the creative-thinking process for attacking specific personal and societal problems. The exercises in this second miniunit provide an opportunity for the practical use of lateral thinking so that students may acquire the lateral thinking habit. Lateral or "zig-zag" thinking, as it is sometimes called, is a means of broadening the scope of alternatives in problem solving by allowing oneself to think about the problems more than the solutions. (Author/RM)

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SKILLS FOR THE FUTURE

by

Gary R. Smith

Center for Teaching International Relations
University of Denver (Colorado Seminary)
Denver, Colorado 80208
September, 1979

we see schools that once provided simple but adequate instruction in the basics and teachers who were dedicated to drilling students until the skills were mastered. But those schools never existed on any wide scale. The number of new programs and changes in educational philosophy in the past fifty years is evidence that this vision of the past is an illusion. We are constantly struggling over what should be taught and how it should be taught.

There are two related problems with this romantic vision of education. One has to do with the hotly debated question of what is "basic." Television documentaries on education and interviews with the man on the street give the impression that if students could be made to read, write, and do basic math functions, accountability problems would be virtually over. But reading, writing, and arithmetic are only a small part of what is basic to life. Despite their obvious importance as skills, they have little to do with a world in which students must anticipate the problems of job security, income, family life, status, and interpersonal relationships. In teaching children to count, schools would do well to keep in mind <u>what</u> counts.

As the "basics" have been defined, it would no doubt calm an unsettled society to hear that they really do offer the keys to the future. But we cannot accept the romantic vision and be realistic because of the second problem--our failure to anticipate what skills will be most relevant for life in the future. Students of the 1950's and 60's remember this problem well. When it came to job security, for example, the schools did such a miserable job of forecasting the job market that many thousands of college graduates are still suffering.

This volume contains all teacher and student materials necessary for classroom use. It is being sold at cost for purposes of evaluation. To order, write to address below.

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University of Denver (Colorado Seminary)
Denver, Colorado 80208

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GENERAL INTRODUCTION

The majority of today's elementary and secondary students will spend most of their adult lives in the 21st Century. Unfortunately, our educational system largely ignores this fact. If schools do any preparation, it is usually preparation for a life style that is or will be outdated. Though history classes are supposed to prevent the younger generation from making the same mistakes as their elders, they rarely succeed at the task. Language arts programs often completely ignore the most influential medium on language and behavior: television. Most written curriculum implies in its content that students only need to learn to deal with the world as it was yesterday, or as it is today, to be able to lead fulfilling lives tomorrow.

A popular view of the future is that it will not be very different from the past. According to this view, the periphery of life will change, but our basic values and beliefs will not. It follows that what is needed is an education that teaches the basic skills to live life pretty much the way it has always been lived.

Somehow we know something is wrong with the way our schools prepare students. This recognition has prompted the "Back to Basics" movement. But even the name of the movement is intriguing. It implies that we have lost something in our schools. In an overly romantic vision, we see schools that once provided simple but adequate instruction in the basics and teachers who were dedicated to drilling students until the skills were mastered. But those schools never existed on any wide scale. The number of new programs and changes in educational philosophy in the past fifty years is evidence that this vision of the past is an illusion. We are constantly struggling over what should be taught and how it should be taught.

There are two related problems with this romantic vision of education. One has to do with the hotly debated question of what is "basic." Television documentaries on education and interviews with the man on the street give the impression that if students could be made to read, write, and do basic math functions, accountability problems would be virtually over. But reading, writing, and arithmetic are only a small part of what is basic to life. Despite their obvious importance as skills, they have little to do with a world in which students must anticipate the problems of job security, income, family life, status, and interpersonal relationships. In teaching children to count, schools would do well to keep in mind <u>what</u> counts.

As the "basics" have been defined, it would no doubt calm an unsettled society to hear that they really do offer the keys to the future. But we cannot accept the romantic vision and be realistic because of the sec^nd problem--our failure to anticipate what skills will be most rele' ^t for life in the future. Students of the 1950's and 60's remember this problem well. When it came to job security, for example, the schools did such a miserable job of forecasting the job market that many thousands of college graduates are still suffering.

Many teachers urged their students to go into teaching and the liberal arts saying that the key to the future was a college education. Teaching certificates and engineering degrees were noted to be particularly valuable. Sadly, for prospective job hunters, the teacher shortage was short-lived and engineers became as common as Fords and Chevrolets. The liberal arts degree became an even less salable commodity in the job market. The mistake was understandable, If we judge the world to be the same in the future as it is now, our estimation of the skills students will need to live in it will be just as incorrect. It's not that change hasn't been with us always; or course, it has. But, as Alvin Toffler has told us, the rate of change is what is totally new.

We cannot afford to tell our children that if they master the basics--the three R's with some history, literature, and classical science thrown in--that they will have the necessary skills to cope with this fast changing society. We must learn to forecast some of the changes most vital to our continued survival. Not predict, but forecast. There is simply no other way to begin figuring out what skills will be appropriate for the changes. Sometimes the task will be to modify our teaching of a particular skill we're advocating now, such as broadening our scope about reading to include more than print. At other times it will be necessary to experiment with relatively untried skills, such as lateral thinking. Whatever the case, by our willingness to forecast change, we can begin to see what kinds of skills may be required for life in the 21st Century.

Design of the Series

These materials represent an anticipation of changes that may be fundamental. For example, we know that population grows exponentially.

Moreover, population growth will create a parallel growth in demand for goods and technology. One population doubling in a finite environment requires unprecedented adjustment of our species. Since our population doubled in the first part of the century, overcrowded beaches, highways, urban congestion, and the like have affected life profoundly. Many can remember a time when fewer people on earth meant a set of much steadier nerves at the wheel of an automobile!

The miniunits in this series are not designed to be comprehensive in terms of identifying the skills needed to live effectively in the twenty-first century. It would be impossible to be that definitive because as the world changes, so will the skills needed to cope with it. These materials represent a rather modest attempt to zero in on skills which seem important to develop given the future as we see it in 1979.

Outline of the Series

Each of the following miniunits contains several exercises to build specific skills:

Miniunit One, "The Arithmetic of Growth," is really about two concepts--exponential growth and doubling time. These two concepts were singled out as appropriate skills for students to develop because they bring into focus the enormous numbers involved in the future of the growth of energy demand and technology.

Miniunit Two, "Lateral Thinking for Creative Problem-Solving," attempts to present concrete ways to enhance the creative thinking process for attacking specific personal and societal problems.

Objectives:

The lessons in these miniunits point towards objectives in the following areas:

Discovery Skills

1. Collection of Data about Growth, Trends, and Forecasts
2. Analysis of Data
   A. Interpretation
   B. Synthesis
   C. Application
   D. Evaluation
3. Hypothesis Formation and Testing
4. Decision Making

Value Analysis

Objectives are as follows:

1. To assess one's personal role in societies of the future
2. To verbalize value positions when called for in the lessons
3. To examine values in the light of new evidence and forecasting
4. To act on values in the light of new perspectives about the future

Knowledge and Recognition

1. Students will be exposed to new information (that is, information new to them) about forecasting and growth projections
2. Students will articulate their recognition and knowledge of the future when appropriate in the lessons

Teaching Strategies

These miniunits use a number of teaching strategies. With skill-building as their primary objective--data analysis and collection, discussion, hypothesis testing, and decision making are used to help build the skills. In fact, the miniunit idea itself could be considered a teaching strategy. Each miniunit is composed of 6-7 lessons directed at skill building. By the end of each miniunit, students will gain competence in the skill emphasized in the title of the miniunit.

Skills

The following is a list of skills and their definitions selected for this series:

1. Math Skills - specifically those math skills concerned with exponential growth and doubling time. Students should be able to learn these two types of growth using basic math.
2. Reading - not merely the reading of the written word but of the media. Students should gain experience in sorting out the faulty logic in the language of the media and advertising.
3. Lateral Thinking - the ability to ask questions outside the immediate context of a particular problem, to generate more possible solutions to the problem.
4. Decision Making - incorporates all the previous skills. Decision making implies the analysis of alternatives as solutions to problems. Of all the skills students will need for the future, perhaps this is the most important. This series should provide a beginning set of lessons for developing this skill.

Grade Level

This series is designed for grades 7-12. It can be adapted for use in grades 4-6 as well.

Where to Use the Series

Within the school curriculum these materials are appropriate in any course of study or unit of study related to the future. Specifically, they can be used in general social studies, history, contemporary problems, government, economics, and sociology. They can also be used in basic and general math courses to apply some of those basic skills.

THE ARITHMETIC OF GROWTH

This miniunit deals with exponential growth. The arithmetic is simple and useful, even for students with high anxieties about math. The content is intended to be interdisciplinary, combining math skills with social studies concern about growth and energy.

Despite the simplicity of the arithmetic of exponential growth, each student needs to realize that this knowledge is profoundly important. The math and analytical skills taught to students do not always prepare them to understand comments made about the energy dilemma. When an institute, such as the Edison Electric Institute, tells us that "by 1988, America will need 40% more electricity than today..." how many of us understand the implications of this kind of unprecedented demand? And who would take the time to think about the absurdity of a statement such as this: "We've discovered over 4 billion tons of lignite coal in a new trend that runs across 5 southern states. Enough new coal to provide all the electricity it would take to power a city the size of Chicago for the next 75 years"?* Only Chicago? For just 75 years? Considering the proportions of the energy crisis, this seems like an infinitesimal amount with which to fill a page of advertising!

The point is that students need a context for all of these numbers. What do they mean to students? In relation to what are they important? How much is a million? A billion? How do students know who to believe? And what do they do with the information once they come to understand its meaning? To be sure, growing demand in a finite environment is a complex issue. But the basic arithmetic of exponential growth is not. This unit can provide keys to understanding these hugh numbers in a setting that makes sense to those concerned about where our world is going in the energy crisis.

Outline of the Unit

This miniunit consists of four parts. Before any lessons are introduced, students will be given a five-question pretest to see how much they comprehend the arithmetic of exponential growth at the outset. Moreover, students will be given a simple exercise that will help them see the relationship between a million and a billion, a relationship they need to comprehend to deal with the large numbers of exponential growth.

The remaining three parts consist of three lessons. Lesson One, "The Power of the Power of Two," presents a series of exercises that vividly show how a few doubling times can lead to enormous numbers. The lesson

*Phillips 66 advertisement from TIME, The Weekly Magazine, July 14, 1978. (See Appendix for this advertisement) serves to familiarize students with exponential growth and doubling times. One of the follow-up questions asks students to draw a line graph of exponential growth. Another exercise asks students to illustrate the definition of exponential growth by doing some compound interest problems.

Lesson Two addresses the practical side of the issue of exponential growth, that is, the limits to growth. Since growth curves continue only in theory, students need to recognize how they reach their practical limits. This lesson also examines how technology can realistically meet the challenge of growth.

Lesson Three presents students with some simple statistics and tables to evaluate the question, "How Much is Really Left?" -- oil and coal, that is. In the appendix, students can look at and analyze the validity of claims made by advertisements of energy companies. In other words, students apply the tools they have acquired in the first three parts of the miniunit to what they read in the media.

