PROBLEM SOLVING--A CREATIVE APPROACH

7 September 1956

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COLONEL BARRETT: Our lecture this morning, "Problem Solving--A Creative Approach," breaks away a little bit from the series on economics and the Government that you have been having up to date. It is customary here at the college during much of the year to use Friday mornings for a general lecture series. The lecture subject this morning, of course, is applicable to your work throughout the year, and is particularly appropriate to the work you will be doing next week.

You have read our speaker's biography. There is supplementary information contained in the magazine, "Life" of May 1955, and I have drawn on that for the remainder of my remarks.

Professor Arnold is characterized by "Life" as being an improbable combination of a psychologist and a mechanical engineer. His teaching is said to shock conservative members of the teaching profession and to agitate the leaders of the engineering profession. It is devoted to liberating minds from mental blocks and releasing their creative energies. Well, as career members of the military services and of the Government services, we should offer him a large supply of rare old-vintage mental blocks to work on.

I am sure that as we listen to him talk we will be agitated, disturbed, and also delighted and amazed.

Professor Arnold, it is a pleasure to welcome you to this college.

PROFESSOR ARNOLD: Thank you, Colonel Barrett. You mentioned the improbable combination of a psychologist and a mechanical engineer. I think it is a kind of impossible combination. Some of my students I am sure are convinced it is impossible.

I was asked to talk to you this morning on the question of problem solving, in general, but most specifically on a creative approach to problem solving. Actually, you are all, I am quite sure, capable problem solvers. You have been doing it for a very long time. You may not be aware of the fact that a good share of your thinking is on

solving problems; at least it should be, if it isn't. If you stop to think for a moment of the various types of problems you solve, if you look at them very carefully, and, if you analyze them, you will probably notice that they tend to group themselves into two quite distinct categories.

Certain types of problems have one and only one right answer--a lot of them do. How do you spell cat? C-a-t. Two and two equal four. The integral of xdx is x squared over 2 plus a constant. Certain problems you have gone through time and time again have one, and only one, right answer.

On the other hand, the other group has a great multiplicity of answers, an almost complete spectrum of answers. They range from bad to good and I think this spectrum has no ending. I am sure if I gave you a pretty lousy solution to a problem, a creative type of problem, that, with some effort, you might find a worse one. There is no end on the low side, and the same is true for the high side. If I give you the best solution available for a certain problem, with some effort, probably more effort, a better one can be found. This is true in industry. I am sure it is true also in the military--that you are always looking for a better solution, because, if you don't find it, your opponent or your competitor will, and you will then have to look for a still better one.

So, in the classification of problems, the one right answer versus the multisolutional type of problem is important to note, because, actually, we have difficulty, I think, in sometimes recognizing that certain problems do have more than one right answer. We very often, as I will point out later, go ahead and operate as if some multisolutional problems actually have only one answer, and usually a very poor answer.

Now, we can distinguish problems, on the number of answers that they have, but also in the way we approach them, the techniques we use in solving these problems. The one-right-answer types of problems are wonderful to solve. We have some very definite procedures that we can use. We can follow certain prescribed rules or certain methodology. In spelling, we go through and memorize the appropriate ways of spelling cat, or dog, or comprehensive, or something like that. There should be no chance for imagination in spelling, for example--only one way of doing it. Although I recall that Ben Franklin said he wouldn't give a damn for any man who couldn't spell a word more than one way. Since that time, I have forgotten how to spell.

Or we can use very definite logical procedures, deductive types of reasoning, inductive reasoning, or reasoning by inference, by syllogistic processes. We can use analogy. We can use these various techniques that, once we start out in the proper fashion, we carry through in a certain prescribed procedure, and we arrive at the one right answer.

Or, thirdly, we can use an empirical approach. We can carry out experiments of various types where we get repeatable observations that can be measured very exactly. We can use this technique for arriving at the right solution to the problem. For example, if I were to give you a problem in mechanical engineering where I want to get the deflection of the center of a beam, uniformly loaded, freely supported at the ends, and so forth, you could use this first method of applying some very general rules. That is, you could look in a handbook. Any handbook on mechanical engineering will have the exact equation for the deflection at the center of the beam. When you put in the appropriate data you have the answer.

Or you could go back by the process of logical reasoning to isolate an element in the beam. You could put it into equilibrium and use any proper procedure to arrive eventually at the equation which you could integrate twice and get the deflection at the center of the beam.

Or, if this seems to be too complicated, you can actually go out and build the beam, and load it as prescribed, and measure the deflection.

In every case you get exactly the same answer, or, at least, you should get exactly the same answer.

This is nice; this is elegant; this is very comforting--to know that no one can get a better answer than you've got. So we enjoy working analytical problems. As I say, they are elegant, they are straightforward, they are very efficient. You use your time to the best advantage. You can easily communicate them to others.

Teaching this kind of course is very simple. You prescribe the rules; the students follow them. If they don't follow them, you fail them. As far as learning is concerned, the learning process is beautifully reinforced, and immediately reinforced; because, as you go through the process of doing these problems, as you exercise yourself, right away you can check the answer in the back of the book.

This provides reinforcement, and it's very beneficial in your learning process. You establish a certain procedure as the one right procedure in solving the problem.

These analytical problems, or one-right-answer problems, as I say, are opposed to the multisolutional problems. Those I will call, for the moment, creative-type problems. The processes we use there in general are quite different. They are less elegant and quite messy at times; they're certainly very sloppy; sometimes they're quite mystic.

One way that a lot of people solve these multisolutional problems, as I mentioned before, is to first of all assume that they are not the multisolutional type, that actually they have one right answer. This simplifies the process, because then you can use techniques of authority, of tradition, of inertia, to solve the problem.

Authority--well, you go and ask the grand old man the answer to your problem. He tells you, and then you accept that without question. Tradition--what was good for grandad, what was good enough for him, is good enough for me. This procedure accepts the established answer as the right answer. Even though there may be a great multiplicity of better answers, if it's good enough for dad, it's good enough for me, and so forth. Inertia--leave the problem alone; maybe it will go away, or somebody else will solve it for you. This is possible when you make this wonderful oversimplification that it has an accepted right answer.

I frequently ask students where information comes from, and they are all quite convinced that information basically is a book or an authority somewhere. Information is never from themselves. Their own experience has no value whatever to them. Somewhere along the line someone quite unlike themselves carried out an experiment or carried out a thinking process, established some information, put it down in a book, or told somebody else, and this is the basic source of all information.

