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Introduction to Problem Solving

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Regardless of what they do for a living or where they live, most people spend most of their waking hours, at work or at home, solving problems. Most problems we face are small, some are large and complex, but they all need to be solved in a satisfactory way. Before we look at the area of problem analysis and solution, though, let's take a few moments to think about just what we mean by a problem.

What is a Problem?

One of the creative thinker's fundamental insights is that most questions have more than one right answer and most problems have more than one solution. In keeping with this insight, we will offer more than one definition of a problem, in hopes of filling out its meaning as fully as possible. Different definitions yield different attitudes and approaches and prevent us from becoming fixed in the rut of "Oh No! A Problem!" as we discussed in Chapter 1.

1. A problem is an opportunity for improvement. A problem can be a real break, the stroke of luck, opportunity knocking, a chance to get out of the rut of the everyday and make yourself or some situation better. Note that problems need not arrive as a result of external factors or bad events. Any new awareness you have that allows you to see possibilities for improvement brings a "problem" for you to solve. This is why the most creative people are "problem seekers" rather than "problem avoiders."

Developing a positive attitude toward problems can transform you into a happier, saner, more confident person who feels (and is) much more in control of life. Train yourself to respond to problems with enthusiasm and eagerness, rising to the opportunity to show your stuff, and you will be amazed at the result.

2. A problem is the difference between your current state and your goal state. A problem can result from new knowledge or thinking. When you know where you are and where you want to be, you have a problem to solve in getting to your destination. The solution can and should be fun and exciting as you think over the various possible solution paths you might choose. When you can identify the difference between what you have and what you want, you have defined your problem and can aim toward your goal.

3. A problem results from the recognition of a present imperfect and the belief in the possibility of a better future. Isn't it interesting here that hope produces problems? The belief that your hopes can be achieved will give you the will to aim toward the better future. Your hopes **challenge** you, and challenge is another definition of a problem.

The Importance of Goals in Problem Solving

As you read these definitions, I hope you noticed that they all include the ideas of goals and ideal states. Problem solving centers on thinking about goals and ideals. When a goal is met, the problem should be concluded *if the goal was an appropriate one for solving the problem.*

Another way of thinking about this would be to say that the goal or ideal state defines how much of a problem exists or even whether or not there is a problem.

For example, let's say you have just brought a pizza home from the pizza parlor and it is beginning to cool. If your ideal state is to eat very hot pizza, then you have a problem, whether you define it as how to keep the pizza from cooling, how to heat it back up, how to eat it quickly, or whatever. On the other hand, if you like moderately warm pizza, then you do not have a problem. Similarly, if your friend comes over an hour later and you offer him a piece of leftover pizza, only to discover that your oven is on the blink, you have a problem: how to heat the pizza up again. But if the friend says, "I really like cold pizza better than hot," you no do not have a problem.

This example demonstrates that one's goal must be considered in conjunction with one's current state in order to determine whether a problem exists and to what extent it exists. People who don't take time to think about their goals before attacking a problem thus don't fully understand the problem. You've probably heard that cracked proverb, "If you don't know where you're going, you'll probably end up somewhere else."

Another important truth to derive from this understanding about goals is that as your goals change, so will the nature of the problems you face. Life operates in real time rather than in timeless theory, so that as we move through our existence, our goals are in a constant state of flux. Some goals change radically, or even reverse, while others undergo minor adjustments and refinements. Be sure that your problems and solutions stay current with your goals.

What is a Solution?

In our ordinary discourse, we often think of "solving a problem" in the sense of making it go away, so that the problem no longer exists. This indeed is one kind of solution, but it is not the only kind. Some problems cannot be eliminated entirely: we are never likely to eliminate trash, or the wear on automobile tires, or the occurrence of illness. We can, however, create solutions or treatments that will make each of these problems less harmful.

For our purposes, then, we will define a solution as *the management of a problem in a way that successfully meets the goals established for treating it.* Sometimes the goal will be to eliminate the problem entirely; sometimes the goal will be only to treat the effects of the problem. The possibilities inherent in the problem, together with the ambitiousness, resources, and values of the problem solver, will help shape the goals.

There are two basic approaches to solving problems, one where the cause or source of the problem is attacked and the other where the effects or symptoms of the problem are attacked. For ease of remembering, we can call these the **stop it** and the **mop it** approaches, respectively. Each of these approaches has three basic forms. As we detail these approaches and their forms, let's use the problem of a leaking water tank to illustrate each one.

Stop It

A stop-it approach is designed to cure a problem, so that, insofar as possible, the problem no longer exists. Its three forms are prevention, elimination, and reduction.

Prevent It. By preventing a problem from occurring (or recurring) we have perhaps the ideal solution. In our water heater example, we would build a very high quality water heater, perhaps with a copper tank, so that it would never leak. The prevention approach is often a difficult one to apply because it requires predictive foresight ("this might be a problem someday if we don't act now") and it is often costly. And, of course, most problems crash into us unexpectedly or for some other reason cannot be prevented.

For example, if you can prevent a cold, or an automobile accident, you will not have to deal any further with a problem or its effects. Similarly, by preventing misunderstandings, the need for lots of damage control and *emotional healing can be avoided.*

Eliminate It. Eliminating a problem once and for all is also an excellent way of attacking a problem. In our leaking water heater example, an elimination solution would be to plug or seal or otherwise repair the leak, the cause of the problem (all that water on the floor). Elimination solutions should be considered in nearly every problem situation.

For example, a neighbor where I used to live had chronic trouble getting TV reception to suit him. Every weekend he was on his roof installing another antenna (he eventually had three), rotating one, putting another up on a higher mast, and so on. He even put in a satellite dish. He might have eliminated the problem by subscribing to cable TV or moving to an area where the reception was better.

Elimination solutions can be expensive and politically unpopular, however, so that they are not always feasible.

For example, an elimination solution to the AIDS problem might involve changing social behaviors (including sexual practices and drug use). Such changes would be resisted. Thus, the usual approach to AIDS is a mop-it one (see below).