Energy Pretest

1. How many years did it take nature to make a pound of coal?

   a. 100 years
   b. 1000 years
   c. 1,000,000 years
   d. 1,000,000,000 years

   Answer: (c) 1,000,000 years

2. How long does it take to burn a pound of coal in an average sized home furnace that has been burning for at least a half-an-hour?

   a. less than 5 minutes
   b. one hour
   c. 5 hours
   d. all day

   Answer: (a) about 5 minutes or less

3. If a loaf of bread costs $0.40 in 1974, and it increases in price by an inflation rate of 6% a year, what will it cost in 70 years?

   a. $2.56
   b. $25.60
   c. it would double in price to $0.80
   d. $7.89

   Answer: (b) $25.60, i.e., according to the exponential formula

4. If you were to place a grain of wheat on the first square of a checkerboard, 2 grains of wheat on the second square, 4 on the third, 8 on the fourth, and so on, doubling the wheat grains on each succeeding square, how many wheat grains would you need to put on the last square of the checkerboard?

   a. 500
   b. 5,000
   c. 500,000,000,000
   d. 500 times the current annual wheat harvest of the world

   Answer: (d) An amount larger than all the wheat harvested in the history of the world! In just 63 doublings.

(Energy Pretest continued)

5. If you could fold a sheet of paper 49 times, how thick would the paper be?

   a. 490 miles
   b. several inches
   c. 22 miles
   d. thick enough to reach the moon

   Answer: (d) Thick enough to reach the moon with plenty to spare!

HANDOUT

Energy Pretest

1. How many years did it take nature to make a pound of coal?

   a. 100 years
   b. 1,000 years
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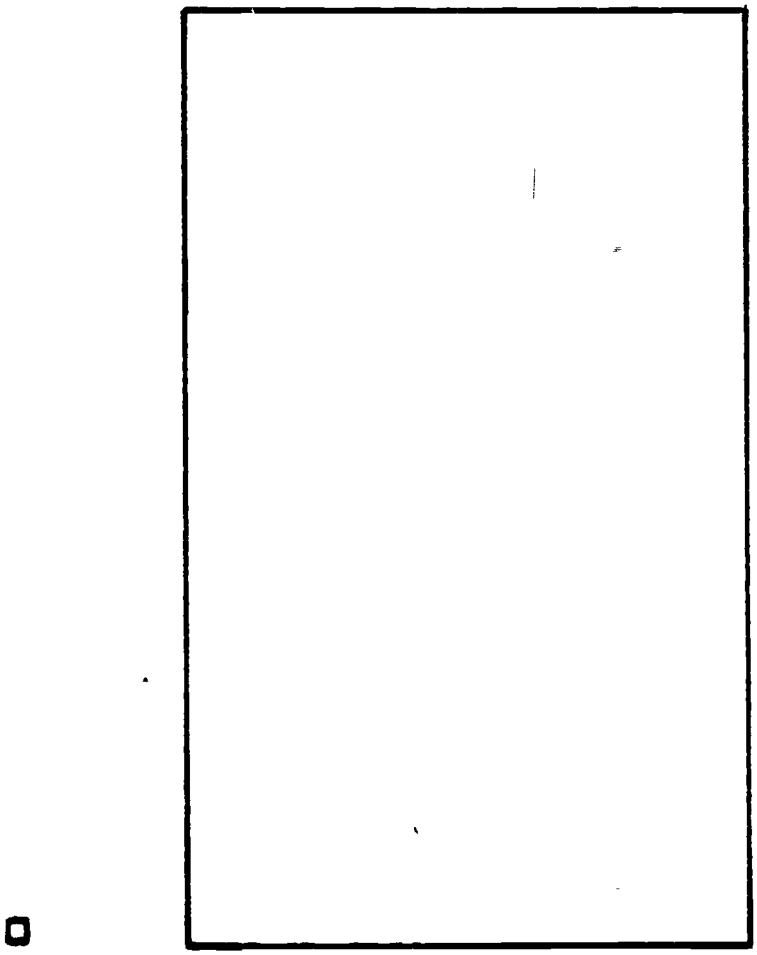
   b. several inches
   c. 22 miles
   d. thick enough to reach the moon

HANDOUT

The Million-Billion Leap

To give you some idea of the difference three zeros in a number can make...



If this represents a million . . . then this would represent a billion.

OR

If this represents a billion . . . then this would represent a trillion.

OR

If this represents one . . . . . . then this would represent 1000.

Lesson One: The Power of the Power of Two

This lesson dramatically illustrates that a few doubling times can lead to enormous numbers. Along with some of the graphs developed for the lesson, students can begin to recognize the tremendous burden exponential growth rates place on a finite environment when they approach their limits. As indicated in the pretest, 63 doublings of the wheat grains would produce 500 times the current annual wheat harvest of the world! The content of the lesson has students actually work with the numbers of the two most important dimensions of growth--doubling time and the exponential factor, i.e., the increase of a quantity of something at a fixed rate of increase when the base is constantly changing.

Exercise One - "That's Quite an Allowance!"

Introduction: If your students would like to practice a lesson in salesmanship, ask them if they would like to become millionaires in thirty days with their allowance. We are kidding of course. But in this exercise students see what happens when they start with a penn y on the first day of the month, and end up with millions on the last!

Objective: The students should be able to recognize the effect a few doubling times can have on a quantity of something.

Time: 30 minutes

Materials: Handout - "A Calendar for Your Allowance"

Procedure: Distribute copies of the handout, "A Calendar for Your Allowance." You will need to use the complementary teachers guide to the calendar unless you care to do the arithmetic with the students.

You might want to introduce the exercise by stating something like the following: "Next time you catch one of your parents in a good mood, propose the following 'slight adjustment' in the way you receive your allowance. Instead of getting a fixed amount every week or month for the next few years, as most allowances work, tell them you will be glad to settle for giving you all the allowance you will ever ask for in just one month. And they need only pay you a penn y on the first day. Here is the way it will work. You are to get 1¢ on the first day, 2¢ on the second, 4¢ on the third, 8¢ on the fourth, 16¢ on the fifth, and so on, doubling the amount each day until you have reached the thirtieth day."

Doesn't sound like much does it? But, just wait until your students figure out what they would have by the thirtieth day. "Now, using the handout, fill in each square of the calendar, starting with 1¢ on the first day and doubling the amount each day until the end of the month."

1. What will you have by the 15th day?

   Answer: $163.84

2. What will you have by the thirtieth day?

   Answer: $5,368,708.80!

When students have finished filling in the squares, explain to them that they have been looking at and dealing with the effects of what is called exponential growth. It is called exponential growth because we commonly associate this kind of increase with numbers which have an exponent of ^{2}, meaning that number doubled. You might ask an eager student to try and plot the growth curve on a line graph. The algebraic equation would be ($y=2^{x-1}$). The student will soon discover that the task is impossible. We cannot create a scale for the vertical axis of the graph which allows plotting the whole curve in a way that makes any sense at all. This is a further indication of the enormity of the numbers we are dealing with.

Conclusion: If you were to propose such an allowance scheme to your parents why might they be likely to accept the proposal on first sight? (Provided, of course, that they are not aware of exponential growth)

Answer: Exponential growth is extremely deceiving. If students are at all observant, they will recognize how slowly things started off with the allowance, and how, all of a sudden, it started to grow very fast. For example, as far into the month as the seventh day, the amount was only 64¢. But in another 21 doublings the allowance ran into the millions!

#

A Calendar for Your Allowance

1	2	3	4	5	6	7
$0.01	$0.02	$0.04	$0.08	$0.16	$0.32	$0.64
8	9	10	11	12	13	14
$1.28	$2.56	$5.12	$10.24	$20.48	$40.48	$81.92
15	16	17	18	19	20	21
$163.84	$327.68	$655.36	$1310.72	$2621.44	$5242.88	$10,485.76
22	23	24	25	26	27	28
$20,971.52	$41,943.04	$83,886.08	$167,772.16	$335,544.32	$671,088.64	$1,342,177.20
29	30					
$2,684,354.40	$5,368,708.80					

HANDOUT

A Calendar for Your Allowance

1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30					

Exercise Two - "The Riddle of Bacteria"[2]

Introduction: What makes exponential growth especially troublesome is the way in which it reaches its limits. The curve is limitless only theorically. Growth goes along apparently harmless and unnoticed for such a long time that people are lulled into a false sense of security. But when growth approaches its practical limits, it does so extremely fast. The exercise illustrates the problem.

Objective: The student should be able to recognize that the take-off point for exponential explosion occurs near the end of the practical limits to growth.

Materials: Table 1, Graph 1

Time: 30 minutes

Procedure: As the allowance did in Exercise 1, bacteria too multiplies exponentially. That is, one bacterium divides and becomes 2, 2 divide and become 4, 4 become 8, 8 become 16, and so on. For certain strains of bacteria this doubling time can occur in one minute. In other words, we have exponential growth with a doubling time of one minute. Given this growth rate, suppose we could put one bacterium in a bottle at 11:00 am and observe that the bottle is full at 12:00 noon. Here is an example of exponential growth in a finite environment. (This is analagous to the case of exponentially growing consumption of finite resources such as fossil fuels.) Distribute copies of the handout with Table 1 and Graph 1.

[2]This exercise is adapted from research work done by Dr. Albert Bartlett, "The Forgotten Fundamentals of the Energy Crisis." An unpublished paper.

Introduce the following questions using Table 1:

1. When was the bottle half full?

   Answer: 11:59 am

2. If you were to play the role of a bacterium in the bottle, at what time would you first realize that you might be running out of space?

   Answer: This is difficult to answer, but we do know that it would be highly unlikely even as late as 11:55 am, when there was only 5 minutes left until the bottle was filled to capacity. Why unlikely? Because at that time the bottle was still only 3% full and 97% empty!!!

3. Suppose that as late as 11:58 am that some far-sighted bacterium recognized a forseeable crisis and set out to find new bottles, to colonize new worlds, so to speak. At 11:59 am it discovers three new bottles, quadrupling the total space resource for the bacteria. How long can the growth of bacteria continue given the additional bottles?

   Answer: Only <u>two</u> more doubling times, or two minutes, or until 12:02 pm!

Conclusion: Quadrupling the resource extends its life by only two doubling times. That is, when consumption grows exponentially, enormous resource increases are consumed in very short periods of time. Look at Graph 1 (World Population: 1 A.D. - 2000 A.D.). The graph clearly illustrates that the growth curve takes off very rapidly. This then is the great deceptive nature of exponential growth. Until well into the 1950s it just did not seem like there was a population problem. In fact, during the 1930s there was some fear that the world would lose population and eventually run out of people. But look what happened to population growth subsequently, especially between 1950 and the present. The last bar on the graph is dramatic.

Extension of the Activity: It would be best if you and the class could actually observe the exponential growth of the bacteria. But the experiment is not very practical, mainly because of a lack of adequate food supply. You might want to research the matter further and use aphids or fruit flies in an actual experiment to demonstrate how they would grow exponentially.