Now, there are other ways in which you can solve these problems. You may recognize that maybe they do have more than one right solution. But, maybe chance, pure chance, will solve the problem for you. One assumes, I suppose, in reading or in thinking about some of the innovations that have taken place in the past, that it was a lucky happenstance that Pasteur happened to notice something wrong with his bacteria culture, that he used them by chance, and happened to stumble upon the

fact that the attenuation of the culture would provide some kind of inoculation. It was pure chance that Fleming happened to notice what he did; it was just luck that Edison kept working long enough so that he finally found a filament that would stand up in an electric-light bulb. There is, I think, a general belief that people are lucky enough in their processes so that they solve some of these problems by chance. Some people have actually tried chance techniques in solving problems.

There was a group of poets in the twenties. They were called the Dadoists. They actually wrote poetry, they did supposedly creative work, by a chance process. They would cut out work from magazines, newspapers, and so forth, and put them into a hat, and then the grand old man of the group would reach into the hat and pick out the first word and they would all jot it down, and when they had five words down they started a new line. This was writing poetry? It was a new combination. It was novel for poetry had never been written before by pure chance. But was it creative?

In Gulliver's travels, you may recall, he went to Horseland. There the horse professors were lecturing to students by lining up a whole series of drums on the platform. On the drums were all the words of the horse language. At the proper signal, they would spin all the drums. When the drums stopped spinning, the students would write down all the words that showed all across the line. As soon as they did this enough times, by pure chance alone, all the information that was available to the horse people in the past and in the future would be indicated on these drums. By pure chance, 50 million monkeys in 50 million years would write Shakespeare, and so forth.

Actually, pure chance does do strange things. All information is encoded in white noise. Ross Ashby of England recently showed that the old expression, $\sin^2 x + \cos^2 x = 1$, might have been doodled by pure chance, by a child 2 or 3 years old. It also could be signalled in a binary type of code by the collisions of molecules in the air. He showed that, if you take one cubic centimeter of air, and if you were able to determine which direction one molecule bounced off the other molecule, to the right or to the left, that, when you added up all the molecules and all the actions that took place, by pure chance alone, the bombardment of molecules would spell out properly the equation 100 thousand times a second. The big question is, of course, to get some kind of device that would read out only the proper sequence.

Well, actually, we are not concerned with some of these oversimplifications--that is, assuming that multisolutional problems have one

a very definite potential for creative activity, for creative problem solving. There is no question in my mind that every individual has some potential for this kind of activity. It may vary from person to person. If we draw a curve of creative potential (drawing on blackboard)--this is creative potential (on the abscissa)--I will put down here the (ordinate) numbers of people--we would get the well known normal distribution curve. You find there are a few down here who are creative morons. They cannot solve a problem that involves imagination, analysis, synthesis, and so forth. They just can't do it. They have to accept a simple solution. Here are a few out here who are creative geniuses--Einstein, Da Vinci, and so forth, who, under all kinds of obstacles, no matter what block is put in their path, will make great contributions to society. The great mass of us lie somewhere in between.

Now, this is the curve at birth. However, I think that, due to various forces acting in society, and so forth, if we were to plot the demonstrated creative ability of an average group we would get a curve somewhat distorted with the peak shifted to the low side. The creative moron is still a creative moron. The genius somehow still comes out and makes his contribution. The great majority of us are away down here. We could be operating at a much higher level, but we are operating below our inherent potential level.

This, then, indicates that it is possible, I think, to increase the effectiveness, the productivity, of mental work in problem solving by proper techniques. In 10 percent, 15 percent, 1,000 percent, I am sure, in some cases, improvement can be accomplished by proper techniques. This improvement, by the way, is my second hypothesis, because I am quite sure that, by proper exercise, by understanding, it is possible to raise your efficiency, to realize to a greater degree your own potential, your inherent potential, for creative activity.

The third hypothesis I mentioned is that I think that the creative process itself is unique and also is a universal process that applies to all kinds of creative activity, whether you are an artist, or a poet, or a composer, or an engineer, in the military, in the business world, in the professional world, teaching, and so forth. If you are being creative, if you are looking at and solving problems in a creative fashion, you are using a similar process in all cases. The tools you work with, of course, vary from individual to individual, from group of activity to group of activity, but the process itself is identical.

What is this process? What do I mean by creative process? To me creative activity is primarily mental activity, even though it leads

eventually to physical action of some kind. It involves combining, recombining, rearranging past experience into new patterns, new configurations, new relationships that somehow better satisfy some basic need of mankind. This basic need may be an implied need or may be an expressed need; it may be a need for beauty or for comfort, or it may be a need for a better toaster, or automobile. In all cases it is a better solution, not just a different solution. This is important to me. It is also a tangible solution. It is not just an idea, an uncommunicated idea, but it is a tangible result; something that people can see, or feel, or react to in some fashion. There is some reaction evidenced by this creative activity. It is also always forwardly oriented in time, and it shows or expresses a synergetic quality.

Let me explain some of these terms. To me, there is a great deal of activity going on under the name of creative activity that leads to different solutions, rather than to better solutions. To me this is a poor excuse for creative activity. It is not difficult to be different, but it is quite difficult to be different and to be better. To me the ultimate test of high-level creative activity is a better solution, one that should be related in some way back to the basic needs of mankind.

It must also be tangible--something you can see and feel and react to--not just an idea by itself. I did some work with a group of young fellows who were doing some graduate studies in the field of creative thinking in business. They happened to be located at a little school in Cambridge, down the river from MIT. I forget the name of it, but they have some reputation for doing good work in business administration, and so forth. They were very intelligent young men and they analyzed and looked over carefully various techniques used in business groups for being more imaginative, more creative, and so forth. They came up with a number of techniques that they examined, and analyzed, and then they said, "These are good things to do."