Reduce It. As we mentioned earlier, some problems, like trash production, cannot be eliminated entirely. In such cases, a strategy of reduction can be highly effective. Almost any problem can be made less of one by reducing its size. In our water heater example, suppose we couldn't perform a repair (an elimination solution) until a day or two later. We could reduce the problem by turning off the incoming water. Without line pressure on the tank, the leak would slow down; that would be better that a full force leak.

For example, current approaches to the flow of illegal drugs into the country include reduction strategies. The flow of drugs cannot be eliminated as long as demand continues, so interdiction focuses on "as much as possible."

Mop It

A mop-it approach focuses on the effects of a problem. As you can guess, the name comes from our leaking water heater example. Instead of treating the leak itself, we mop up the water on the floor--the effects of the problem.

Treat It. Here the damage caused by the problem is repaired or treated. We mop up the water, fix the damaged floor, hang the rugs out to dry. Note two things: (1) by itself a treat-it solution is not going to be nearly as effective as some form of stop-it solution and (2) treat-it solutions are often needed in addition to an elimination or reduction form of solution.

For example, some of our drug and alcohol treatment programs are aimed at symptomatic relief of the effects of these problems rather than at eliminating the problems to begin with.

Tolerate It. In this form of mop-it approach, the effects of the problem are put up with. In our leaky water heater example, we might install a drain in the floor, or waterproof the floor. The effects are taken for granted and measures are taken to endure them.

For example, graffiti and vandalism are now taken for granted in many large cities, so tolerance measures have been implemented, such as installing lights that are harder to break or cheaper to replace, not planting trees that would be destroyed, and so on.

Redirect It. Here the problem is deflected. Sometimes the problem will simply be redefined as not a problem. It's hard to think of a legitimate redirection for our leaking water heater problem, but suppose that the leak is small and the floor is not being damaged. We might say, "Well, we need the humidity; the leak is actually a good thing." Remember that a problem is a problem only when someone defines it as such.

Some police departments have been known to buy bus or airline tickets for chronic offenders (prostitutes, usually) to send them to another state far across the country, thus "solving" their own problem.

Sometimes, as when you get a cold, a mop-it solution is all that's available: there is no elimination solution that works yet. In general, however, be careful to investigate the possibility of implementing a stop-it solution before you focus on mop-it ones. There is a temptation to focus on symptomatic treatments for our problems when we should be looking for treatments of the underlying causes.

General Guidelines for Problem Solving

Here are some guidelines that will help you analyze, define, and solve problems in an orderly way. Use these guidelines to help create a problem-solving habit of mind and to give some structure to your problem solving activity. Remember, though, that problem solving does not proceed by recipe, nor is it necessarily linear, as these guidelines might imply. Problem solving is a recursive process; you must continually go back and forth between steps and do some parts again. Similarly, you might not always proceed in exactly this order. Thus, these guidelines are not meant to be rigid and absolute. Think of them rather as a checklist designed to assure that you include all the important features of problem analysis in your thinking. (After the outline of the guidelines you'll find a commentary and elaboration on them.)

I. Problem Exploration
1. State the Problem.
A. State what the problem is
B. Restate the problem
C. State the problem more
2. Clarify the Problem.
A. Define the Key terms of the problem.
B. Articulate the assumptions
C. Obtain needed information
3. Explain the Problem.
A. Discuss the problem with someone else.
B. Look at the problem from different viewpoints.
C. Ask a series of whys.
4. Put the Problem in Context.
A. What is the history of the problem?
B. What is the problem environment?
C. What are the constraints?

II. Goal Establishment
1. Consider Ideal Goals.
2. Establish Practical Goals.

III. Idea Generation
1. Generate Ideas for Possible Solutions.

IV. Idea Selection
1. Evaluate the possibilities.
2. Choose the solution(s).

V. Implementation
1. Try the solution.
2. Make adjustments.

VI. Evaluation
1. Determine whether the solution worked.

Discussion of the Problem Solving Guidelines

I. Problem exploration

The problem is investigated, broken into subproblems, terms are defined. A determination is made about the nature of the problem (sociological, personal, technological, historical). Some research is made into whether or not it has been met in the past, and if so, how. Steps:

1. State the Problem.

A. State what the problem is. Does it have multiple aspects? If so, what are they? This should include a written description of the problem in the clearest way it can be put. The statement might begin with the problem as given, put in quotation marks to remind you that that's the way it was received. But the problem should always be stated in your own words, too. Make the problem your own, and do not let it become attached to the verbal clothing in which it was originally delivered to you.

A useful aspect of any definition or problem statement is to state what the thing is *not*. By clearly identifying what is *not* the problem, you'll clarify what it is.

B. Restate the problem in entirely different words, or in a completely different way. Do this several different times (three to eight is recommended). Again, the purpose of this process is to break the problem away from confusing or restricting verbal maps of it, so that the "problem in itself" can be isolated.

For example, "Carry the filing cabinet upstairs to my office." How about "Take the file to my office upstairs," or "Move the cabinet into my office." This latter description may enable you to cease focusing on the stairs and carrying and to remember that there is an elevator nearby.

C. State the problem more generally or more broadly. Put it abstractly or even philosophically. The idea here is to find out whether the given wording of the problem is really only a specific statement of a more general problem. Often general statements allow the problem to be seen in entirely different terms and therefore suggest solutions that otherwise wouldn't be thought of.

Compare the difference in orientation: Design a better mattress, or Design a better bed, or Design a better way to sleep. The mind moves from considerations of springs and padding to the possibilities of a water bed, air flotation, maybe even an armchair design bed. How about sleeping standing up? Or in a big armchair? Or floating in a tank of water?

2. Clarify the Problem.

A. Define the key terms of the problem. (What is an X?) Use synonyms; move from genus to species or species to genus. Continue to define in more and more general or specific ways. This kind of definition allows the breaking of the problem into attributes, components, and general features. The result is to shake loose some possible solutions.