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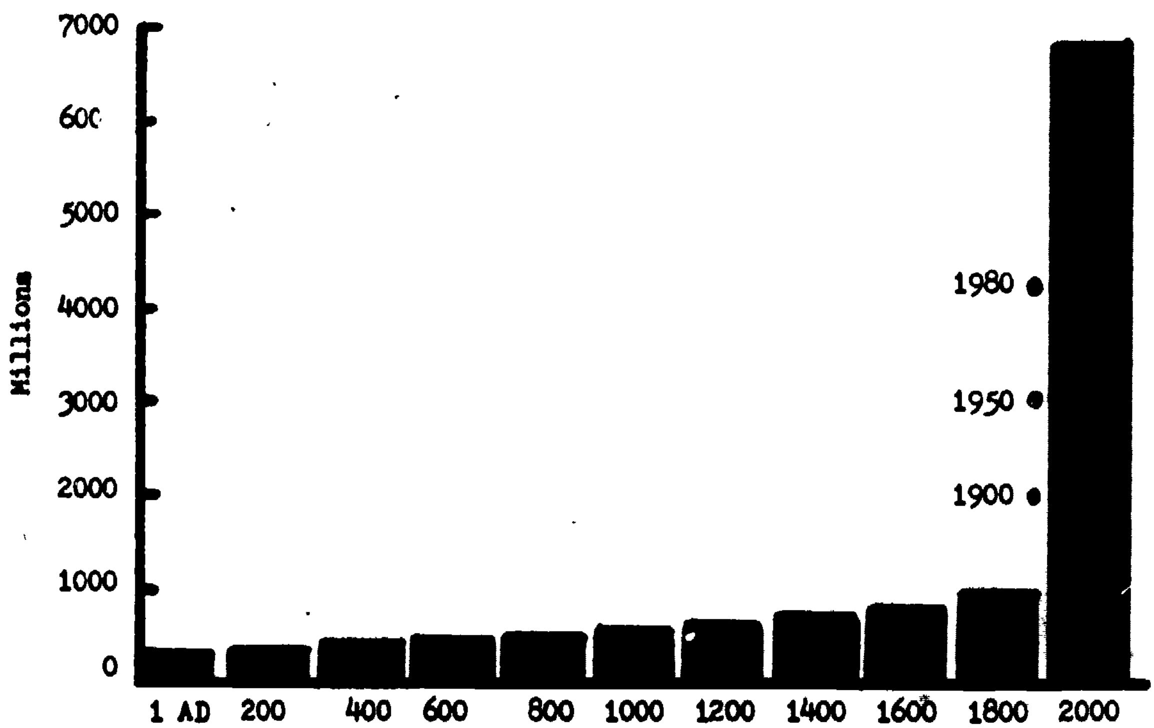
11:58 am	First bottle is ¼ full
11:59 am	First bottle is ½ full
12:00 noon	First bottle is completely full
12:01 pm	Bottles 1 and 2 are both full
12:02 pm	Bottles 1, 2, 3, and 4 are full

Table 1. Growth of Bacteria when Doubling Time is One Minute
Source: Albert Bartlett



Graph 1. World Population, 1 AD - 2000 AD

Source: UN Statistical Yearbook, 1975

Exercise 3 - "The Basics of Growth"

Introduction: This series of three exercises can help students apply the definition of exponential growth. So far, in exercises 1 and 2, we have dealt only with doubling times, not exponential growth per se. The problems below serve to demonstrate how a relatively small percentage rate of increase can produce large growth over time.

Objective: The student should be able to recognize that a relatively small yearly percentage increase, a fixed yearly increase, can result in large growth over time.

Time: 30 minutes

Procedure: Put the following problems on the chalkboard or on an overhead transparency:

* If you were to put $100.00 in the bank at a yearly rate of interest of 5%, how much money would you have in 25 years? How long would it take to double your money? Answers: In 25 years you would have $338.64. It would take 15 years to double. This problem is a classic example of the principle of exponential growth. When a quantity, such as the changing amount in the bank each year, grows at a fixed percent, the growth is exponential.

* During the 1960s the Gross National Product of Japan was growing at 10% per year. How long did it take to double? Answer: 7 years

* If the population of the world is now 4.2 billion persons, and the rate of increase is 2% per year, how long will it

take the population to double to 8.4 billion?

Answer: Just 35 years! An easy way to compute this is to divide 70 by the rate of increase (2%). Therefore, 70 ÷ 2 = 35. This also works in reverse. If you know the doubling time of a resource, you can find out the rate of increase by dividing 70 by it. Therefore, 70 ÷ 35 = 2.

Review: After doing the exercises above, it would be wise to go over a few points about growth before proceeding to Lesson Two:

1. Exponential growth is one of the most important kinds of trends to to understand in dealing with the problems that society faces. Here are a few items that tend to grow exponentially ---
   - population
   - demand for scarce resources, such as energy
   - inflation
   - the number of miles of highway in the U.S.
   - populations of insects such as flies, aphids, etc.
   - many of the things that are undesirable to man in terms of quality of life
2. A quantity which is growing exponentially has a constant doubling time. We can rest assured (or not rest, as the case may be!) that if the rate of growth of our population is fixed at 2%, our numbers will increase every 35 years.
3. A quantity growing exponentially within a limited environment appears to grow very slowly at first, and then to "explode" towards the limit; this creates a problem because it is contrary to normal

intuition and creates a false sense of security until the limit has been reached.

#

Lesson Two: The Limits to Growth

Overview: As implied in Lesson One, most people seem astounded by the mathematics of exponential growth. We are accustomed to thinking of growth as a linear process. If we put away $5.00 a month in a cookie jar, the amount will grow linearly. The amount of the increase each month is not affected by the amount of money already in the cookie jar.

But so far in this miniunit we have been dealing only in theory. A given quantity can increase exponentially only if there are adequate physical and social resources to continue doing so. In other words, there are practical, if not theoretical limits to growth. In our example of the allowance, what happens when the money supply reaches its limit? There is only so much money available, only so many resources to make it available. Besides, Mom and Dad could not deliver on their promise after a few days went by. In the example of the bacteria, what happens if there is no adequate food supply to feed the growing colonies? Obviously the growth curves and doubling times cannot continue indefinitely.

This lesson has students work with the limits to growth. Moreover, students are asked to assess how well technology is equipped to meet the problems implied in exponential growth.

Objectives: The students will be able to:

- rank order some of the practical limits to population growth, both physical and social
- recognize the uses and limits of technology to meet the crises implied in exponential growth

Exercise One: "What Limits Growth?"

This exercise provides students with a list of some of the possible physical and social factors that could limit population growth. Of course, no one knows for certain when these factors will be responsible for significantly leveling the growth curve, nor do we know which of the factors may be most important in curtailing growth in the long run. But there are social scientists and scientists working to coordinate the various factors and attempting to make reasonable forecasts. We suggest that your students look into some of the literature listed at the end of the miniunit to compare their choices in this exercise with some of the best research on the limits to growth.

Materials: Handout - "What Limits Growth?"

Procedure:

Step 1 - Distribute copies of the handout.

Step 2 - Read through the introduction on the handout with your students to make sure they understand the task they are to do.

Step 3 - Ask students individually to rank order the 12 items.

Step 4 - (Optional) Ask students to break into groups of 3-5 students. Then, ask each group to rank order the 12 items.

Questions:

1) Why did students make the choices they did?

2) What differences were there between individual and group rank ordering?

3) Which of the factors listed are interdependent? That is, which factors depend upon other factors to limit population growth? (For example:

"voluntary family planning" depends on the availability of "birth control devices and methods" which depends on "inability...to distribute... services," and so on.)

Handout

WHAT LIMITS GROWTH?

Introduction: The exercises in Lesson One may have left you with some interesting questions. For example, what if you could really get your parents to promise to double your allowance everyday for a month? Would you really end up with $1,342,177.20 at the end of the month? Certainly not! You know that there is a limit to the amount of money your parents can give you. This limit we can call the practical limit to growth because despite our calendar of projected growth, we know the lack of available money will curtail it. (Look at "A Calendar for Your Allowance" again. On what day would your allowance reach its practical limits?)

One of the things that grows exponentially is the earth's human population. Each year the population base changes by a fixed percentage. Which of the following factors do you think will most dramatically curb population growth? Rank order your choices from 1-12 by placing the corresponding number in the blank to the left of the items:

_____ amount of productive land on earth for agriculture

_____ birth control devices and methods

_____ food shortages and famines

_____ mental illness caused by overcrowding

_____ lack of money to invest in food production, housing, services, etc.

_____ industrialization, making children uneconomical to have

_____ government regulation of family size

_____ voluntary family planning

_____ lack of space on earth

_____ depletion of natural resources that cannot be renewed

_____ widespread disease

_____ agencies and governments unable to distribute food, goods, and services where they are needed

Exercise Two: "Solutions and Consequences"

This exercise asks students to determine the consequences of proposed solutions to problems created by growth. The debate over whether or not technology can supply all of the solutions needed is too complex and lengthy to consider here.* But what can be accomplished is a recognition by your students that technological solutions themselves have ramifications which need to be considered.

Materials: Handout - "Solutions and Consequences"

Procedure:

Step 1 - Distribute copies of the handout to groups of 3-4 students.

Step 2 - Instruct each group to put down as many things as they can think of that would fit in Column 3.

Step 3 - Discuss results among the groups.

Questions:

1. What social changes--changes in lifestyle and attitudes--will have to be made for the solutions in Column 2 to be accepted?
2. What limits to growth will each solution in Column 2 change? What new limits will be or have been introduced by the solutions to the problems?

*For an introduction to the literature of this debate see: Donella H. Meadows, et. al., The Limits to Growth, Universe Books, 1972; Mihajlo Mesarovic and Eduard Pestel, Mankind at the Turning Point, E. P. Dutton, 1974; Robert L. Heilbroner, An Inquiry into the Human Prospect, W. Norton and Company, 1974.

Handout - "Solutions and Consequences"

Column 1 "Problems"	Column 2 "Solutions"	Column 3 "Consequences"
Ex. Land space in large cities	Build skyscrapers	transportation snarls, parking problems, increased pollution
Lack of arable land to grow crops	Soil enrichment Crop hybrids	
Traffic congestion	Build more freeways	
Flooding	Build dams	
Insects eating crops	Increase use of pesticides	

Lesson Three: How Much is Really Left?

Overview: The title of this lesson is a question almost impossible to answer with any precision. No one can say with certainty just how much of our nonrenewable energy resources we have left. But in this lesson two fossil fuel resources are calculated so that we can gain at least some degree of perspective. Interspersed with the tables are some advertisements from popular magazines which students are asked to examine critically (advertisements are located in the appendix at the end of miniunit one.)

Objective: The student should be able to recognize the importance of utilizing knowledge of exponential growth in assessing how much coal and oil the earth has left to yield for energy

Materials: Handout - Tables of the World's Oil and Coal Resources

Time: Two class periods (approximately 90 minutes)

Procedure: Estimating the life expectancies of our vital resources in energy is perhaps one of the most important questions we can ponder. Ask students to review the information on the handout on the longevity of crude oil and coal reserves. Then have them look at some examples of energy advertising in the appendix for critical analysis.