In all cases they were techniques that lead to ideas, and ideas only. We had a number of talks about whether or not the idea was the essence of the creative process or just merely a part of it. I said, "Do you mean to say that the idea is so important that if I had had a wonderful idea and I went to Beethoven and said, 'Listen, Ludwig, I have a wonderful idea for a symphony (singing) da, da, da, da. You take those notes and add a few more here and there and call it the Fifth Symphony--oh, just dress it up a little bit, and so forth' --that I had the basic fundamental idea and Beethoven was more or less the hack writer who worked out the job?" I said, "This is the way some engineers feel about the

draftsmen. They've got a wonderful idea for a new machine, so they say, 'Let's do so-and-so,' and then they give it to any draftsman and he carries out the work. They did all the creative work; the draftsman did the routine drudgery. Well, the chances are pretty good that the draftsman did an awful lot of work, that he did a good job, that he really did high-level imaginative work in order to have the creative engineer be successful with his idea."

They said, "No, that's silly. We don't mean that at all." I said, "What do you mean?" They said, "Well, we had a session with a grocery firm not long ago, in which they were looking for a new product to manufacture for market. We came up with 150 ideas in a certain length of time; we culled these over and picked out 5 or 6 that we thought were pretty good. The client picked one, and that was that they would manufacture and market a little pill, which the housewife would drop into a nice cold glass of water, and immediately thereupon she would have a nice colored, flavored, and carbonated drink--a soda, like coca cola, and so forth."

I said, "Fine. What do you do next?" They said, "Well, you can go to any chemist and in a matter of two weeks he will give you the pill."

This again is overemphasizing, I think, the idea. The creative action is not completed until the chemist does have the pill. Well, maybe it's possible. I haven't seen that any chemist has done this, yet. But maybe it's possible that some day one will, and we will have coca cola in pill form or powder form. They haven't yet, and the idea is not really a creative idea until it is transmitted into some kind of a pill.

Afterwards we were talking for some time, and I said, "Actually, you are not as creative as you think you are." They said, "Why?" I said, "Well, instead of a coca cola pill, why didn't you think of a martini pill or a beer pill, or something like that? With the martini pill you would make it green and it would swell up and you would have the olive right there." They said, "We didn't think of that." I said, "O.K., I had the creative idea. I want half the royalties when you give it to any chemist and he gives you the result." I haven't spent any of the money yet, though, and I am not going to.

Creative acts must be tangible, then. You must end up with something before you can say you have been creative. The idea is important, but it is the starting point and not the sum total of the process.

It must be forwardly oriented in time. I put this in only to distinguish between another type of multisolutional problem and this. I said we would temporarily call those that have a great many solutions creative. There are some, I think, that are probably more judicial than creative in effect. There are multisolutional problems that are associated with the law. They are dealing with problems that happened in the past, trying to correct problems of prior injustice, in some cases having no concern with the future. This is not true of law in general, however. There have been very creative jurists, and always will be, men who are concerned with the decision they made about something that happened in the past and the effect it will have on actions in the future. But there are multisolutional problems that are associated with past activities and, in effect, past thinking--not future thinking. Creative problems are always concerned with future situations, in making things better for man in the future.

Let's see--results must be synergetic. That is that you cannot predict the total value of the new combinations, new organization, new relationships which you have brought together, by looking at the individual parts themselves. Somehow or other 2 and 2 equal 5 now. Something additional has been added; something you can't buy, you can't weigh, you can't measure, and so forth; something--I suppose the stamp of genius, the mark of the innovator, himself--that gives it increased value.

For example, you can't look at a pot of paints and a blank canvas and try to weigh the results that accrue after a man like Titian puts them together; and you can't properly evaluate a piece of glass and a piece of copper wire and a charred piece of thread until someone like an Edison puts them together and makes a light bulb.

These simple ideas, these simple components, have increased value when they are put together in a creative fashion. This is what we call synergy.

Now, then, how do we go about coming up with these new combinations, these new arrangements out of a past experience that provide better solutions, bring tangible results that have synergetic quality, and so forth? What are the steps we can use? Well, in general, all problems are solved by, I suppose, pretty definite steps. We may not use them all each time. There is a little book by Polya, called, "How to Solve It." It came out some years ago. It is a very nice little book. If you have a chance you should look at it sometime.

I recommend it for my students, but I guess they are oversophisticated. They found it too simple for them. They don't see the real value in the book. I think you men would. He lists four general steps in problem solving.

First of all, you have to understand what your problem is, define it in proper terms, and so forth. Next you devise a plan of attack of some kind. Thirdly, you carry out the plan. And, fourthly, you look back and check to make sure that your solution is correct, fits the situation, and so forth.

This type of procedure can be applied, of course, to creative problems, as well as to analytical problems. I think of four general steps myself. I think that the creative problem solving, or the problem-solving situation in general, is associated with, first of all, questioning; secondly, observing very carefully; thirdly, associating ideas; fourthly, predicting.

This ties in very closely with what people call the process of science, or even the cognitive process in general. How do we know anything? We do it by observing very carefully, getting information into our system, or sometimes, I suppose, by generating information, by taking thought. We must retain the information, by bringing it together in certain combinations and patterns so that we can retain it easily, by association of ideas, and so forth; and finally, by transferring this information to some new situation. It might be by making a prediction, by saying such-and-such is so, that this is the answer, this is the way we should proceed.

So that you question; and this, of course, is basic to all thinking. You observe, you get facts, and data. You then relate these together in new patterns, new processes, new variations. Then you finally make a prediction, and make this tangible result.

Others have listed other types of steps. They all generally fall into the same categories. You may have read books by Alex Osborn, or Graham Wallas, or Dewey, on how to solve problems. They list a series of steps. What is your problem? You orient yourself. You get the data together. You analyze your data to make sure that there aren't too many holes in the data, that it's relevant, and so forth. Then you start to make hypotheses of various sorts. You suggest that this might be solution A, this might be solution B, and so forth. Sometimes you cannot arrive at a decent solution to begin with. So you try the

process that Wallas calls incubation, and you forget your problem for a while. You hope that a subconscious type of synthesizing will take place, and the next day you will arrive at a solution while you are shaving.

Then, once you get the solution, you synthesize, you bring together various aspects of the problem, and make the final tangible result, and then you go back and check; you verify.

Let's look at some of these steps and see if they are adaptable to more organized, logical steps, in order to arrive at a good solution. We start with a problem although usually, we are not quite sure what the problem is. This is the general case. We have a vague feeling that something is wrong somewhere. What it is, we are not quite sure. This is what I call problem sensitivity, being aware that a problem exists. Now, some people seem to exhibit this trait to a greater degree than others. Some people seem to be more sensitive to problems. They are the people who can read over a scientific report and right away pick out some line or some equation and say, "This is wrong, not because of experimental error, but because of fundamental error. This does not tie in with my own experience, my own idea of what this should do." They check into it, and sure enough, they discover some new relationships.