For example: Problem: Rides cost a lot to build and when people get tired of them they cost a lot to replace. Moreover, they take up a lot of space. Goal: Build a ride in a small space that's cheap and easy to replace. Definition question: What is a "ride"? It's an experience, physical, psychological, of sight, sound, motion, events. A feeling or process of going from beginning to end and seeing or experiencing things along the way, usually exciting and different. Okay, how can we build a ride in a small space that will give this long experience of motion and movement, and that's cheap and easy to replace? Solution: Build a ride simulator. Implementation: Star Tours at Disneyland. A programmable simulator allows bumps and motion. A film creates visual effects. The simulator doesn't move laterally so it takes up little space. And when ride gets tiring, a new film and a new program of different bumps yields a new ride.

Clarify anything about the problem that is ambiguous or uncertain. Often, problems as given are unclear in their original form. "Improve the magazine," is an unclear assignment because it doesn't specify what the area of improvement should be. Does this mean choose better articles, change the typefaces and layout, get classier advertisers, get a bigger circulation, or what? "Cure condition X" might be problematic until we discover for certain whether condition X is an infectious kind of disease, a hereditary condition, a chemical poison, or what.

B. Articulate the assumptions being made about the problem and describe the way a solution would have to work. Assumptions can be tricky because they tend to be automatic and submerged--not consciously made. This articulation step in the problem solving procedure involves the conscious listing of all assumptions that can be identified. The listing is without prejudice or judgment or hostility. Just list as many as can be thought of.

It is especially important when listing assumptions to list the extremely obvious ones, because often it is those that later turn out to be alterable. Examine these assumptions to discover if they are necessary, not necessary, or uncertain as to their necessity. Many assumptions are quite necessary, of course. In the problem, Develop a better way to destroy kidney stones, one obvious and necessary assumption is that the patient should be alive after the procedure. But often assumptions turn out to be made for no good reason--that is they are not necessary assumptions. These can be challenged and new routes to success can then be discovered.

C. Obtain needed information. Research into past approaches to the problem or to similar problems will help you get new ideas as well as gain understanding of the nature and environment of the problem itself. If your problem is to improve self-stick brackets, you might do some research into how glues work.

3. Explain the Problem.

A. Discuss the problem with someone else. Explain it carefully. Listen to your own explanation. Discussion has two important features. First, there is the possibility that you will find a solution in the head of another person. Discussion enables you to get information, suggestions, and ideas. Important: even if the ideas have nothing to do with the problem, or if they are in themselves unworkable, they can still be valuable stimuli because they will show a new approach to the problem or they will suggest something practical to you. So even though your friend can never understand your problem technically, emotionally, intellectually, artistically, or whatever, you can still gain valuable insight by discussing it and by hearing a response.

Secondly, discussing your problem with someone allows you to see what you really think. Philosophers and writing theorists have long noted that people think and work out ideas as they talk. You don't really know what you think until you consciously verbalize it. Francis Bacon noted that one value of friendship was to have someone to talk to so that you can see how your ideas look when they are turned into words. Some people have reported remarkable insights just by talking to their pets, where no intellectual feedback from the "listener" was possible. So when you discuss your problem or idea, listen to yourself as well as to the other person.

Explain why the problem is a problem. What are its negative or undesirable features? Again, a couple of functions here. One, by explaining why the problem is problematic, you discover more about its nature and whether it really is a problem. James Adams remarks that there have been a lot of solutions to problems that didn't exist. So this explanation phase allows you to discover just whether a problem is real.

Next, by explaining in detail the negatives of the problem, a set of more specific targets can be identified, thus better lending themselves to being solved.

For example, first statement: Here at the amusement park, our problem is that rides are expensive and people get tired of them. Why is this a problem? Because we have to replace the rides so people will continue to come to the park. The negatives are that we have to (1) keep tearing the ride down, (2) building a new ride, (3) spending a lot of money, (4) disturbing the amusement park with major construction, (5) advertising the new ride, etc.

This statement allows the clarification of possible goals, like building a ride people won't tire of, figuring out a way to build rides quickly and cheaply, and so forth.

B. Look at the problem from different viewpoints. How would different people look at it? (What are the thoughts of those who cause it, those who suffer from it, those who have to fix it, those who have to pay for it, etc.?) Remember that your view of reality, as an intelligent, concerned, conscientious, middle class person, is only one view. By imaginatively taking on the viewpoints of various other people affected by a particular problem, you can sometimes discover solutions that you **as yourself** would never think of.

For example, let's say your assignment is to reduce litter on the beaches. One way to proceed would be to write out the viewpoints of various people. How do the people doing the littering view the situation? Are they thinking, "I like littering?" Or are they thinking, "I'd throw this in a can, but there isn't one nearby, so I'll toss it on the ground," or "I see that can nearby, but it smells so I don't want to go near it"? What about the person who has to pick up the trash? What are his thoughts? What about the taxpayers, or the beachgoers?

Again, suppose your job is to improve the juvenile justice system. Imagine that you are, in turn, the juvenile offender, the parents, the victim, the sheriff or arresting officer, the head of Juvenile Hall, the judge, a man on the street, and so forth. By constructing these different viewpoints, you will be able to generate solutions that meet some of the cynical, prejudiced, or even thoughtful attitudes of the various parties.

Another example. We, as users of medical services, often complain about the poor service, lack of knowledge, and high costs. What does the doctor think? He's probably worrying about getting sued. Addressing his concerns as well as our own will be the most likely way to improve the situation, rather than, say, passing new laws based only upon our own viewpoint.

The importance of being able to see different sides or angles has been reinforced in folk wisdom worldwide. The French have a saying, for example, "To know all is to forgive all." The American Indians have the saying, "Don't criticize your neighbor until you have walked a mile in his moccasins." The better you become at understanding where others "are coming from," the better you'll become at choosing solutions that will be acceptable and effective for all involved.

C. Ask a series of clarifying whys. By asking "why" of every statement of the problem, possible solution, or identified goal, clearer definitions are made. Asking why can serve a purpose similar to that of broadening the definition of the problem, and can lead to new ways of looking at the problem and at possible solutions.

Example problem: Let's make computers smaller and lightweight and portable. Why? So people can carry them around? Why do we want people to carry them around? So they can take them on trips with them and use them, say in hotels. Why do we want them to use them on trips and in hotels? So they can make efficient use of their extra time when traveling. (Possibility: put computers in hotel rooms for guests to use.)