Debriefing: Considering the advertisements for coal, what could be the problem with the one that says "What fuel could supply America's electricity for about 250 years? ---- COAL"

Answer: It would depend entirely on the rate of growth. Most advertisements fail to point out that their projected life expectancies regarding coal leave out the consideration that these projections are "at current levels of output." It has been estimated that we will begin to up the yearly production of coal to 13%. According to that figure, the high and low life expectancies would be 46 and 35 years respectively--not anywhere near the 250 years suggested by the advertisement.

Looking at other ads in the lesson, most of them say there is plenty of coal left. What they consistently fail to consider is the exponential factor. Thirty-five years, at the most forty-six, is not much time.

#

Sources for this Unit

Albert Bartlett, "The Forgotten Fundamentals of the Energy Crisis," University of Colorado, Unpublished Paper.

Robert L. Heilbroner, An Inquiry into the Human Prospect, W. Norton and Co., 1974.

Draper L. Kauffman, Jr., Teaching the Future, ETC. Publications, 1976.

Intercom No. 72, "Teaching About Population," Global Perspectives in Education, 218 E. 18th Street, New York, NY 10003.

Intercom No. 77, Robert Hanvey, ed., "Explorations in the Emergent Present," GPE, New York.

Donella H. Meadows, et. al., The Limits to Growth, Universe Books, 1972.

Mihajlo Mesarovic and Eduard Pestel, Mankind at the Turning Point, E. P. Dutton, 1974.

William Opnuls, Ecology and the Politics of Scarcity, W. H. Freeman and Co., 1977.

HANDOUT

World Crude Oil Resources - Years Left

Column 1	Column 2	Column 3	Column 4
Zero	101 years	113 years	147 years
1	69.9	75.4	90.3
2	55.3	59.0	68.5
3	46.5	49.2	56.2
4	40.5	42.6	48.2
5	36.0	37.8	42.2
6	32.6	43.1	38.0
7	29.8	31.2	34.6
8	27.6	28.8	31.8
9	25.7	26.8	29.5
10	24.1	25.1	27.5

Table 1. Life expectancy in years of various estimates of world oil reserves for different growth rates of annual production

Column 1 = the percent annual growth rate of production
Column 2 = the lifetime of the resources, minus shale oil
Column 3 = the lifetime calculated representing crude oil + shale oil
Column 4 = the lifetime calculated assuming that the amount of shale oil is four times the amount which is known

Source: Albert Bartlett, "The Forgotten Fundamentals of the Energy Crisis"

U.S. Coal Resources - Years Left

	High Estimate	Low Estimate
Zero	2872 years	680 years
1	339 "	205 "
2	203 "	134 "
3	149 "	102 "
4	119 "	83 "
5	99 "	71 "
6	86 "	62 "
7	76 "	55 "
8	68 "	50 "
9	62 "	46 "
10	57 "	42 "
11	52 "	39 "
12	49 "	37 "
13	46 "	35 "

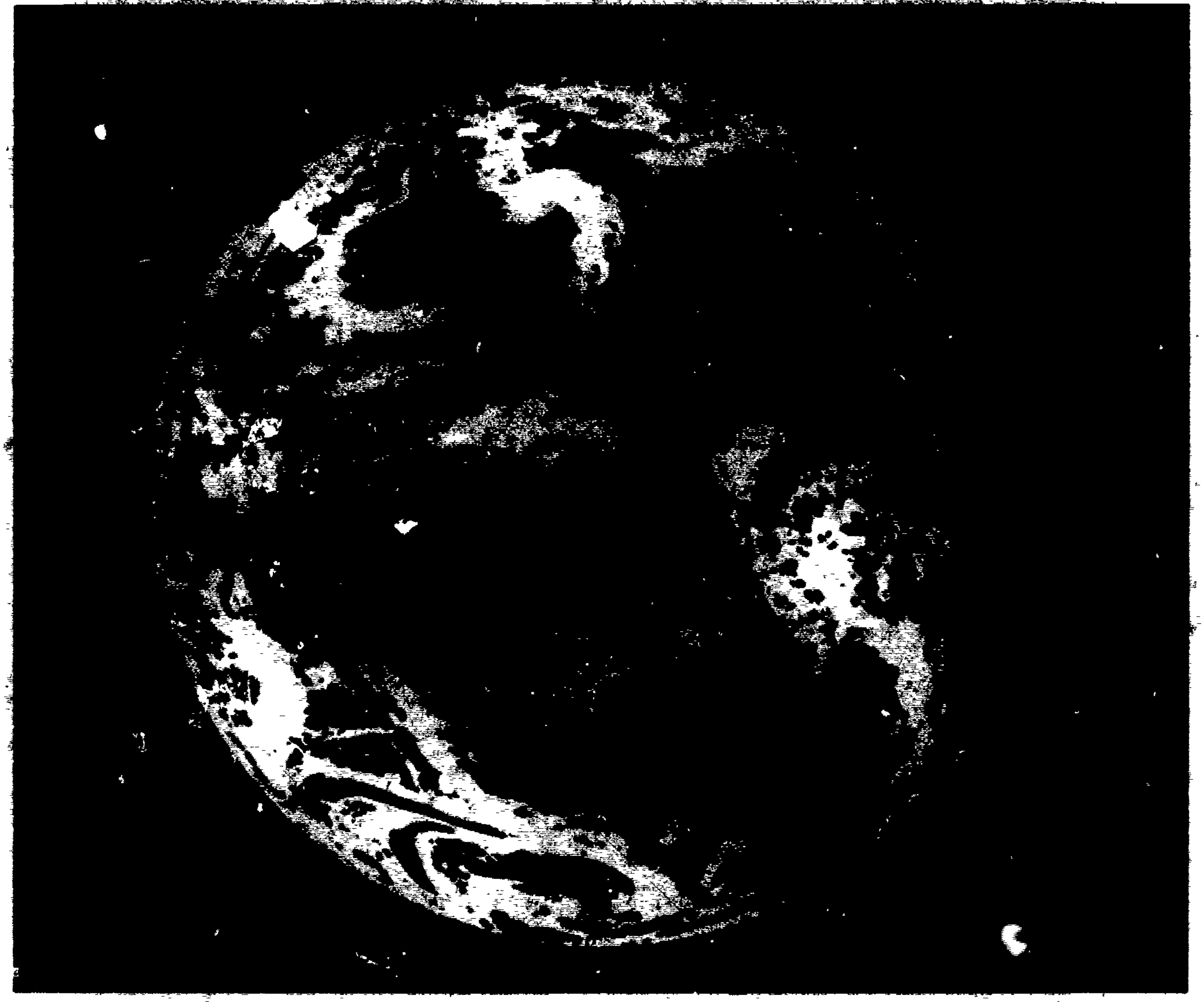
Table 2. Lifetime in years of U.S. coal reserves shown for several rates of growth of production

Source: Bartlett, "The Forgotten Fundamentals of the Energy Crisis"

Appendix - Advertisements

BEST COPY AVAILABLE

It's going to take a lot more than oil to keep this ball rolling.



The world runs on oil. More than 100 million barrels a day. But even that's not enough to satisfy our constantly growing energy needs.

So Phillips Petroleum is searching for new types of fuels to add to America's dwindling energy reserves.

In New Mexico, we recently discovered major new deposits of uranium ore. The fuel that will power our nation's nuclear reactors for future generations.

We've also discovered over 4 billion tons of lignite coal in a new trend that runs across 5 southern states. Enough new coal to provide all the electricity it would take to power a city the size of Chicago for the next 75 years.

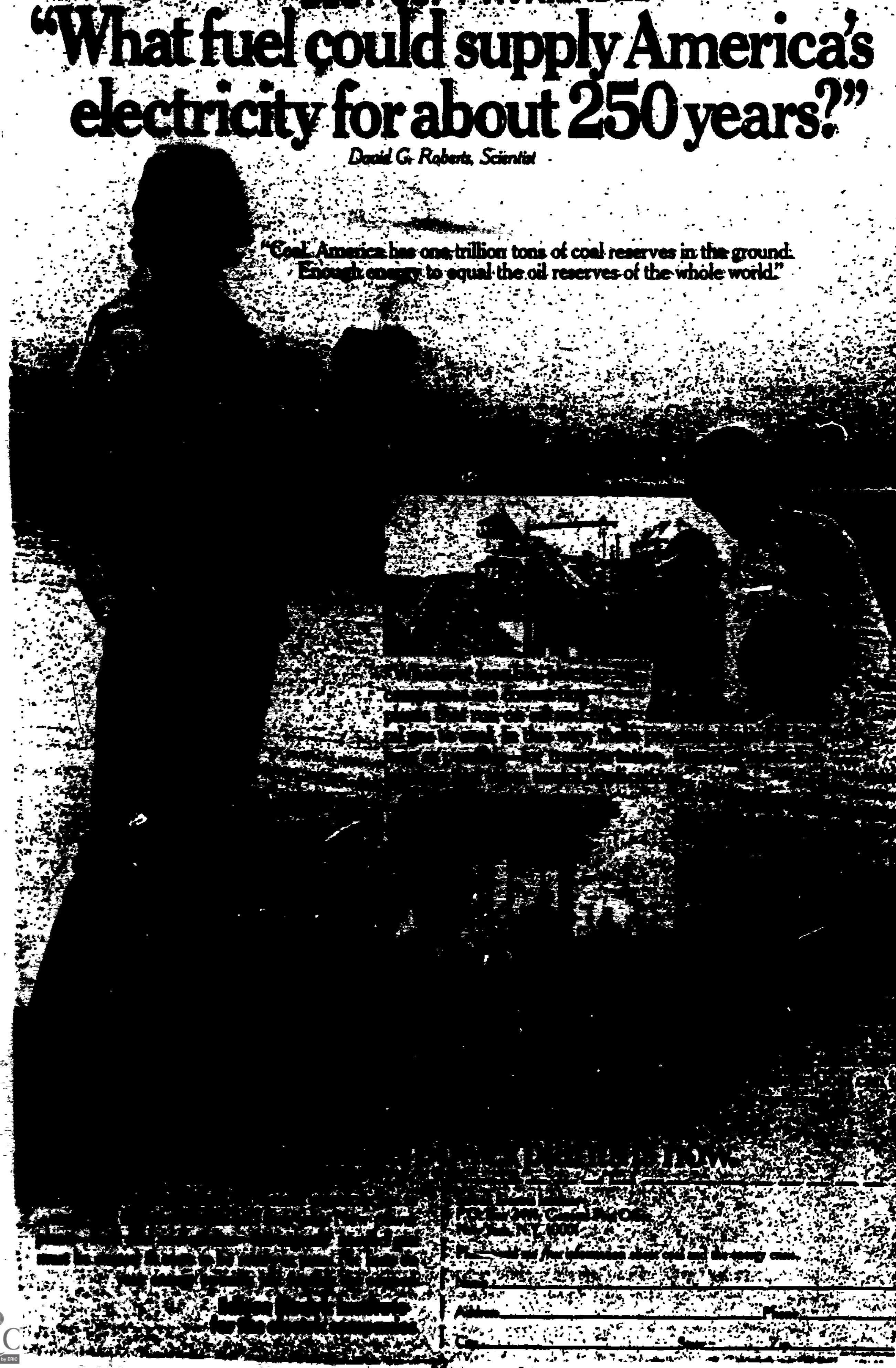
And in both Northwestern Nevada and Utah, Phillips is developing additional sources of energy by drilling deep beneath the earth's crust to tap the enormous power of natural geothermal wells.