One of the Directors of Research at RCA told me of a number of examples where experiments had been carried out by men in the laboratories and where the expected results were not observed on the oscillograph. They said, "Wait a minute now; this might be a shorted tube or a burned out condenser; but it might be something else. We will go back and check very carefully." They did, and they found out that there was a new law that they had discovered, a new relationship that no one else had observed or noted before, and a new discovery was forthcoming.

There are other cases where similar situations had taken place, where they said, "Something is obviously wrong; something has gone haywire." They might try it again and get the same results, and they might say, "Damn it all; every tube in the place is no good. We'll forget the thing." They might make a note in their book, or they might not make a note, because it was a failure of some kind; they did not get the expected results. And then some competitor would come out with the solution a year later. They missed the idea because the men were not sensitive to problems, were not aware that there was something new staring them in the face.

So problem sensitivity is important. But I think it can be developed. You can become more sensitive to problems; you can be more aware of your own surroundings. Men like Mooney, Rogers, and so forth, speak of this as openness to experience. The really creative individual is open to his total experience, the things in his environment, the things within himself. He knows what's going on. He can relate them to each other, recognize them, and so forth. This can be trained, by being more questioning, using checklists and attribute-listing techniques. All these kinds of things will help you to be more questioning, more observant, more sensitive to problems.

Try making up for yourself a little series of questions to ask yourself every time you see something new or different. How is this done? Why was it done? How can it be done better? How can it be done differently? What is it composed of? Can I break it down? Can I rebuild it, reform it into new patterns? Can I make it smaller? Can I make it larger? Can I turn it inside out or upside down? Ask yourself a series of questions, see if you can't improve things.

I have lots of inventors who come into my office at various times with ideas that they have. Some of them are pretty good. Some of them are pretty lousy. Usually, in the good ones, once a man describes what he is trying to invent, almost immediately I, or someone else in the office, can tell him a good way of doing the job. An idea comes to our minds as a way of solving the problem. The reason we haven't invented the same thing is because we didn't think of the problem. He defined a problem in a certain area where something should be done. Once this is done, almost anyone can come up with a pretty good solution to that problem. But defining the problem is important. You can do this by questioning very carefully.

It may be interesting to note that when Gillette was trying to search for a really hot idea with which he could make a lot of money he used a technique he called the alphabet system. He would go through the alphabet letter by letter and list, first of all, all the products that began with A that he could think of. He would say, "How can I improve any of these?" Or he would list all the processes that began with A and try to improve those--or the machines that began with A. Then he would go through B, and so forth. He was searching for something that would really make a killing. He was selling at the time, I think, crown seals for beer bottles. He was a salesman, and he was not making as much money as he liked. He knew if he got a really good idea he would be a wealthy man.

One day someone told him that what he really should be doing was to search for something just like the crown seal, that people would use once and throw away. Once he established a market for the thing, the people would be using them over and over again, and he would build up his market very rapidly. This he thought was a wonderful idea, and then he applied his alphabet technique to that, but got nowwhere with it. Finally, one morning, while he was shaving, strangely enough, the idea of the safety razor popped into his mind. The picture was so clear in his mind that he sat down and immediately sketched out the idea. The picture that he drew at that time was very close to the existing Gillette safety razor.

He was aware of a problem. He was constantly questioning in search for an answer. Actually, on the surface, most of his conscious work did not seem to help him, but I am sure that all this thinking, this cogitation, this search, this organized approach was setting a certain number of wheels in motion, and eventually the subconscious mind carried through with this process. Finally a combination was arrived at that he thought was pretty good, and this was his razor blade. Actually, it took him some five years after he thought of the idea to get the thing on the market, to convince people that it would work.

So the idea at the first stage was about like making a coca cola pill. Everybody laughed at him. They said it couldn't be done. He went to all the experts. He even went to MIT, and, strangely enough, they said it was impossible to harden thin steel and get a sharp edge on it; it couldn't be done. But he wasn't convinced, and he went on, and he finally found a way of doing the job; and he made and sold his razor blades.

I like to think of two different approaches to creative activity. One I call the "organized" approach, and one I call the "inspired" approach. Most of them involve logical processes of thinking, I am sure. One, though, the organized approach, seems to go in little steps, the building-block process. The inspired approach is where you think of the biggest idea you possibly can; you ask yourself the biggest question you possibly can; and then you search every way that you know in order to make this idea come true.

Gillette was an example of the inspired approach. He tried the organized approach first, step by step, trying to find an improvement to some existing product. Finally this big idea came to him, and he fought, as I say, for five years to make this idea come true.

Dr. Land of the Polaroid Corporation, invented the Land camera using the inspired approach. He said he dreamed the biggest dream possible, and that was to combine a camera and a dark room in one little package and carry it around with one, so that one could take a picture, a full color picture, and have it available in a few seconds after one snapped the picture. He dreamed of having a full color picture in a matter of seconds after he snapped the picture. He tried various techniques to arrive at the solution. He found that he couldn't for various reasons, chemical reasons, and so forth, get this full color picture as soon as he liked. So he dropped down one dream. He thought that maybe a black and white picture would be good, a minute after he took the picture. That wasn't possible, so he dropped down one more dream. He knew of a chemical process where he could get a sepia colored print in a matter of a few seconds. So this was his final idea. He worked it out completely, and then gave it to his engineers and they carried on with an organized approach. They made improvements on the chemical process; they made improvements on the process of manufacturing the film, on manufacturing the camera. They raised the level of the product. After he had the one big workable idea, they used organized techniques to improve it, and now I understand that they will have, before too long, a full color picture available for the Land camera in a matter of a few seconds.

You can, then, become more aware of problems by asking yourself some questions. You know, actually, all people are born with a tremendous amount of curiosity. They are born with a great deal of imagination. These are two prime requisites of creative problem solving. Somehow or other, though, between childhood and adulthood, we lose this ability to ask questions. We lose this ability to fantasy, to imagine and, in effect, we lose two of our most important tools for doing creative work. We find that asking too many questions gets us into trouble. Lots of places, if you ask questions, it means you've got another job on your hands. I think in some places that instead of the word "Think" up on the wall they should put "Keep Your Nose Clean," because this makes the organization run smoothly, and you are happier yourself; because when you ask questions you cause trouble, and you get an extra job to do. Somehow we have to revive this questioning spirit if we want to be sensitive to problems.