Example problem: We need a better way to kill mice. Why? Because we are overrun by mice and they are bothering us. Why are we overrun? Because there is food all over. Maybe we should get rid of the food. Or, maybe we should redefine the problem into, We need a better way to keep mice from bothering us. This may suggest a different solution from that of killing them, like driving them away, keeping them out of the house in the first place, etc.

Is the problem really a symptom or result of another problem? Is there a problem behind the "problem"?

For example, the "problem" of low quality cars may really be only a symptom, with the real problem behind it quite different, like poor management, low quality parts and materials, old machinery, careless labor, or *whatever. A search for the causes of a problem often reveals one or more underlying problems which need to be solved first or which, when solved, will solve the originally identified problem.*

4. Put the Problem in Context.

A. What is the history of the problem? Knowing where it came from can help focus your efforts toward a solution to try or away from a solution not to try. If a particular solution has been tried already and met with a sensational disaster, you might not want to try it first again. The problem solvers who caught Typhoid Mary eventually noticed that various families' problems with typhoid began just after Mary began to work for them.

B. What is the problem environment? What are the surrounding contexts? Are there associative factors that helped cause or perpetuate the problem? Have there been similar problems and solutions that may be useful in solving this one?

An understanding of contributing or perpetuating factors will help you to take steps to prevent a problem from coming right back once you solve it. Similarly, studying how similar or analogous problems have been solved may lead you to a shortcut solution to this one.

C. List the constraints of the problem. What limitations are imposed, what is required, what must be observed in solving the problem? This is pretty straightforward. Constraints are givens that must be followed--a budget you cannot exceed, legal or contractual requirements that must be met and so on.

For example, if your problem is to develop a new American sports car, one constraint is that it must meet federal air pollution standards. If your problem is to make an educational tour more affordable for students, one probable constraint is that the tour company can't go broke in the process.

Constraints are simply requirements to keep in mind, part of the problem's basic dimensions. Writing them down helps to keep them in the foreground as you work toward solutions. And, of course, occasionally the identified constraints turn out, upon listing and examination, not to be necessary after all. They can be eliminated or worked around.

II. Goal Establishment

1. Consider Ideal Goals. We too often set our goals as the solving of the immediate problem or the minimum solution rather than considering how we would like reality to be ideally.

For example, if Jane always criticizes everything I say, I could set as my goal that she would stop criticizing me. But what would my ideal goal be? That not only would she stop criticizing me, but she would begin to support and encourage me, and even become a partner in my efforts. Instead of the goal of reducing pollution on the beach, or even stopping it, why not a goal of an improved ecology, where the beach will be cleaner than ever before?

2. Establish Practical Goals. What are the goals to be achieved that would make this problem be declared solved? The listing of definite and precise goals is useful in problem solving because the attempts at solution can then be measured against the goals to see how much progress is being made.

Example problem: Unemployment is too high in inner city America. We want to reduce it. What will the solution look like? Goal: Reduce unemployment for both males and females over eighteen to five percent or less within the next year.

Note that setting up goals (1) helps to clarify the direction to take in solving the problem and (2) gives you something definite to aim at. What will the solution be like? That is, what will occur as a result of the solution? Describe the world as it will be after the solution is implemented.

In our unemployment example above, we could say the solution will involve setting up a permanent job finding service that will continue to operate after the goal is met, to insure that unemployment (the problem) doesn't return later on. The solution might also include educational services to train workers or to train people in job finding strategies (like looking in the paper, going to job sites, and so forth).

Note that the description of the solution here can be pretty vague and dreamy if necessary, because sometimes you will have only an uncertain notion of what that solution will ultimately be. But try to be as specific as possible. If your problem is an unhappy marriage or love relationship, you could say that your goal is "a happy relationship," but more progress toward the goal will be probable if you can be more specific, such as, "stop yelling at each other," "become more affectionate," "do more things together," and so forth.

III. Idea Generation

1. Generate Ideas for Possible Solutions.

A. Read, research, think, ask questions, discuss. Look for ideas and solutions. Begin with a period of information gathering and mental stimulation. Knowledge is power. Get facts. Learn as much as you can about the problem.

For example, suppose you are faced with the task of making a more durable conveyor belt. You might think on your own about using stronger materials, like Kevlar or steel reinforcing, but a little research would reveal how many other people have solved the same problem, and you might happen upon the idea of the Mobius strip. Here, you simply rotate one end of the belt half a turn before connecting the two ends of the belt together. This produces a belt with only one side, with twice the life of an ordinarily made belt. It's a brilliant idea that you might never come across unless you did a little research.

B. Use idea generation techniques (brainstorming, forced relationships, random stimulation, and so on). Generate a large number of ideas of all kinds so that you'll have a good selection to choose from, adapt, or stimulate other ideas. Don't worry about whether the ideas are practical or wild at this point. As we will continue to see throughout the class, some wild ideas turn out to be quite practical. Just one example: Problem: How to inhibit corrosion and increase electrical contact on electronic plugs. Solution: plate them with gold--an excellent corrosion inhibitor and conductor. That's what's often done. This "wild" solution became practical because gold can be plated on very thin, reducing the cost to something very reasonable.

C. Allow time to incubate during various phases of idea generation. The major cycle of creativity that has long been identified is **preparation** (initial thought, research, study, work), **incubation** (time to let the unconscious work), **insight** (the flash of recognition of a solution path--the eureka experience), **implementation** (working out the solution), and **evaluation**.

Small problems will require only a short period of incubation. Difficult problems will require longer periods. Some people require longer periods than other people. The main thing is to remember the cycle of work, incubate, work, incubate. The eureka flashes do not come without previous periods of preparation and hard thinking. In the mythology of genius we often see the wizard sitting around when the flash suddenly comes to him. And that's often what happens--the insight comes during a period of relaxation. But what's left out is that same genius' long months of very hard work.

Do allow time for incubation, though. When you have worked a long time and are up against a wall, leave the problem and go out and do something relaxing. Then return to the problem. The idea of "sleeping on it" is excellent.