Uranium ore. Lignite coal. Geothermal power. It may sound like a lot of energy. But we've just begun to scratch the surface.

Developing alternate fuels for the future, while we make fine products for your car. That's performance. From Phillips Petroleum.

The Performance Company

PHILLIPS 66


"What fuel could supply America's electricity for about 250 years?"
David G. Roberts, Scientist
"Coal. America has one trillion tons of coal reserves in the ground. Enough energy to equal the oil reserves of the whole world."
Address

A Message for Involved Americans from Atlantic Richfield Company.

I think America's future is black. Coal black.

Coal was our main source of energy until about 1940. The energy from coal kept us warm in winter. Cool in summer. Powered our first radios. Vacuum cleaners. Electric toasters. In those days, America ran on coal.

Today, America runs on oil and gas. And it looks like we have about a 30 year supply left. Scientists, the government and the energy companies are busy developing alternate energy sources. But those new sources won't be available for many years. We need more time.

Coal can buy us that time.

There's still plenty of coal left. And today, we have better ways of extracting it. Safer, more efficient ways of burning it. If we start developing our coal reserves now, we can make a smooth transition to other energy sources such as solar energy or nuclear fusion—both with unlimited energy potential. If we wait around, we may be in trouble.

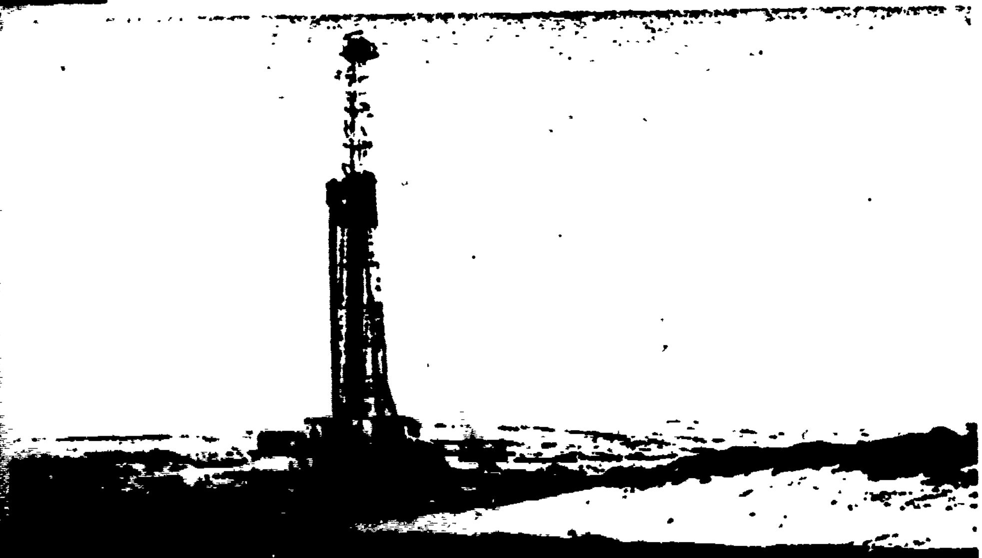
The way I see it, sometimes you have to dig up an old idea before you can come up with a new one.

Atlantic Richfield Company believes that one of our national goals must be a national energy policy that includes a plan for the prompt and orderly development of our country's coal reserves. You can help make it happen. Consider the facts. Take a stand. Get involved.

For a free booklet with additional information on this issue, please write: Atlantic Richfield Company, Coal, P.O. Box 30169, Los Angeles, CA 90030.

ARCO

Amoco has found enough reserves at one site in Wyoming to fuel the harvests on 5,000 farms for 35 years.



But that's only part of solving America's energy problem.

St. Ansgar. Population 991. For generations of farmers, it's been a good place to live. The Iowa loam is rich, ideal for corn and soybeans. And there's usually just the right mix of sun and rain to make the harvest plentiful.

Harvesting the crops takes energy—most of it petroleum energy. And unfortunately, nearly half the oil America depends on comes from foreign sources.

At Amoco, we're working to lessen this dependency. One way is by using new, highly sophisticated exploration equipment to find more energy supplies here in America.

In southwestern Wyoming, for example, we've gone back to previously explored areas with more sensitive sound-wave devices. As a result, over the past two years we've found enough new reserves to provide the diesel fuel needed to harvest the crops on five thousand average-sized farms in the Midwest for 35 years.

But we're still a long way from solving America's energy problem. New reserves are becoming harder to find. So the search for more American energy must be intensified.

It's a challenge we're meeting. Because we want to help keep the living good in America's heartland.

You expect more from a leader.

STANDARD

Standard Oil Company (Indiana)

SKILLS FOR THE FUTURE
Miniunit Two

LATERAL THINKING FOR CREATIVE PROBLEM SOLVING

Many forecasts of the future by scientists and social scientists seem frightening. We are told that our natural resources are being depleted very rapidly. We are warned about the prospects not only of skyrocketing fuel bills, but of possibly no fuel at all. You and your class could probably fill the chalkboard with lists of problems you see forthcoming in the next century. But perhaps the most frightening part of it all is the prospect that we may not be able to generate viable alternatives to many of the problems we can forsee. Aside from a sort of blind optimism on the part of a few who believe humans can solve any crisis that faces them, the limitations we impose on ourselves and our own creativity may well be the biggest obstacle we will have to overcome.

This miniunit centers on creativity as a means of generating alternatives in problem solving. It will not provide answers to the problems we face. No thinking process can bypass the fact that many of those problems are extremely complex and difficult to deal with. Rather, these materials can help students ask questions about the problems that ordinarily get overlooked in our methodical attempts to find solutions.

The process used in the exercises is called lateral thinking. Lateral or "zig-zag" thinking, as it is sometimes called, is a means of broadening the scope of alternatives in problem solving by allowing oneself to think about the problem more than the solutions. For example, if one were to see a gang fight on the evening news, a question might arise as to how to stop such fights. Ordinarily the vertical thinker, one who goes about solving problems in a logical step-by-step fashion, would be inclined to think of such things as the number of ways one could keep the rival gangs apart. A lateral thinker, on the other hand, would not focus on finding the solution as the central task. Instead he might concentrate on the personalities in the gangs, or on street fighting, or on group behavior, etc. The essential point here is that the lateral thinker would try to deviate from a single, best solution to the problem by asking questions that do not necessarily relate to any solution at all.

The basic principle involved in lateral thinking is that any particular way of looking at things is only one from among many other possible ways. By broadening the number of perspectives towards a problem it is logical to assume that one could similarly broaden the range of possible alternative solutions.

The word "lateral" suggests a movement sideways to generate alternative perspectives rather than proceeding straight ahead with finding a solution. In vertical thinking one proceeds to dig a hole deeper and deeper, using a step-by-step approach, to find a solution. In lateral thinking one digs a different hole.

The purpose of the various exercises in this miniunit is to provide an opportunity for the practical use of lateral thinking so that students may acquire the lateral thinking habit. For you and your students' clarification the following items about this thinking process are worth noting:

1. When we try to solve any problem - a small one, big one, personal one, societal one, or whatever, we usually look for alternatives only so that we may end up with the best possible approach or answer. In the lateral search we are trying to generate as many alternatives as possible. We are not necessarily looking for the best approach but for as many different approaches as possible.
2. In the normal vertical search for alternatives, we stop when we come to a promising answer or approach. In the lateral search we go beyond what seems like the best approach generating other alternatives.
3. Lateral thinking does not have to arrive at reasonable alternatives. The main purpose is to come up with different ones.
4. The search for alternatives in no way prevents us from using the most promising approach to a problem. It merely delays the use of the most promising approach.

5. The following point is very important to remember: even if the search for alternatives proves to be a waste of time for your students, it may help to develop the habit of looking for alternatives instead of blindly accepting the most obvious approach.

Outline of the Unit

The miniunit consists of three parts:

Part One: Practice in Generating Alternatives

Part Two: Challenging Assumptions

Part Three: Making Application: The Reversal Method and Brainstorming

Objectives:

As a result of practicing and applying the lateral thinking method the student will be able:

To demonstrate the ability to generate multiple alternatives in problem solving by stating the alternatives to the class

To recognize the unconscious or hidden assumptions that limit creative problem solving and recognize that one has to challenge assumptions in order to be more effective as a problem solver

To practice and apply the reversal method of starting the lateral thinking process

To utilize brainstorming as a formal setting and apply it to generating multiple alternatives to a problem deemed important to the class

Part One: Practice in Generating Alternatives

Although you may be familiar with some of the basics of lateral thinking, chances are your students are unfamiliar with the term. Before you can proceed with the exercises you will need to spend a few minutes introducing the process and purpose of lateral thinking. To help you we have provided a student handout, "The Basics of Lateral Thinking."

Exercise One - "The Basics of Lateral Thinking"

Introduction: This exercise is designed to introduce students to the concept of lateral thinking and what it can mean to them as problem solvers. If you find that students are still confused about the concept, reassure them that the practice exercises which follow should clear up most of the confusion.

Time: 20 minutes

Materials: Handout - "The Basics of Lateral Thinking"

Procedure: Distribute copies of the handout. Allow a few minutes reading time. Ask for questions, but remind students that getting into the exercises will help clear up the confusion. It is suggested that after a brief introduction to the concept you proceed with Exercise Two as soon as possible.

#

HANDOUT - THE BASICS OF LATERAL THINKING

IN THE NEXT FEW DAYS YOU WILL BE WORKING WITH AN IDEA CALLED LATERAL THINKING. LATERAL THINKING IS A DIFFERENT WAY OF THINKING THAN YOU ARE USED TO. USUALLY YOU THINK IN STEPS WHEN YOU TRY TO SOLVE A PROBLEM. FOR EXAMPLE, IF YOU WANTED TO MAKE A PAIR OF MOCCASINS FOR YOURSELF YOU WOULD FOLLOW WHAT YOU BELIEVE IS THE BEST STEP-BY-STEP METHOD FOR GETTING THE JOB DONE. STEP 1 MIGHT BE TO TRACE A PATTERN; STEP 2, CUT THE PATTERN; STEP 3, MAKE HOLES OR EYELETS FOR THE LACES; STEP 4, ATTACH THE SOLE TO THE TOP WITH LACE; AND SO ON. BUT SUPPOSE YOU WANTED TO BE MORE CREATIVE. HOW WOULD YOU PROCEED? YOU WOULD PROBABLY NOT WORRY ABOUT GETTING THE MOCCASINS MADE, AT LEAST FOR THE TIME BEING. YOU MIGHT EXPERIMENT WITH DIFFERENT PATTERNS AND STYLES. YOU MIGHT LOOK AT DIFFERENT MATERIALS, EVEN DIFFERENT ITEMS TO MAKE. YOU MIGHT EVEN END UP INVENTING A WHOLE NEW TYPE OF MOCCASIN! THIS MORE CREATIVE (BUT NOT NECESSARILY BETTER) WAY OF THINKING IS CALLED LATERAL THINKING BECAUSE INSTEAD OF SETTING OUT TO SOLVE THE PROBLEM - THAT IS, MAKE THE MOCCASINS - YOU FOCUS ON THINKING OF AS MANY DIFFERENT DESIGNS AND PATTERNS AS POSSIBLE.