Defining a problem is extremely important, once we are aware that one exists. As I say, you start out with a sort of nebulous feeling that something is wrong. You think; How can I define this problem so that I eventually will have something to work with? It's very important,

in defining a problem, that you do two things: First of all, you choose your words very carefully and secondly, you state your problem as broadly, as generically, as possible. This question of the meaning of words enters into problem statement a great deal. You choose the wrong word and you condition your thinking along narrow lines. You choose a better word, and you open up complete vistas for you to investigate.

I was giving a lecture a number of years ago to a group in Cleveland at a convention on automation. We were concerned with the problems associated with the design implications of the automatic factory. My point was that many of the products we are now producing should be rethought, rethought very carefully, to make the automatic factory as efficient and effective as possible. For example, I thought it didn't seem reasonable to expect shoes as they are made today to be made in a completely automatic factory, that there are too many styles, there are too many shapes, there are too many colors, and this and that, to make it a simple automatic assembly line. I said that maybe they might sell a little kit of partly completed shoes, and that the woman of the house would add the proper spangles and the color and the ribbons, and so forth, of her own choice, and this would simplify and make automatic production possible. One might also step into a pan of quickly polymerizing plastic in the morning and it would harden easily. You could walk on it during the day and cut it off at night and throw it away. I am thinking now of "foot coverings," rather than of shoes. The choice of the words "foot coverings" allows you to think of all possible ways of protecting the foot or beautifying the foot, or whatever you want to do with the foot in covering it, whereas the word "shoes" connotes a certain definite solution.

The choice of words is important. Afterwards, one of the men came up and said, "That was an interesting lecture, but there was a lot of junk in it." I said, "Yeah? That's typical of my lectures. Which junk were you referring to?" He said, "Well, this part about using the proper words, and so forth, and defining your product, rethinking your product." I said, "What do you manufacture?" He said, "I manufacture ball bearings." I said, "Well, why don't you think of that as a device overcoming friction and rotary motion?" He said, "Well, what's that but a ball bearing?" Well, I am sure there is more than one answer to overcoming friction and rotary motion. This fellow happened to be a director of research for a ball bearing manufacturer. Well, if he keeps on the way he was at that time, he will end up with nothing but cheaper ball bearings, more efficient ball bearings,

prettier ball bearings, or something like that. They'll get anything else but ball bearings, because that's all he thinks of as to overcoming friction in rotary motion.

Choosing your words, then, is important. What am I working on? Is it a bridge, or is it a device that allows me to go from A to B? Is it a ball bearing? Is it a friction reducer?

One should try, in the second place, to be as generic, as basic, as all-inclusive as one possibly can, at least, in your first problem statement. What is the basic need that you are trying to satisfy? What is the most fundamental term that you can use to express this need? What is the most inclusive system that allows one to look into this problem? The statement of the problem is, almost a complete systems analysis. What is the system I am working on? What is the input? What is the output? How can I describe it as generically, as basically as I possibly can?

Usually, when I worry about a problem, I start with this first nebulous feeling. Something is wrong. Then I let the lightning sort of strike. I let ideas come in a random fashion. I was concerned one time about safety on the highways. I thought there are too many deaths; there is the hypnosis that occurs on superhighways; there's traffic congestion; there is this fact that we have 1.6 passengers per hundred square feet per 4,000 pounds per 260 horsepower. The cities are congested; we have drive-in banks, drive-in theaters, drive-in grocery stores; but not a single drive-in city have I seen for a long time.

What is the problem? Now, as you look over these random thoughts, the questions that you asked, the attributes that you listed, and so forth, you will usually find some patterns that will emerge. The first pattern that emerges I call the first general problem statement. In this case, the first statement was: "A man is a mobile creature and we want to keep him mobile, and yet keep him alive, and not too frustrated." Thinking about this general statement I see that there are a number of ways in which it might be approached. The city planner, the traffic engineer, the highway engineer and the automobile designer all can make contributions to the solution.

You rewrite new substatements, and new patterns seem to emerge from them. This new pattern I call the generic problem statement, which in this case, seems to be not so much a question of mobility as it is a question of communication. Man has to talk to other people

and to other machines. How should he do it, and what techniques should he use? Does he have to use face-to-face communication all the time? Are there ways where other techniques can complement this face-to-face communication, closed-circuit television, for example? Can I use existing equipment more efficiently? Can I use my subway system not just for hauling people but also for hauling freight? Radical new ideas might come from the car manufacturer--can I develop disposable cars? Someone has suggested common rolling stock. We will all own interest in the common rolling stock so that, when someone drives up here to your building and gets out, you own part of that car also, so you pick it up and go to your place, and somebody else picks up his part and goes his way. It's a pretty wild idea.

Your problem now is not just highway death, or city congestion, or the size of cars, but it is trying to get man to communicate as efficiently as he possibly can, both face-to-face and at a distance. This gives you quite a different picture, and still allows a lot of subproblems to come out that you can work, problems which you now have related to a bigger, overall, more generic problem statement. This insures a more complete search for the best possible solution.

Once you have stated your problem and have gotten data together to solve it, then you start searching for possible solutions. This is the area, I think, that has had the most ballyhoo in the last year or so. How do you get ideas to possible solutions? There are a lot of techniques that can be used. The one that has had the most publicity is this technique of "brainstorming." You get a group of 5 or 10 people together, and they sit down and rule out all evaluation and all judicial thinking. They try to be as wild as they can, because it's easier to tone down a crazy idea than it is to dream up or improve a prosaic idea. They want as many ideas as possible, for quantity breeds quality. And you are perfectly free to steal anybody else's idea, modify it and change it slightly; and pop it out as another idea.

These are the types of conditions that provide complete psychological safety and complete psychological freedom. This is a very nice type of group therapy. The fact that it also produces ideas is also a particular benefit for the game. It does work. But I think it produces only ideas. It does not produce solutions to problems. There has to be a lot of hard work, polishing and repolishing, digging, and working, before the idea that ever comes out of the brainstorm session eventually winds up as a tangible, worthwhile, useful, producible solution. Brainstorming, at least as far as I am concerned, is not a problem-solving technique; it is an idea-generating technique.