IV. Idea Selection

1. Evaluate the Possibilities. Evaluate the collection of ideas and possible solutions and approaches. What possible solutions, either individually or in conjunction with each other, will solve this problem? An important thing to remember here is not to get fixated on the single solution idea. You may want to adopt two or three separate solution paths at the same time--kind of like the triple antibiotic ointment approach. You might also want to set up "Plan B," a possible solution approach that can be implemented if your main plan does not work. So in your evaluation, don't focus on choosing just one solution and tossing the others away.

When you evaluate, you want to find the solution that will be the most effective (work best), efficient (cost the least, whether in terms of money, time, emotions, or whatever), and have the fewest drawbacks or side effects.

2. Choose the Solution(s).

A. Select one or more solutions to try. In the evaluation state above, you should establish some rank ordering. Choose from among those near the top of the list. Note that (as we will find later on in decision analysis), the very top ranked solution is not always the one to get chosen for implementation. Subjective, emotional factors, sudden changes, peculiar circumstances, the desire for beneficial side effects not directly related to the solution, intuitive feeling, and so forth, often shift the choice to something ranked below number one or two.

It's just like hiring someone or marrying someone. The person who looks best on paper may not "feel" right, and you may have a preference for someone further down the so-called objective list.

B. Allow others to see and criticize your selected solution and to make suggestions for improvements or even alternatives. The best way to turn your idea light bulb into a chandelier or floodlight is to let other people comment on it. This takes a certain amount of ego strength, since only intermediate friends will say how good the idea is. Strangers and close friends will quickly point out absurdities and weaknesses. But that's good, because you'll have a chance to improve your solution idea before attempting to implement it.

You have to walk a narrow path here. Don't be swayed too easily by criticism to change an idea that you are confident is really good; after all, the typical person is not a creative visionary and will be controlled by the prejudices of ordinariness. You can expect resistance to good new ideas. On the other hand, don't be so in love with your idea that you cannot see the legitimacy of criticisms that point our genuine weaknesses. And always be willing to incorporate new ideas and improvements from fresh minds looking at the problem and solution from a different perspective.

V. Implementation

1. Try out the solution(s). Experiment, test. "Do it, fix it, try it." "Ready, fire, aim." The real test of an idea is to try it out. The key concept here is action. Get going and begin the solution. Once you choose a solution path, get to work on it. Don't worry if objections or problems remain. Start working. Samuel Johnson noted that if all possible objections to a proposal must first be overcome, nothing would ever be attempted. And remember to give your solution sufficient time to work. Too hasty an abandonment of a solution or solution path is as common a problem as too obsessive a commitment to a particular solution path. A solution may take weeks or months (or years) to work, so use judgment in determining how long to wait before abandoning the choice.

2. Make adjustments or changes as needed during implementation. Remain flexible in this application phase. Practically every solution needs some modification in the process of being put into effect. Blueprints are changed, scripts are rewritten, your parenting methodology is adjusted. Don't expect that your solution will be exactly as you originally proposed. Remember that the goal is to solve the problem, not mindlessly to implement the solution exactly as proposed.

VI. Evaluation

1. Investigate to determine whether the solution(s) worked, and to what extent. Do modifications need to be made? Do other solutions need to be selected and tried? Is a different approach needed? One of the most frequent failures of problem solving is the lack of evaluation of the implemented solution. Too often in the past, once a solution has been chosen and implemented, people have wandered off, assuming that the problem was solved and everything was fine. But the solution may not have worked or not worked completely, or it may have caused other problems in the process. Staying around long enough to evaluate the solution's effectiveness, then, is an important part of problem solving.

2. Remember that many solutions are better described as partially successful or partially unsuccessful, rather than as an either/or in a success/failure division. If you propose a solution that reduces drug addiction by even ten percent, your solution is a good one, even though it didn't work for the other ninety percent of cases. In many cases, an incomplete remedy is better than none at all.

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Problem-Based Learning

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Goals & Objectives

Problem-Based Learning Defined: Finkle and Torp (1995) state that "problem-based learning is a curriculum development and instructional system that simultaneously develops both problem solving strategies and disciplinary knowledge bases and skills by placing students in the active role of problem solvers confronted with an ill-structured problem that mirrors real-world problems" (p. 1). Specific tasks in a problem-based learning environment include:

- determining whether a problem exists;
- creating an exact statement of the problem;
- identifying information needed to understand the problem;
- identifying resources to be used to gather information;
- generating possible solutions;
- analyzing the solutions; and
- presenting the solution, orally and/or in writing.

Short Cut to Problem-Based Learning: This is a simplified model. Note that it is an iterative model. Steps two through five may be conducted concurrently as new information becomes available and redefines the problem. Step six may occur more than once--especially when teachers place emphasis on going beyond "the first draft."

1. Present the problem statement. Introduce an "**ill-structured**" problem or scenario to students. They should not have enough prior knowledge to solve the problem. This simply means they will have to gather necessary information or learn new concepts, principles, or skills as they engage in the problem-solving process.

2. List what is known. Student groups list what they know about the scenario. This information is kept under the heading: "What do we know?" This may include data from the situation as well as information based on prior

References:

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knowledge.

3. Develop a problem statement. A problem statement should come from the students' analysis of what they know. The problem statement will probably have to be refined as new information is discovered and brought to bear on the situation. Typical problem statements may be based on discrepant events, incongruities, anomalies, or stated needs of a client.

4. List what is needed. Presented with a problem, students will need to find information to fill in missing gaps. A second list is prepared under the heading: "What do we need to know?" These questions will guide searches that may take place on-line, in the library, and in other out-of-class searches.

5. List possible actions, recommendations, solutions, or hypotheses. Under the heading: "What should we do?" students list actions to be taken (e.g., questioning an expert), and formulate and test tentative hypotheses.

6. Present and support the solution. As part of closure, teachers may require students to communicate, orally and/or in writing, their findings and recommendations. The product should include the problem statement, questions, data gathered, analysis of data, and support for solutions or recommendations based on the data analysis.

Students are encouraged to share their findings on-line with teachers and students in other schools, within the district, region, state, nation, or internationally. Teachers will find that students pay more attention to quality when they have to present or show their written products to students in other schools.