HERE ARE SOME IMPORTANT POINTS TO KEEP IN MIND AS YOU VENTURE INTO THIS NEW WAY OF THINKING:

1. LATERAL THINKING IS NOT STEP-BY-STEP. YOU HAVE THE FREEDOM TO JUMP AROUND LOOKING AT ALL KINDS OF POSSIBLE APPROACHES TO A PROBLEM.
2. LATERAL THINKING DOES NOT HAVE TO BE REASONABLE. THE IDEA IS TO ENCOURAGE ZANY, FAR OUT IDEAS, TO THINK OF AS MANY DIFFERENT

WAYS OF LOOKING AT A SITUATION OR PROBLEM AS YOU CAN. YOU MAY BE UNREASONABLE BECAUSE IT MAY BE NECESSARY FOR YOU TO BE "WRONG" TO PROCEED TO ANOTHER ALTERNATIVE.

3. THE PURPOSE OF USING LATERAL THINKING IS TO IMPROVE YOUR CREATIVE ABILITY. IF YOU ACQUIRE THE HABIT OF LATERAL THINKING THROUGH PRACTICE, YOU MAY BE ABLE TO SOLVE PROBLEMS MORE CREATIVELY AND PRODUCTIVELY.

... .cise Two: "Applying Lateral Thinking"

Introduction: The first practice exercise will use some simple geometric figures to illustrate the application of lateral thinking to generating alternatives in problem solving. You can start off with geometric figures to indicate what the generation of alternatives is all about. ' en the idea is clarified, you can move on to less artificial situations.

Time: 30-40 minutes

Materials: Handout - "Figures"

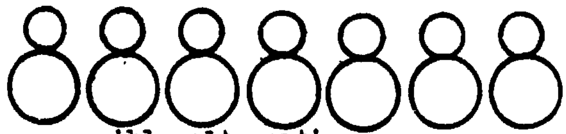
Procedure:

Step 1 - Distribute copies of the handout.

Step 2 - Ask students to list as many different ways of looking at each of the figures as possible on a separate sheet of paper.

Step 3 - Collect the written alternatives.

Step 4 - Pick out a few of the papers and read the alternatives listed. Ask for other variations. (Note: It would be a good idea to have one of your students list all the descriptions in a composite list on the chalkboard as they are stated by the class.) Your function is to encourage and accept various descriptions, not to judge them. Do not reject ideas that seem outrageous, rather encourage the students who made them to explain them more fully. If there is difficulty in generating variations, you will need to insert a few possibilities on your own.

Figure 1. 

Some possible alternatives:

figure-eights

balls on top of balls

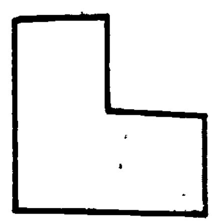
snowmen

unfinished drawings of people (head and torso)

____

____

____

Figure 2. 

Alternatives:

an L-shaped figure

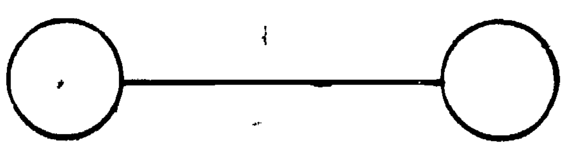
a carpenter's square

half of a picture frame

two rectangles placed against each other

____

____

Figure 3. 

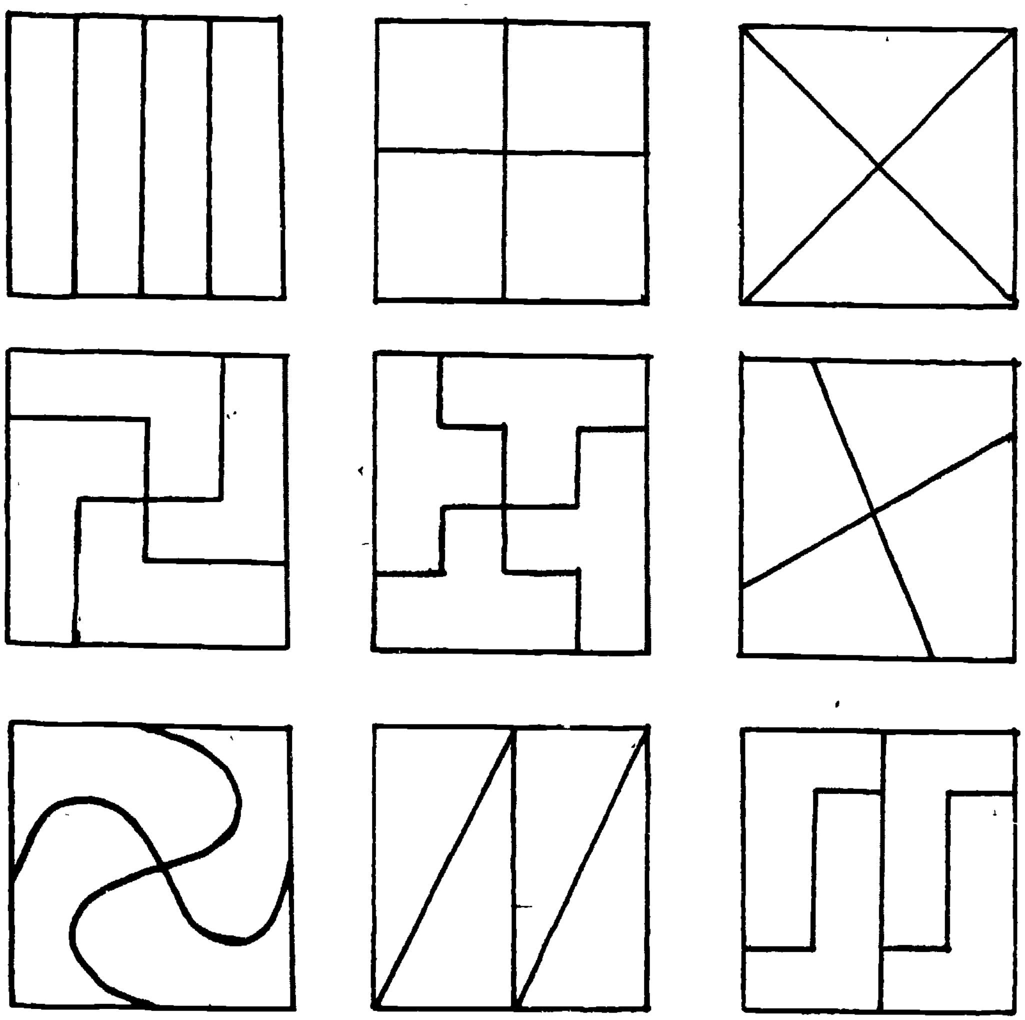
Alternatives:

a barbell

two circles joined by a line

____

Figure 4.



HOW WOULD YOU DIVIDE A SQUARE INTO 4 EQUAL PIECES?

NOTE: Many students stick to the first three patterns or to slight variations of them. In fact there is an infinite number of shapes one could use as variations of the designs shown above. A suggested role for you as teacher would be to show that there are other ways to make the four equal pieces even when students are convinced there cannot be. Thus you should wait until no further ways are offered by the students and then introduce the variations suggested above at one time.

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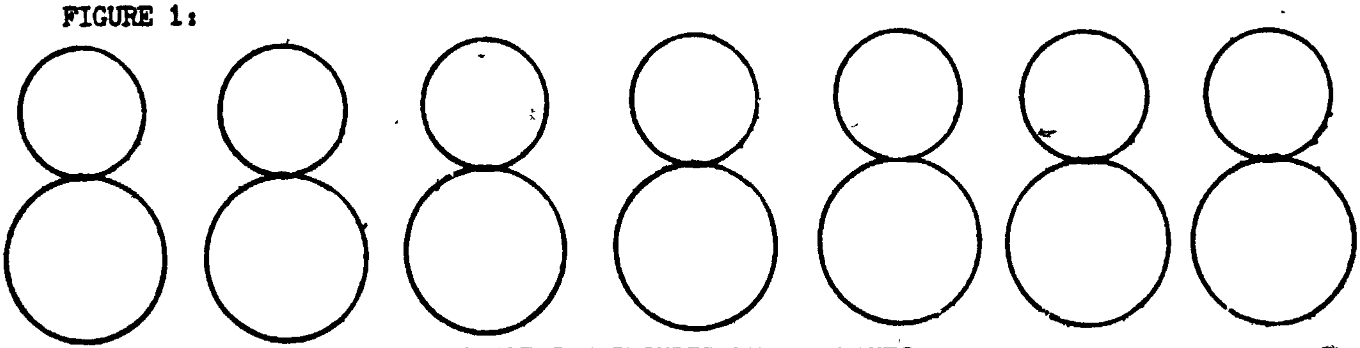
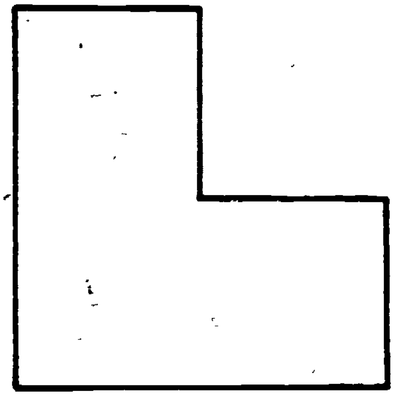
*Adapted from Edward de Bono, <u>Lateral Thinking</u>, New York: Harper and Row, 1970, pp. 76-78.

FIGURE 1:



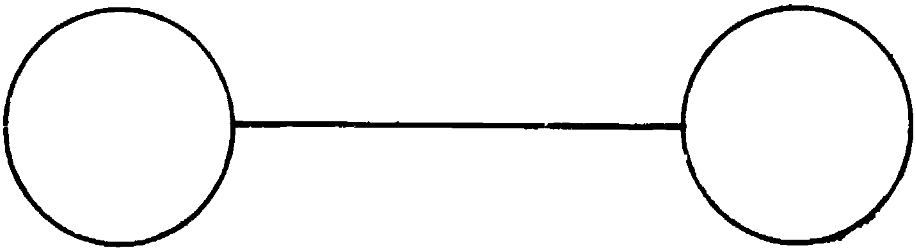
HOW WOULD YOU DESCRIBE THE FIGURES SHOWN ABOVE?