Now, there are a lot of other ways in which you can use organized approaches to get ideas. I have mentioned checklists before and they are very useful for getting ideas. Professor Robert Crawford, of the University of Nebraska, developed a technique he calls attribute listing, where you define each problem very narrowly, very specifically, and then you list the attributes of the device that you are trying to improve. You change these attributes one at a time and you end up with a hopefully improved product.

There is a somewhat similar technique developed by Fritz Zwicky out at "Cal Tech," that he calls "morphological analysis." This is a type of analytical procedure whereby you list the basic fundamental attributes, not of a specific, narrowly defined problem, but of a broad, generally defined problem.

For example, I was working with a group that was interested in printing processes. They wanted to make a better printing press. This was the general idea. I said, "O.K., but do you mind if we change the wording of the problem somewhat?" They said, "O.K., what will you call it?" I said, "Well, let's say we want to get a device for producing multiple copies of permanent visual records." They said, "Well, what is that but a printing press? But, if you want to call it that, let's call it that--a device for getting multiple copies of permanent visual records." So then I said, "What are the important independent variables associated with similar devices?" We decided there were four. First of all, we had to have an information source. This might be punch-cards, or magnetic tape, or, I suppose, a chemical change, a PH change in certain chemicals. It might be a photographic negative; it might be a prototype model. These are all information sources.

We had to have some information transfer device, to take this information from one place over to some place else. The printing press leaves an impression of type on the paper. We might do it electronically, or magnetically, or mechanically, or hydraulically, or optically, and so forth.

We had to have some visual rendering. In a printing press it is ink. The ink makes the impression visible. We might use chemical procedures, and so forth.

We had to have some way of getting multiple copies through the machine, feeding "paper" through, and so forth.

Well, these are the four independent variables, as I say. We looked for variations of these variables and then cross multplied them for all possible combinations. We crossed optical information source with mechanical information transfer, with chemical visual rendering, with gravity-type feeding--something like that and we came up with 4,765 possible combinations. At the same time we had another group out working in a brainstorming session. They came up with 65 ideas--in the same length of time. They got 65 and we got 4,765. Some said, "Let's consider the brainstorming ideas, the number is smaller, and who wants to go through 4,765 ideas? It doesn't do any good; it takes too long."

Actually, someone said this very seriously. The creative process of problem solving is more a process of evaluation, decision making, than it is of idea generation, because ideas can be generated mechanically quite rapidly. You can feed the data into a computer and come out with at least 4,000 combinations very quickly. Then some one has to go over these combinations and decide whether or not they are good ones, or feasible ones, or practical ones, and so forth. This is the difficult job.

One of the important steps of creative problem solving is this one of decision making. You've got your ideas. Then you say, "What is the best idea? How can I make it the most effective?" This is the synthesizing process and the evaluation process that distinguishes creative problem solving from analytical problem solving. In an analysis you can use deductive reasoning alone; in creative problem solving you must also involve a synthesizing process along with analysis and the evaluating process.

A good share of the time we spend in our classwork is on techniques that might be more useful in decision making, rather than on idea generation.

Now, I haven't mentioned a thing about the blocks that prevent people from being more effective in creative procedures, things that prevent a logical process from taking place in creative problem solving. I haven't mentioned a thing about the management techniques that might be useful in making our own people more effectively creative, productive, and so forth. The time just doesn't allow me to go into them. Maybe

they will come out in the question period. I was told to talk 40 minutes, and I have gone 60. I beg your pardon but will be glad to answer any questions that you have later on.

Thank you.

COLONEL BARRETT: I presume there are no questions.

QUESTION: Professor Arnold, would you continue with the remarks that you were about to make on the subject of blocks?

PROFESSOR ARNOLD: Blocks? Well, it's quite easy to describe some of the techniques that are useful and creative. You can outline them, you can set up exercises for practice; you can become more observant; you can become more problem sensitive; you can become more flexible in your thinking, more fluent in your thinking; you can look for techniques that will make you more original, more novel in your thinking. These things can be done, and they are effective. But they're not all that you can do. You must also remove certain negative factors that prevent people from being as original and flexible, and so forth, as they would like to be. These blocks I list in three general categories:

Blocks that prevent complete perception--perceptual blocks--the things that prevent you from seeing reality as it really is. Cultural blocks--the influences of other people and the way they think, and the products of their hands and minds. These are the living people as well as the dead. Then, the emotional blocks--the things that you do to yourself, because your emotions make you less effective, the fears and the anxieties that you have--and they are numerous. I will try to give you an example of each one.

One of the most damaging perceptual blocks is this wonderful little mechanism that we have called projection. The things we see are not reality, but the joint product of what we think reality is and the things we are observing. They are parts of ourselves, plus the objects we are observing. We see what we like to see, what we expect to see. We don't hear the things we don't want to hear, that we find painful, and so forth. This prevents us from getting a true picture of the problem; it prevents us from getting true information to work with. An example that is easily observable is that, after you have been in an area for a while, you are an expert. You know all the things that can be done, all the things that can't be done. So that

there are certain things you classify as trivial and unimportant. As soon as you do that you no longer see these things. They can't enter into your problem-solving situation. Some amateur comes along. He doesn't know what is unimportant, trivial, and so forth. He picks these ideas up, he combines them with something else, and he's got a solution for you. You say, "Why didn't I see it?" Obviously you couldn't. It was in the background, and it was unimportant. Lots of people say, then, that the only way to be an inventor is to become an amateur, because an amateur is the only person who can invent. This is not true; but you have to think like an amateur. You have to be open to your total environment to prevent these perceptual blocks from taking place.

Cultural blocks are all the things that other people do to you that inhibit creative activity--your education at home and at school--elementary school, secondary school, college--your colleagues on the job. They all have certain attitudes that impinge on you, that govern somewhat the way you react, the way you solve problems, or the way you respond to certain situations. The question of imagination is an interesting one. As I said, all children are born with a great deal of imagination. They can fantasy beautifully. When you see a child playing with a block on the floor, you don't know whether that block actually is a fairy princess or a dragon, or a fire engine, or something else. He sees something there quite different than the block. He is having fun with it. But very quickly he is taught that fantasy is a waste of time. Day dreaming has a bad name. You shouldn't day dream. You should be a practical person. This is a sort of cultural block.