What do we know?	What do we need to know?	What should we do?
..	..	..

Adapted from Stepien, Gallagher, & Workman, 1993

Review of research: (1) learning in a PBL format may initially reduce levels of learning (this may be due to the difficulty in determining what students learned using traditional competence measures), but may foster, over periods up to several years, increased retention of knowledge; (2) some preliminary evidence suggests that

PBL curricula may enhance both transfer of concepts to new problems and integration of basic science concepts into clinical problems; (3) PBL enhances intrinsic interest in the subject matter; and (4) PBL appears to enhance self-directed learning skills (metacognition), and this enhancement may be maintained (Norman & Schmidt).

Goals of PBL: PBL is used to engage students in learning. This is based on several theories in cognitive theory. Two prominent ones are that students work on problems perceived as meaningful or relevant and that people try to fill in the gaps when presented with a situation they do not readily understand. Teachers present students with a problem set, then student work-groups analyze the problem, research, discuss, analyze, and produce tentative explanations, solutions, or recommendations. It is essential to PBL that students do not possess sufficient prior knowledge to address the problem. In the initial discussion, students develop a set of questions that need to be addressed. These questions then become the objectives for students' learning.

Norman and Schmidt (1992) state there are three roles for PBL. The first is the acquisition of factual knowledge, the second is the mastery of general principles or concepts that can be transferred to solve similar problems, and third, the acquisition of prior examples that can be used in future problem solving situations of a similar nature.

Acquiring Factual Knowledge: Activation of prior knowledge facilitates the subsequent processing of new information. Small group discussion helps activate prior knowledge.

Elaboration of knowledge at the time of learning enhances subsequent retrieval.

Matching context facilitates recall. This means that retrieval of information is facilitated by retrieving under the same conditions in which the information was learned.

Transfer of Principles and Concepts: to insure successful transfer

First, students need to get the problem cold. Any advance organizer that identifies the problem in advance appears to detract from the PBL process. It appears important that students learn and acquire concepts while

Botti, J.A., & Myers, R.J. (1995). A paradigm for success: Training teachers for the on-line classroom. Paper presented at the Satellites and Education Conference VIII, West Chester University, West Chester, PA.

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Glasser, W. (1993). The quality school teacher. New York: Harper Perennial.

wrestling with the problem.

Feedback: The problem solver must receive corrective feedback about the solution immediately upon completion **Note:** feedback may vary depending upon the situation. Some problems may be convergent, others may allow multiple correct solutions.

Resources for Learning: The Exploring the Environment™ (ETE) materials have enough information to get students started with the problem set. Background information is provided, but we have purposely avoided duplicating everything available about a given subject. Within the World Wide Web and other Internet features is a seemingly infinite amount of information. In some cases, the ETE modules point students to additional areas. Often, students will have to conduct Internet and Web searches to find materials. Teachers should avoid having a group of three to five students rely only on the electronic or on-line materials. Students must be encouraged to divide the work through a delegation of tasks. Some students may be working with the computer while others are finding or using written references, seeking out and interviewing experts, or using other audiovisual aids.

Activation of prior knowledge, taking place while a problem is initially discussed, may have a stage-setting function for new knowledge that facilitates students processing it.

Actual Steps: Have the students discuss the scenario, listing everything they know under a heading entitle: "What we know." This process helps activate and elaborate prior knowledge, which is subsequently used for the comprehension of new information.

Creating the ill-structured Problem: (Adapted from Stepien, Gallagher, & Workman, 1993).

1. Students need more information than is initially presented to them. Missing information will help them understand what is occurring and help them decide what actions, if any, are required for resolution.

2. There is no right way or fixed formula for conducting the investigation; each problem is unique.

3. The problem changes as information is found.

Keller, J.M. (1983). Motivational design of instruction. In C.M. Reigeluth (Ed.) Instructional-Design theories and models: An overview of their current status. (pp. 383-429), Hillsdale, NJ.

Newman, D., Griffin, P., & Cole, M. (1989). The construction zone: Working for cognitive change in school. New York: Cambridge University Press.

Nussbaum J., & Novick, S. (1982). Alternative frame-works, conceptual conflict and accommodation: Toward a principled teaching strategy. Instructional Science, 11, 183-200.

Miller, J.D. (1989, January). Scientific literacy. Paper presented at the American Association for the Advancement of Science annual meeting, San Francisco, CA.

Myers, R., Purcell, S.L., Little, J.O., & Jaber, W. (1983). A middle school's experience with hypermedia and problem-based learning. Paper presented at the annual conference of the International Visual Literacy Association, Rochester, NY.

4. Students make decisions and provide solutions to real-world problems. This means there may be no single "right" answer.

Problems in Implementing PBL:
Students: Students familiar with the traditional "talk and chalk" classroom are likely to be uncomfortable with the PBL format for some time. It will be up to the teacher to convince students that they are researchers looking for information and solutions to problems that may not have one "right answer." Here are likely problems:* Students will want to know what they really have to do to get their grade. They will expect the teacher to prescribe a number of tasks, events, concepts, and a set "number of pages" for written products.

Those students adept at "book learning" may feel uncomfortable in PBL roles in which they have to conduct research, coordinate with peers, and generate unique products. These students' parents may express some concern when their son or daughter isn't comfortable with this new environment.

Ownership. Students must feel that this is their problem, otherwise they'll spend their time figuring out and delivering exactly what the teacher wants.

Teachers: Teachers unfamiliar with PBL are in for some surprises. Moving into "untraditional" instructional modes may appear risky, scary, and uncertain. If students are new to PBL, they may actually learn less at first. Becoming comfortable with PBL will take at least a year, perhaps more, and this mode will consume more of the teacher's energy. The good news is that this environment is exhilarating, meaningful, and rewarding. It may turn out to be one of the most exciting things teachers have experienced.

Relevance. Look for windows into students' thinking in order to pose problems of increasing relevance.

Challenge. The problem scenario should challenge students' original hypotheses. We have tried to make the Exploring the Environment modules engaging; don't hesitate to elaborate upon the scenario to engage students.