FIGURE 2:

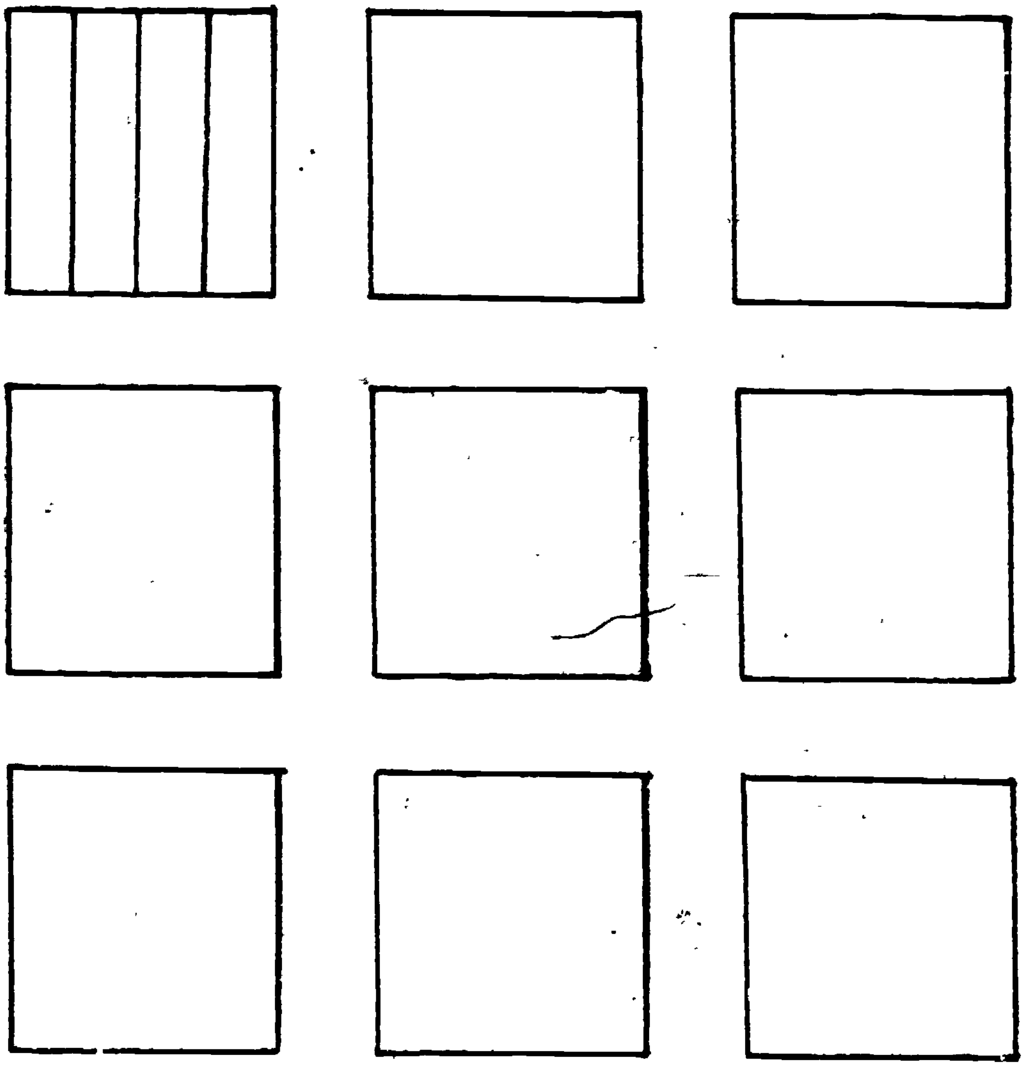


HOW WOULD YOU DESCRIBE THE ABOVE FIGURE?

FIGURE 3:



DESCRIBE THE FIGURE ABOVE.



ON THE FIGURES ABOVE DRAW IN AS MANY DIFFERENT WAYS AS YOU CAN THINK OF TO DIVIDE A SQUARE INTO 4 EQUAL PIECES. THE FIRST SQUARE IS DRAWN IN FOR YOU AS AN EXAMPLE. (Use additional paper to draw additional squares if you need to.)

Exercise Three: "Picture and Story Interpretations"

Introduction: As stated in the introduction to the previous exercise, once students have gotten the idea of what it means to generate alternative ways of looking at a few simple geometric shapes, they can move on to some less artificial material.

Photographs from newspapers or magazines and stories that contain different points of view can be used to carry the lateral thinking process a bit further. The subtleties and shades of difference in interpretation make these materials very appropriate for generating large numbers of alternative viewpoints.

Time: 45 minutes

Materials: Picture, p. 48; stories clipped from newspapers or magazines

Procedure:

I. Pictures-

Step 1 - The picture selected for this exercise is sufficiently vague to raise differing interpretations of what is happening in the scene. Hold up the picture so the students can see it.

Step 2 - Ask students to generate as many interpretations as they can about what might be happening in the photograph. Is the old White man being attacked? Is the White man shoving his way through the group of Black men? What other interpretations can be offered?

Step 3 - Cover up various parts of the picture with a blank piece of paper. From what students see as you cover up sections of the picture, what new and different interpretations can be offered for what is happening?

Step 3 - Ask students to clip pictures from magazines or newspapers to repeat this exercise.

II. Stories-

Clip at least three news stories from the newspaper. Use the following procedure with each story:

Step 1 - Read the story to the students.

Step 2 - Ask them to generate the different points of view in the story.

Step 3 - Change a favorable or a positive story to an unfavorable or a negative one, not changing the material but by changing the interpretation of the story.

#

Exercise Four: "Problems"

Introduction: By now your students should be ready to generate alternatives to problems. The format suggested for use here can be applied to all kinds of problems.

Time: 40 minutes

Procedure:

1. Problems can be taken from the everyday difficulties we all encounter, from newspapers, magazines, or other media sources. In using problems to generate alternative perspectives ask students to generate alternative ways of stating the problem. The emphasis is not on actually trying to solve the problem, but on finding different ways of looking at it. You and your students may look at a solution, but it is not essential. What is important in this exercise is for students to see that alternative ways of looking at a problem also open up many more alternative solutions to it.

EXAMPLE: THE PROBLEM OF A DOG BARKING LATE AT NIGHT IN A RESIDENTIAL NEIGHBORHOOD

Alternative ways of stating the problem:

The problem of a dog barking at night

Preventing people from being bothered by a dog barking

Problem of barking dogs

Making it unnecessary for the dog to bark

Problem of having to have quiet at night in a residential neighborhood

Problem of residential neighborhoods with barking dogs

Some of these alternative ways of looking at the problem may suggest solutions to the problem. The more general the statement of the problem, the less likely it is to suggest a solution. However, even though our original purpose was to generate alternative ways of looking at the problem, notice how these alternative perspectives affect the range of possible solutions:

PREVENTING PEOPLE FROM BEING BOTHERED BY A BARKING DOG - This statement suggests a solution that has to do with the people, i.e., wearing earplugs, filtering the sound in some way, or making the sound fit in with one's dreams.

PROBLEM OF BARKING DOGS - This statement suggests that solutions to the problem lie within the dog, i.e., muzzle the dog, give the dog attention.

MAKING IT UNNECESSARY FOR THE DOG TO BARK - This is somewhat like the previous statement, but the emphasis is not on the dog, rather on someone doing something with or to the dog to prevent the barking.

PROBLEM OF HAVING TO HAVE QUIET IN A RESIDENTIAL NEIGHBORHOOD - This statement indicates that solutions are to be found in the structure of the neighborhood.

2. Experiment with other problems that students can suggest:

Step 1 - State the problem.

Step 2 - Restate the problem in a number of alternative ways.

Step 3 - Explore the range of possible solutions opened up by doing Step 2.

END OF PART I: AT THIS POINT STUDENTS SHOULD HAVE A GOOD IDEA AS TO WHAT LATERAL THINKING IS. MOREOVER, THEY SHOULD SEE THAT THE MORE ALTERNATIVE WAYS OF LOOKING AT A PROBLEM ONE CAN GENERATE, THE MORE POSSIBLE SOLUTIONS THERE WILL BE.

PART TWO: CHALLENGING ASSUMPTIONS (45 minutes)

Part One was concerned with alternative ways of looking at problems. This part is about challenging rigid assumptions. It is necessary for students to gain practice in challenging assumptions because in problem solving one always assumes certain prohibitive boundaries. Repeated validation of these boundaries is crucial if we are to be free to maximize our choice of solutions. The boundaries are usually self-imposed, and therefore, can be changed. In questioning assumptions, we challenge the necessity of limits, not because they are necessarily wrong, but because we are attempting to alter the pattern as lateral thinkers.

Exercise One - "Nine Dots"

Introduction: This problem makes the point about challenging assumptions quite nicely. The problem appears impossible because of the limits persons almost automatically impose on it.

Materials: Handout - "Nine Dots"

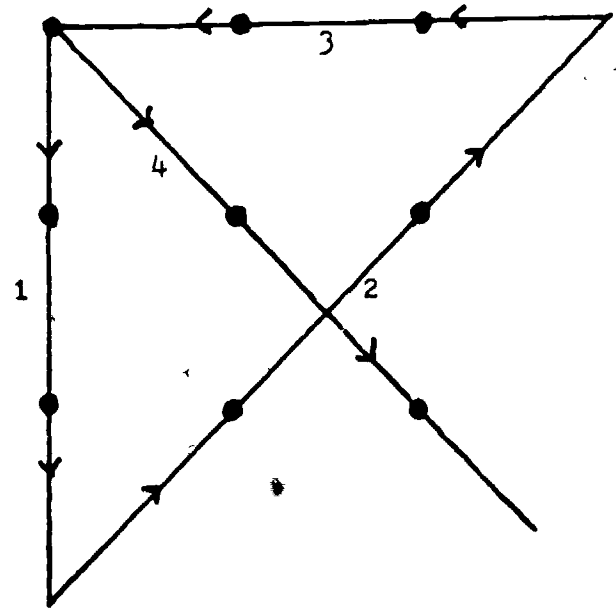
Procedure:

Step 1 - Give each student a copy of the handout with the nine dots.

Step 2 - Explain the problem:

"THE PROBLEM IS TO LINK UP THE NINE DOTS USING ONLY FOUR STRAIGHT LINES WHICH MUST BE DRAWN WITHOUT RAISING YOUR PENCIL FROM THE PAPER."

The assumption being challenged is that the four lines must link up the dots without going beyond the boundaries of the outer dots. If one breaks through this assumption the problem is easily solved.



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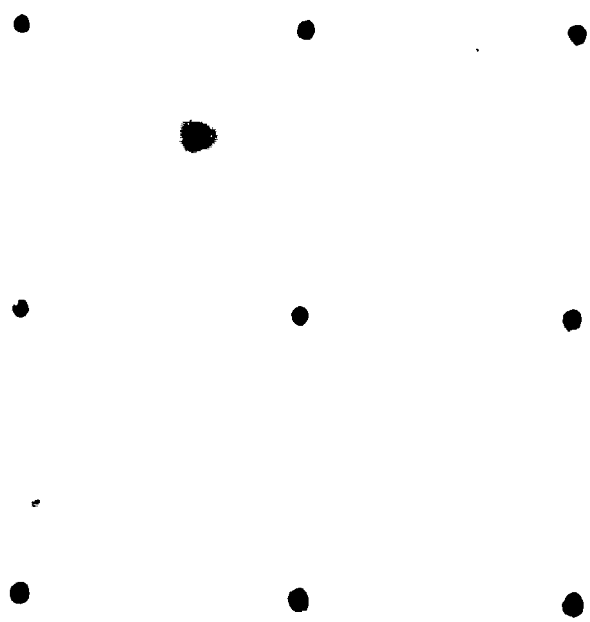
HANDOUT - "NINE DOTS"



LINK UP THE NINE DOTS USING ONLY FOUR STRAIGHT LINES
WHICH MUST BE DRAWN WITHOUT RAISING YOUR PENCIL FROM THE PAPER.