I was speaking to the general outside about a very interesting example. An experiment was run with students to try to solve the problem of getting a ping-pong ball out of a rusty pipe bolted to the floor. They came in one by one to a room. In the middle of the room was an old pipe 1-1/2 inches in diameter and 12 inches high, bolted to the floor. In the room there were a lot of tools--straws, strings, bent pins, gum, rulers, screwdrivers, hammers, crowbars, and so forth. The students tried all these things, but they couldn't get the ping-pong ball out. In one corner of the room was a pail of old dirty wash water. Eventually all students would see the pail of water and would pour it into the pipe and float the ball out. Fine.

But, when the only water in the room was water contained in a beautiful crystal pitcher, ice water, clear, bright, and cold, on a

table on which there was a linen tablecloth, with a lot of nice crystal goblets around it, not one student used that water for pouring into the pipe to get the ping-pong ball out.

You just don't think of it. Your culture teaches you that this is ice water for drinking purposes, and it's not for pouring into pipes. There are a lot of taboos that we have been raised with that prevent us from thinking in certain areas. We think this is nasty, this is outside of our way of thinking. These things do not enter into your thinking as information in a problem-solving situation.

The emotional blocks, of course, underlie almost all blocks. There is the fear of making a fool of yourself, of being impractical. There is anxiety; you must have security, above all things. There is the unwillingness to take a chance, to gamble--it is better to be safe than sorry. We have a whole bunch of cliches that we use along that line that just prevent us from taking chances. Daringness is essential. The innovator has to be willing to take a chance, has to be willing to fail.

Boss Kettering said that we train our students to be right all the time in school. They must solve the problems correctly. The inventor has to train himself to fail. He can fail many many times in order to arrive at a good solution to his problem. This involves a rather different emotional attitude than the ones we are brought up with.

This is a very quick survey of the three types of blocks that hinder people. Now, to be effective, you must recognize that these blocks exist. You must search yourself very carefully. You must go back to Socrates and know yourself as best you can, and decide whether or not you are avoiding certain areas because of fear or anxiety. You have to decide whether or not certain things in your own culture have prevented you from being effective in certain situations; whether there are certain areas that you are avoiding because of training, tradition, and so forth. You have to be very careful that you are not seeing things you expect to see or want to see in your perceptual processes.

QUESTION: Professor, do we have any methods of recognizing individuals with creative thinking ability? You had your diagram on the board showing the curve of people who are normal. But those who are above the normal, with creative ability--have we developed methods and processes to recognize them?

PROFESSOR ARNOLD: A lot of work is being done at the present time on testing, trying to develop definitive tests that will differentiate between a man with high creative potential versus one with low creative potential. I think most of these tests indicate not potential so much as they indicate realized creative ability. A man who has potential and is also using his potential will test high on these tests, as opposed to one who does not develop his potential. You may have, for example, a person pretty close to a genius who, because of cultural situations or emotional situations, does not realize his own potential. He wouldn't show up very well on the tests.

I have used some of the tests on occasions, and the big discrepancies I have noticed are in those cases where students, for example, really have high creative ability. They are given the test on the first day of the term and they may have scored down in the 10 percent level, but eventually they showed up to be highly creative people, and got A in the course.

In some cases this is because they didn't realize they had the potential. They didn't have confidence in their own ability to solve problems, perhaps, or they may have thought that the test was rather silly, or that they just couldn't at that moment get themselves in the sort of free, easy situation that the test demands in order to get a good mark.

Those who have been questioning, who are flexible, fluent, who are original thinkers and have done that all along the line, will test rather high.

So I think the test measures demonstrate ability more than they measure potential. Now I think that you can measure that ability just as well in some cases by a very careful interview, by looking at a man's past record of what he has done, his interests, the kind of activity he has engaged in most of the time, his avocation, to get some idea of the drive he has, how enthusiastic he is, and so forth.

There are very definite signs that indicate those who are highly creative. If you have the chance, get hold of a book by Maslow, called "Personality and Motivation." An important chapter of this book is also included in the book, "The Self," which came out this summer. This book was edited by Moustakas and published by Harpers. Maslow calls the creative person a self-actualizing person, and lists ten or so attributes that are vital and necessary to his personality. He has this openness to experience; he is naive in some respects; he is a nonconformist in certain areas. He thinks differently and he is not afraid of speaking

up and even making a fool of himself at times. Maslow was talking to a group of mine one time about these things, and after he got through one of the men in the group said, "From the things you say, this man sounds like a bum." Maslow said, "Yes, he is; he's the uncommon bum."

QUESTION: Professor, would you say that in today's life the many avenues open to an inquiring mind hurt his creative ability by spreading his effort too thin on everything, so that he is less creative than the specialist who follows a single field and whose interest lies only in that field?

PROFESSOR ARNOLD: I would say, no. Generally speaking a man who is very broad-gauge in his thinking is the only man who has a chance to be creative. I will amplify this a little bit. The creative process, as I said, is one where you combine together old ideas in new patterns, new configurations, new arrangements to better satisfy the needs of mankind. Now, in combining old ideas together, you want, of course, a better solution; and a novel solution. To be novel and original in your combination, you must have interests in a number of fields. In other words, you are trying to combine ideas that are habitually not associated together, that are seemingly disparate. This is important to creation.

Now, if you are an expert in one narrow field, the chances of your bringing an idea from some other field to combine with something in the area in which you are expert is pretty remote. I think you have to have a rather broad, comprehensive viewpoint, a global viewpoint, a wholistic approach, rather than an atomistic approach to the problem in order to be creative.

You can be a discoverer in a very narrow field. You can discover relationships that have always existed in nature. The more expert you are in the field, the more chances you will have of discovering these relationships; so that you can be a highly creative, imaginative scientist, let's say, in the field of nuclear physics, and discover new relationships in that area that are important to man. But the chances of inventing in the field of nuclear physics are remote. For this reason I keep invention and discovery apart. The broader you are, the more expert you are in lots of fields, the more chances you have of inventing or innovating, of bringing together a new combination that never existed before.

QUESTION: Sir, have you studies which will lead you to have conclusions as to the effect of the military system on the creative potential of its personnel?

PROFESSOR ARNOLD: I suspect that that is a loaded question. I suppose the military system could have some effect on the creativity of its men, just as I suppose a religious way of thinking could have an effect on your creative potential. I suppose a very strict home life, or a very dogmatic parent, or a very well established routine school, or any kind of a job could have an effect on your creative potential. I am sure if you are working for an industrial group and everything is done the way good old J. B. would have done it, your chances of doing creative work are pretty limited. If in the same way, in the military you must do something because this is protocol or this is the way we do it here, again you are going to be limited in your ability to do new things and arrive at better solutions.