Time. Students must be given time and stimulation to seek relevance and the opportunity to reveal their points of view.

Savery, J.R., & Duffy, T.M. (In Press). Problem-Based learning: An instructional model and its constructivist framework. Educational Technology.

Stepien, W., & Gallagher, S. (1993, April). Problem-Based Learning: As authentic as it gets. Educational Leadership, pp. 25-28.

Stepien, W., Gallagher, S. & Workman, D. (1993). Problem-Based learning for traditional and interdisciplinary classrooms. Journal for the Education of the Gifted, 16 (4), pp. 338-35.

Ownership. If the teacher appears to be heading students in a particular direction, they'll see that this really isn't their problem after all. They'll see that there is a correct solution and that it belongs to the teacher.

Complexity. Teachers new to the PBL classroom may be tempted to give students key variables, too much information, or problem simplification. Complexity of scenarios has been shown to increase student motivation and engagement.

Second questions. Avoid using the dreaded "second question" as a signal the student is wide of the mark. Regularly asking students to elaborate sends the message that the teacher wants to know what the student thinks and why. Brooks and Brooks (1993) state that "awareness of students' points of view is an instructional entry point that sits at the gateway of personalized education...teachers who operate without awareness of their students' points of view often doom students to dull, irrelevant experiences, and even failure" (p. 60).

Note: Questioning Techniques. In a PBL classroom, teachers should act as metacognitive coaches, serving as models, thinking aloud with students and practicing behavior they want their students to use (Stepien and Gallagher, 1993). Students should become used to such metacognitive questions such as: What is going on here? What do we need to know more about? What did we do during the problem that was effective? Teachers coax and prompt students to use questions and take responsibility for the problem. Over a period of time, students become self-directed learners, teachers can then provide less scaffolding, fading into the background (Stepien and Gallagher, 1993).

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Problem-Based Learning Background & Objectives A Primer for Teachers Using the Exploring the Environment™ Modules Education's purpose includes preparing people to lead fulfilling and responsible lives. Science education should help students understanding the biophysical environment and human interaction with that environment. Such understanding should lead to informed decisions concerning how humans treat their life-support system, the biosphere (AAAS, 1990).

Our project, Exploring the Environment (ETE), is developing earth science modules for delivery over the Internet. Technology, such as remote sensing, simulations, and ground-truthing provide us with a myriad of tools with which to study globa-scale interactions and to make informed predictions and decisions about our planet. Remote sensing allows students to see Earth subsystem interrelations on a grand scale. It is ideal for the study of change and of the wider relations between components of the biosphere. Before remote-sensing technology became available, it was difficult for humans to realize the global impact of their actions. With the advent of remote-sensing capabilities it bacma evident that the interconnectedness of Earth systems, however, means that human-induced changes are seized upon and magnified by nature, to be passed through the chain of natural events, to have far-reaching, and sometimes, unexpected effects.

These tools, however, seem to be making little impact in elementary and secondary schools (Cuban, 1986). Studies show that science learning at the high school level has little effect upon students' science literacy, including their understanding of basic concepts, the process of science, or the impact of science on society (Miller, 1986). Our experience and research indicate that change in science classroom methodology can lead to student understanding of critical issues. Our goal is to engage and motivate students to explore and understand issues in depth. The challenge is to provide teachers with alternative approaches to teaching and learning that will achieve the goal. Problem-based learning (PBL) is one of these alternatives.

Problem-Based Learning Finkle and Torp (1995) state that "problem-based learning is a curriculum development and instructional system that simultaneously develops both problem solving strategies and disciplinary knowledge bases and skills by placing students in the active role of problem-solvers confronted with an ill-structured problem that mirrors real-world problems" (p. 1). What is desired is a real-world program that combines science content and skills to create useful experiences for learners by drawing connections between students' lives and the Earth's interacting environmental subsystems and environmental resource issues. The benefits of PBL include engagement in learning due to cognitive dissonance, relevance to real-world scenarios, opportunities for critical thinking, metacognitive growth, and real-world authenticity that promotes transfer and recall (Finkle and Torp, 1995).

Remote Sensing Datasets in the ETE modules will provide the major source of information for students' problem solving initiatives. The core of problem-solving is to learn to use information in a logical, useful way. The only real purpose to gather information is to use it (Glasser, 1993)! These data are derived from real-world remote-sensing tools, employed by practicing scientists and accessed through the Internet. A very simple design of events for PBL comes from Stepien, Gallagher, and Workman (1993). In their iterative model, students are presented with an ill-structured scenario. team of students then pool information and list it under a heading "What do we know?" They evoke prior knowledge and discuss the current situation. This analysis leads to a problem statement. Although the problem statement is sometimes misdirected, it is a starting point and may be revised as assumptions are questioned and new information comes to light. Under the heading "What do we need to know?" students list questions that must be answered to address missing knowledge or to shed light on the problem. Under a third heading, "What should we do," students keep track of such issues as who to interview, what resources to consult, or what specific actions to perform. Students gather information from the classroom, through electronic sources, the school's library, and from experts on the subject. As new information comes to light, it is analyzed for its reliability and usefulness in either refining working hypotheses or aticulating the problem statement.

It is important to train teachers to adopt new frameworks for the classroom when operating in PBL environments. For example, students begin the problem cold. They discuss the problem, generate hypotheses, identify relevant facts, and learning issues. Unlike standard classes, learning objectives are not stated up front. Students generate the learning issues or objectives based on their analysis of the problem. If prerequisite knowledge relevant to the problem's resolution is missing, then students are responsible for its accumulation (Savery and Duffy, In Press).

Design Savery and Duffy (In Press), discuss issues for instructional design in constructivist environments:

- Anchor all learning activities to a larger task or problem.
- Support the learner in developing ownership for the overall problem or task.
- Design an authentic task.
- Design the task and the learning environment to reflect the complexity of the environment students

should be able to function in at the end of learning.
- Give the learner ownership of the process used to develop a solution.
- Design the learning environment to support and challenge learners' thinking.
- Encourage testing ideas against alternative views and alternative contexts.
- Provide opportunity for support and reflection on both the content learned and the learning process.