Exercise Two: "The Elevator"

Introduction: As in the previous exercise, this problem can be solved only if one thinks laterally and changes a basic assumption.

Procedure:

Step 1 - State the problem:

"A MAN WORKED IN AN OFFICE BUILDING. EACH MORNING HE GOT ON THE ELEVATOR ON THE FIRST FLOOR, PRESSED THE ELEVATOR BUTTON TO THE TENTH FLOOR, GOT OUT OF THE ELEVATOR AND WALKED UP TO THE FIFTEENTH FLOOR. AT NIGHT HE WOULD GET INTO THE ELEVATOR ON THE FIFTEENTH FLOOR AND GET OUT AGAIN ON THE FIRST FLOOR. WHY DID HE FOLLOW THIS ROUTINE?"

Step 2 - Ask for explanations. Usually, you will get responses such as the following:

The man needs exercise.

He wants to visit with a secretary on the twelfth floor.

He stops off for coffee between the tenth floor and fifteenth floor.

He wants to admire the view on the way up.

He wants to talk to someone on the way up.

In fact, the reason for the man's behavior is that he has no control over the decision. He is a dwarf and cannot reach past the tenth floor button. This is a categorically different response from those listed above. Those responses assume that the man is perfectly normal, but that it is his behavior that is abnormal.

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Exercise Three - "The Accident"

Procedure: State the Problem:

> A BOY AND HIS FATHER WERE OUT DRIVING ONE DAY. SUDDENLY THE CAR MISSED A CURVE AND WENT OUT OF CONTROL INTO A DITCH. THE FATHER WAS KILLED, BUT THE BOY SURVIVED WITH CRITICAL INJURIES. THE BOY WAS RUSHED TO THE HOSPITAL FOR EMERGENCY SURGERY. THE DOCTOR CAME INTO THE OPERATING ROOM TO OPERATE, LOOKED DOWN INTO THE BOY'S FACE, AND EXCLAIMED, "MY GOD! IT'S MY SON!"

-HOW COULD THIS BE?-

Step 2 - Ask for explanations.

The problem here is that so many people unconsciously assume that the doctor could not be the boy's father because he was killed in the accident. Remove the assumption that all doctors are men and the answer is easy. The doctor in the operating room was the boy's mother.

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END OF PART II: You and your students can generate other problems of this sort. The purpose in each case is to show that the blind acceptance of certain assumptions can impose limitations that make it impossible to solve certain problems.

Part Three: Making Application: the Reversal Method and Brainstorming

There are many variations of the lateral thinking process, but few are as simple and useful as the reversal technique and brainstorming. Brainstorming will be introduced in Exercise Two below.

Because it is relatively easy to understand and to apply to problem solving, practice in reversal can be very beneficial for students. If you give your students an open-ended creative problem, there is usually difficulty in getting started. You are probably very aware of this by now. The question is, "What do I do first," or "How do I get started?" The reversal method of lateral thinking gives one a place to start. Whenever a problem is stated, one simply pursues it in the opposite direction. Below are two examples of the reversal technique:

> A flock of sheep were moving slowly down a country lane which was bounded by high banks. A motorist in a hurry came up behind the flock and urged the shepherd to move his sheep to the side so that the car could drive through. The shepherd refused since he could not be sure of keeping all the sheep out of the way of the car in such a narrow lane. Instead he reversed the situation. He told the car to stop and then he quietly turned the flock around and drove it back past the stationary car.*

> In Aesop's fable the water in the jug was at too low a level for the bird to drink. The bird was thinking of taking water out of the jug but instead he thought of putting something in. So he dropped pebbles into the jug until the level of water rose high enough for him to drink.*

A word of caution. Very often the reversal procedure leads to a way of looking at a situation that is obviously ridiculous. However, one must remember that the main purpose of using the technique is to be provacative.

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*de Bono, op. cit., p. 144.

By disrupting the original way of looking at the situation, one disrupts the student's inability to see only conventional solutions. Succinctly, reversals are not especially useful in themselves but only in what they lead to -- a variety of perspectives towards the problem or situation heretofore overlooked in the conventional vertical search for alternatives.

Exercise One - "Practising Reversal"

Introduction: In practice present students with a number of situations that can be reversed in as many ways as possible. The same thing can be accomplished by giving out a subject, then asking for volunteers to reverse it, and listing the reversals on the chalkboard as they are stated.

Time: 20-30 minutes

Procedure:

Step 1 - Explain to students: "I AM GOING TO ASK YOU TO PRACTICE A FORM OF LATERAL THINKING CALLED REVERSAL. AS I GIVE YOU A SUBJECT, I WILL ASK YOU TO STATE IT IN REVERSE. FOR EXAMPLE, IF YOU WERE GIVEN THE SUBJECT, 'TEACHERS TEACHING STUDENTS,' YOU MIGHT REPLY, 'STUDENTS TEACHING TEACHERS,' OR 'TEACHER LEARNING FROM STUDENTS.' IN EACH CASE, WHEN I GIVE YOU A SUBJECT, TRY TO STATE THE REVERSE OF THE SUBJECT IN AS MANY WAYS AS POSSIBLE. HERE ARE SOME PRACTICE SUBJECTS:

'STREET SWEEPER'

'A BOY THROWING A FRISBEE FOR HIS DOG'

'MAILMAN DELIVERING MAIL'

'MEN LAUGHING'

'CLERKS HELPING CUSTOMERS'

'DOCTORS TREATING PATIENTS'

Step 2 - As students respond with reversal statements list them (or ask a student to do so) on the chalkboard. In some cases, reversal may seem ridiculous. It does not really matter if you can get across the point that by having students practice being ridiculous they are practicing reversal.

Step 3 - Have students discover how reversal leads to other lines of thought by presenting a subject and its reversal and having students expound on the reversals. For example: "Teachers teaching students"--"Students teaching teachers." The idea of "students teaching teachers" might lead to the idea of "new teaching techniques" or "redefining what teaching is all about" or "what students know that teachers don't." It is not always easy to develop further ideas from a reversal, but the important thing is that students recognize how reversals can be starting points for various new ways of looking at a situation--an exciting prospect in itself!

Exercise Two - "Brainstorming"

Introduction: Brainstorming is a formal setting for the use of lateral thinking. It is a group activity that does not necessarily require your intervention in the role of teacher.

The necessary requirements for the brainstorming setting are the ability of the group members to suspend judment of the ideas presented and the formality of the setting. Regarding suspended judgment, it is crucial that students understand that no idea is too ridiculous to be put forward in the group. Such statements as "That wouldn't work!" or "I don't see your point!" or "That's a silly idea!" can reduce brainstorming to complete ineffectiveness. It is imperative that students refrain from evaluating the ideas presented until the appropriate time.

The formality of the setting is important because the more formal the setting the more chance there will be of informality in ideas within it. The formality of the setting gives students the freedom to do what they like with their thoughts without fear of the criticism of others.

Brainstorming is presented here as a highly structured and useful setting within which your students can apply all of the basics and techniques of lateral thinking to creative problem solving. Below is a suggested structure for the setting:*

<u>Size</u> - Groups of 6-12 students

<u>Leader</u> - One who can guide the discussions without controlling or directing them. He has the following duties:

1. He stops people from evaluating ideas.
2. He sees that people do not speak all at once.
3. He fills in gaps by offering suggestions himself.
4. He defines the central problem and keeps pulling people back to it.
5. He ends the session at the end of a fixed time period.

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* An adaptation of a format suggested in de Bono, *op. cit.*

6. He organizes the evaluation session and the listing of ideas.

Notetaker - Converts the ideas into a list that is immediately readable and succinct.

Time Limit - 20 - 45 minutes are minimums and maximums. The selection of an appropriate time frame between these limits depends upon the complexity of the problem.

Warm Up - This is a trial run using a subject different from the main agenda. The idea is to show the type of ideas that can be generated and to show how evaluation is excluded.

Follow Up - The collection of additional ideas after the session has ended. These should be recorded and made available to the group.

Evaluation - As noted above there is no attempt at evaluation during the brainstorming session itself. Rather, it is carried out later by either the same group or a different group. It is the evaluation session that makes a worthwhile problem solving venture of what would otherwise be a fruitless exercise. The main points are as follows:

1. To pick out ideas which are directly useful.
2. To extract from ideas that are wrong or ridiculous whatever useful grain of information may be there.

3. To list workable ideas; new aspects of the problem; ways of considering it heretofore unmentioned.

4. To pick out ideas which can be tried out with relative ease. These may seem wrong at first.

5. To pick out ideas that have already been tried.

Ideally there should be three lists at the end of the evaluation session:

1) IDEAS WHICH CAN BE USED IMMEDIATELY

2) AREAS WHICH NEED FURTHER EXPLORATION

3) NEW APPROACHES TO THE PROBLEM

Formulation of the Problem- When you and your students have decided on a problem you deem important to subject to the brainstorming setting, the following points are worth noting:

1. Too broad a statement of the problem may make the session unproductive because the ideas will not relate or interact. For example: "Better schools."

2. Too narrow a statement may restrict the ideas too much. For example: "Improvement of schools through information decided on by student council and the student body." This restricts the possibilities going into the brainstorming session.

3. A middle ground should be chosen, such as: "Ways to make school more responsive to the needs of students given the present school physical setting." Here we have narrowed the possibilities by stabilizing the physical setting, but we have broadened the possibilities by using words like "ways," "needs," and "responsive."

Exercise 3 - "Practicing And Applying Brainstorming"

Introduction: The class is divided into groups of suitable size. Each group elects its leader. The notetaker is selected.

Procedure:

Step 1 - Following the preliminaries outlined in the introduction above; the principles of brainstorming previously stated above are explained with emphasis on the following:

1. No evaluation or criticism.
2. Encourage far-out, zany ideas, even ridiculous ones.
3. State your ideas in a few words. Do not develop ideas to length.
4. Choose a time limit and stick with it.

Step 2 - After students understand the procedure, the next step is to formulate a problem. Here are some suggestions for brainstorming sessions:

The design of the UN flag

The lack of sufficient parks

The uses of outer space

Making the desert fertile

Heating a house

Fueling an automobile

Mining the sea

Limiting population

Step 3 - After the brainstorming session is over begin the evaluation session. It should not be held on the same day. Divide evaluation information into categories, e.g.:

1. Directly useful ideas
2. Interesting approaches
3. For further examination
4. Discard

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References for Lateral Thinking:

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