I don't think the system itself demands that you cannot be creative. I'm sure that it is possible to be highly creative in the military. I am sure there are highly creative people in the military. There have been in the past. There will be in the future. I'm afraid that a lot of people have the feeling (and it happens in companies, too)--"Well, I'm in an organization where, no matter how hard I try, I just can't do something new." Therefore, they sit back very comfortably and never try anything new, and are happy and contented. This is just a good excuse. To be creative in some of those restricting atmospheres requires more talent, but it can be done.

QUESTION: Professor, considering the vast majority, is there any correlation between age and creative potential?

PROFESSOR ARNOLD: Yes and No. The published figures seem to indicate that there is correlation between creative ability and age. I don't think that the figures actually show the whole truth, however.

Lately there has been some research, searching among creative people in all kinds of fields--in the physical sciences, the social sciences, art, music, religion, philosophy, government, industry, and so forth--and there have been plotted a number of curves on creative activity versus age. The general shape of the curve is that the high point is reached usually before 30 years of age. In the case of physics, great contributions in the field of physics have been made by men in the twenties--24, 25, and 26 years old. Great contributions in the field of medicine,

for example, have been made by men who are around 30, 32, and 34 years old. Strangely enough, the great contributions in fields like, say, philosophy, or religion, have been made by men of 60, 70, and so forth. Most of the curves show the peak to be around age 30.

This, I think, can be explained in a number of ways. First of all, the young man is an amateur in a way; he is just starting in. He's looking for all kinds of cues. He's free to combine lots of ideas in a rather playful way, and he comes across new combinations that are important. As soon as he does this, he is an expert in this area, and, try as he will, he can't get out of it. I have talked to a number of outstanding physicists and they substantiate this observation.

This may be repeating what I've already said about taking the broad viewpoint. A person should, I think, go for breadth as well as depth so that he can get new ideas to be combined, to provide, I suppose, grist for his mill.

Being over 30 myself--just 31--I am convinced those figures are wrong. If you look at Edison, for example, he was still bringing out new ideas at 80. Kettering is still bringing out a new idea now and then. He's just about 80.

The actual number of inventions decreases as you get older. One reason for that is that you are not as hungry.

DR. HUNTER: The examples that you have cited, that you have been drawing, Mr. Arnold, are in the mechanical and physical fields. Has this technique of creative problem solving been applied in the social sciences in the field of human behavior and human relations to any extent?

PROFESSOR ARNOLD: Yes, a great deal. A good share is in the area of group behavior, group dynamics. Many of the psychologists who for a long period of time studied in the field of abnormal psychology have shifted now to studying mental health. Instead of studying the abnormal people, they are now thinking about--what is the most effective, most efficient human being? What are his properties? What are his attributes? Can we develop those kinds of things?

This is the kind of person we are talking about now, the efficient problem-solver, one who can adapt himself to a wide variety of environments, one who can solve many problems and make important decisions.

Creativity appears under different names. If you look in the literature, under the term "creative problem solving" you might find a certain number of articles listed. But you should also look in the other areas pertaining to group and individual activity for you will find a great many more.

Problem solving is getting increased attention all along the line in the social areas. This is to be encouraged. I think a good share of this activity has to be in how to make individual people more effective--not just that they get along with each other, but that they can also produce more effectively.

QUESTION: Your remarks so far have not touched on the time element of problem solving, yet many of these multisolutional problems must be done within relatively short time limits. Do you have any suggestion on time phasing of the various steps within the time alloted?

PROFESSOR ARNOLD: Yes, there is no question but that time can be a very definite limiting factor in some creative-problem situations. I think, though, that its inhibiting factor is emphasized more strongly than it should be. Creative men in the past have created on demand. Mozart would write an opera on demand. Rembrandt would paint a picture on demand. These things have been done and they still can be done. Chances are that these people spent a rather much larger proportion of their time--much larger than you and I would do, for example--in reorienting themselves, in searching for problem statements and definitions, in getting a clear picture of what they wanted to do--and a relatively short time in actually carrying out the solution.

This is one thing that I think is typical of people who are goal oriented, rather than technique or method oriented. Most students, for example, if you give them a problem to do, even an analytical problem, jump right away into some kind of procedure on how to solve it. They don't sit down and try to think "What am I trying to do? What is the goal I am aiming for? What is the given data? What are the conditions?" They start looking for some method. They try, oh, integration, or a differential equation, or things they know worked in some similar type of problem.

I am sure that if a great deal more time were to be spent in actually formulating a basic, generic, very broad, comprehensive picture of what you are trying to do, one would be much more effective in arriving at an outstanding solution.

I say to my students, "All you have is a week in which to do this problem," and suggest that they don't do any work at all until they have spent 3 or 4 days rewording the problem and coming up with 4 or 5 or 6 or 10 problem statements, finally picking one, and then not finding one solution, but 10 possible solutions. In fact, when they come in for criticism on design problems, for example, I won't criticize a single solution by itself. They've got to bring in three solutions and I'll criticize their three solutions. Criticism is a process of comparison. Evaluation is a process of comparison. If they bring in only one solution to a design problem, I've got to compare it with what I would have done myself, or what I think would be the ideal solution that's up in the sky. This is not a good way of training students. If a student brings in three solutions, I can compare his three ideas. Idea A is better in some respects than idea B, and idea B is better in some respects than idea C. Combine the good points of these three and you might come up with a still better solution. This is a good starting point for him, and if he goes through all those ideas, he may come out with a still better one. But he realizes there is more than one way of doing the job, and he has given full consideration to at least three ways.

Now, time spent on that kind of activity is very worth while. Once you pick the good solution, you can usually procede fairly rapidly. In some of the courses at the Harvard Business School at final examination time they hand the students the question at the beginning of the examination, but no paper to write on until they've had an hour to think about the question. When they are given the paper they can write very efficiently and very quickly, because they know exactly what they want to say by that time.

If we will do the same thing in a problem-solving situation, it will be more effective.

COLONEL BARRETT: Professor Arnold, on behalf of the Commandant and the College, I wish to thank you for a stimulating morning.

PROFESSOR ARNOLD: Thank you very much.

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