Teachers unfamiliar with PBL will profit from elaboration of the issues listed above. First, create an ill-structured problem based on desired outcomes, learner characteristics, and compelling situations from the real (relevant) world (Finkle and Torp, 1995). The ill-structured problem addresses one "big question or idea" in a "whole to part" form. The ill-structured problem must raise the concepts and principles relevant to the subject matter area, but data critical to the problem must not be highlighted. If critical data is highlighted the whole procedure then becomes a mere procedure of finding what the teacher deems essential, then feeding it back.

Brooks and Brooks (1993) state that learners of all ages are more engaged in problems addressed in "whole to part" forms. This structure allows for multiple-entry points and addresses multiple learning styles. Providing an overarching problem set also creates a purpose for engagement, as opposed to the usual assignment of a chapter and end-of-chapter study questions. Students know from the outset where they are headed and why (Savery and Duffy, In Press).

Relevance is a primary issue. Brooks and Brooks (1993) deem it one of the universal or guiding principles of constructivist teaching. They suggest searching for windows into students' thinking in order to pose problems of increasing relevance. The problem scenario should also challenge students' original hypotheses. The challenge, incongruity, anomaly, or discrepant event creates a springboard to activity based on cognitive dissonance (Keller, 1983). For example, Nussbaum and Novick (1982) state that in order for accommodation of a new concept to occur, students must first recognize a problem as well as their inability to solve it. Students' inability is brought about by presentation of a "discrepant event." A discrepant event is simply an inexplicable condition, statement or situation. The discrepant event creates a state of disequilibrium (or cognitive dissonance). The key in Nussbaum and Novick's argument is that once students are in a state of disequilibrium, they are motivated by "epistemic curiosity" (Berlyne, 1965) to reduce the disequilibrium. Nussbaum and Novick (1982) suggest that traditional instruction seldom provides for students to experience cognitive conflict. Bruce and Bruce (1992) suggest that logic-defying problems often make us feel disequilibrium. Motivation from the disequilibrium causes questioning, snooping, and searching to reduce uncertainty and re-enter a state of equilibrium.

Execution Finkle and Torp (1995) refer to the actual execution as "cognitive coaching." In this phase, students are actively defining problems and constructing potential solutions. Teachers model, coach, and fade--supporting and making explicit students' learning processes. Students must be given time and stimulation to seek relevance and the opportunity to reveal their points of view. They also need time to ponder the situation or scenario, form their own responses, and accept the risk of sharing responses with peers (Brooks and Brooks, 1993). Using remote-sensing databases within ETE, students will be expected to synthesize and evaluate such matters as the cause and effect relationships of degradational and tectonic forces concerning the dynamic Earth and its surface; the relationship of atmospheric heat transfer to meteorological processes; and the relationship between Earth processes and natural disasters. Students should also be able to make and support insightful and informed recommendations to alleviate environmental problems.

Teachers and students used to traditional instruction may be in for some surprises. It takes time, patience and a willingness to accept risk and uncertainty to begin using these types of classroom methods. It may take teachers one to two years to feel confidence with these approaches to learning. Students, for example, will likely be very reluctant to take risks on their own--especially if they are used to having the objectives, assignments, and problems handed to them. If they are used to standard objective tests, then students may dwell more on what they have to do to "get their grade" than in readily adapting to the PBL format (Myers, Purcell, Little, and Jaber, 1993).

During the PBL process, teachers new to this technique, may be tempted to give students key variables, too much information, or problem simplification. Depending on the students' ages, complexity generates relevance and interest (Brooks and Brooks, 1993). Barrows (1992) states that teachers' interactions should be at the metacognitive level and that opinions or information sharing with students must be avoided. Doing so implies that there is a "correct answer" and takes away student ownership of the problem.

Student ownership is essential. If they do not own the problem, they spend their time figuring out what the teacher wants. One signal teachers and students will have to pay attention to is the presence of the dreaded "second question." In traditional lecture and recital classrooms teachers ask questions. A follow-up question to a student's reply usually sends the message that the answer was "incorrect." The student then spends more time trying to figure out "what the teacher" wants. Regularly asking students to elaborate sends the message that the teacher wants to know what the student thinks and why. Brooks and Brooks (1993) state that "awareness of students' points of view is an instructional entry point that sits at the gateway of personalized education...teachers who operate without awareness of their students' points of view often doom students to dull, irrelevant experiences, and even failure" (p. 60).

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Summary Our project, Exploring the Environment, is developing Earth Science modules for delivery over the Internet. Our position is that new technology such as remote sensing databases and electronic means of delivery are important tools that will create "wall-less" classrooms. Teachers' roles, however, may be the essential ingredient in effective technology use in the teaching-learning scenario. We have presented means for teachers to use in helping students engage in learning and reaching new levels of understanding. This paper reinforces the role of the teacher as the primary agent in successful teacher-student interactions. If anything, teachers' roles will become even more important. As Newman, Griffin and Cole (1989) state: "We have seen that the process of instruction cannot be reduced to direct transmission of knowledge, nor are creative learning processes necessarily entirely internal to individuals" (p. 112).

ETE students need time for exploring, making observations, taking wrong turns, testing ideas, doing things over; time for collaboration, collecting things, and constructing physical and mathematical models for testing ideas. They also need time for learning prerequisite mathematics, technology, or science they may need to deal with the questions at hand; time for asking around, reading, and arguing; time for wrestling with unfamiliar and counterintuitive ideas and for coming to see the advantage in thinking in a different way (AAAS, 1990). Teachers need time too--time to reclaim the skills of curriculum development and instructional creativity. Time and resources are needed for teachers to develop and deliver the ETE curriculum, to train and work together, to restructure the entire science classroom teaching practice to meet the diverse needs of students that comprise today's student body. To accomplish these vital tasks of staff development, the ETE Instructional Design Team will provide adequate time and funding for the kind of experimentation and risk taking needed to create motivating experiences for learners and teachers using contemporary science tools and topics to be successful in this new era of Science Education. (Botti and Myers, 1995) [back to top]

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