2-27-1975

"Education for Managing Complexity"

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February 27, 1975
Portland State University

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Transcribed by Ruby Bontrager, September 9 - September 25, 2020
Audited by Carolee Harrison, December 2020

HAROLD LINSTONE: [*recording begins mid-sentence*] ...start off with by telling you about a project sponsored by the United Nations to define and clarify the concept of systems. They prepared a statement and various countries did studies and then came back with these studies. The Germans came in after a year with a report, a thirteen-volume treatise called *An Introduction to Systems Science*. The Russians came in with a book with the title, *The Systems Approach as a Tool of Capitalism*. [*laughter*] The French had a rather small volume called *The Story of F: Confessions of a Systems Analyst.* The Chinese had a little red-colored booklet called *Mao's Thoughts on Systems.* The Italians had a book entitled *Roman Traffic: a Case Study in Applied Systems Analysis.* And the American contribution was a book with a rather fancy cover, looseleaf bound, called *Sixty Ways to Beat the Stock Market and Improve Your Love Life with a Systems Approach*. [*laughter*]

It will become obvious to you that there are… it is rather difficult to give nice, clear, simple explanations, because what we're dealing with is basically complex. I first really heard the word "systems" used in the 1940s; Bell Telephone labs was designing new, rather complex telephone networks; the radiation lab at MIT was, in the 40s, working with radar systems which were complicated. Notice these were very application-oriented "systems." Von Bertalanffy was approaching the idea from a more theoretical point of view really based in biology, what he called "general systems theory." The key features of all of these are a) you're dealing with new and future concepts. New systems, design of new concepts, worrying about the coming rather than, let's say, how to best use existing systems. The order of operations research was of course already… also became very well known at that time. It really got its start in how to use existing systems better. Search problems and things of the sort. So one key concept is the idea of worrying about the new, designing the new.

The other problem was complexity. In fact Norbert Wiener had a definition of systems at one point where he said, "The system is organized complexity." Now, the way you organize it doesn't have to be necessarily through a tremendous amount of mathematics; it can be… for example, Herman Kahn once said, "The simplest system approach is making a list." A list of choices, a list of alternatives. Now, what are some of the characteristics of complex systems? The reason I want to mention these is because when we talk in an educational environment, and when you deal with systems, you inevitably have to break quite a few taboos, and I'm going to mention quite a number of fallacies which are rampant and are still being propagated in the kind of institutions which we have, whether it's in government, whether it's in the university, and so on.

The first fallacy, you might say, is that the total of the whole is equal to the sum of its parts. Something which in geometry seemed to be reasonable enough, but you know very well, if you think about it, that a symphony is not simply a collection of scores or instrumental scores. A symphony involves more than a sum of parts. The world *problematique*, really the whole problem of survival in the present situation, is more than an economics problem. Traditionally, the way we have approached science and technology—and it's not been very successfully, obviously—is through dividing a complex problem into parts. Subdividing, compartmentalization; in Europe they call it Balkanization. Kenneth Boulding, in fact, right here at this school once said that the name of the devil is Sub-optimization. And Heinz von Foerster, if he doesn't mind my quoting one of his laws, maybe he'll get into some of the others, but I think it's your first law which says that "The more profound the problem which is ignored, the greater are the chances for fame and success."

Now that's quite reasonable, because if you're stuck with a complex problem the most obvious thing to do is keep cutting off parts of it until you… and if you still can't solve it, reduce it some more until you get to something you can solve. So it's bound to be a success and very often it ends up in a Ph.D. dissertation.

Another fallacy is that the best solution for the parts is the best solution for the whole. In other words, if you take it and try to do the best you can with each of the parts, you have then got the best solution for the total. Joe Coates called something very related to this "the fallacy of the second best." Namely when all conditions for an optimum cannot be met, the strategy is to meet as many of the conditions as possible.

Again, it sounds reasonable enough, until you work with complex systems. Often, and this shocks—as I say, you have to break a few heads in the process—and it shocks quite a few people after they've been brainwashed in any educational system, to learn that there are systems that have no optimum; that there may not be a best solution. When you've been through lots of courses where every problem in the book is practically asking for a best solution. You heard Buzz Holling talk this morning about the problem of safe fail situations, which may be much more critical than the problem of the best solution, because of the complexity; hence the uncertainty, the unknown. You find out that inefficient systems, from a strictly technical sense, inefficient systems tend to also be more survivable than highly efficient systems. You as an individual don't operate at maximum efficiency, although you may delude yourself you do. But it also at the same time makes you more survivable.

Then there is something called "Gresham's Law," which can be applied, and again it's something which... you're used to dealing with quantifiable items, many of you who study come from the hard sciences, and even the soft sciences these days. You measure what is easily measurable. You disregard that which cannot be readily measured. That tends to be misleading. You presume that which cannot be easily measured is unimportant. That's blindness. And worst of all, you presume that that which cannot be easily measured does not exist. That can be suicide. In other words, we have the situation that so often, quantitative analysis tends to drive out qualitative analysis. And we have to do a lot of unteaching and unlearning in this area.

A good example is to use the GNP, the Gross National Product, as a measure of the quality of life, because it's something that's definable and I can generate numbers, and I have it in the yearbooks, so that's what I use. But these complex systems that we're talking about have peculiar characteristics. They have long lag times. For example, if you wanted to stabilize the world population starting right now and you took the necessary steps, it would probably take about 75 years to do the job. It's not something… it's like a big ocean liner; you can't turn it around on a dime. You have the problem of stability and instability. The very curious characteristics, which were very beautifully discussed this morning.

Let me mention another fallacy as a kind of thing I just cannot resist. Science has... inculcates the idea of objectivity. We're objective. We deal with data, and obviously data is objective. I think that's a fallacy. Data is highly subjective. Just ask people, for example, who've witnessed an accident what they saw, and the different stories that you get from observation. The way we select what we define as data from the real situation is subjective. Again, the kind of example… subjective for example… to illustrate in the way we select quantifiable information as opposed to things which are difficult to quantify. So we have the problem of so-called objectivity; you get this problem by talking about probabilities, the idea that I, for example, I used to do a risk analysis in business, and we were dealing with an advanced technology business. We went to the engineers and said, "You're building a new vehicle; what is the risk that you'll be fifty percent over your cost estimate?" A very relevant question. They would say, "Well, we don't have a database. We haven't done this a lot of times. How can we give you a probability?" They're used to the concept of probability the way you toss a coin: the ratio of the number of successes to the number of total trials as that ratio approaches infinity. The fact that you have such a thing as subjective probability, most of them don't even know. Very few places even teach courses in subjective probability, which you might define as a degree of confidence. And yet, the same engineer who refuses to give you information on this chance of overrun because it's a one-time occurrence, has no compunction at all about making a bet on a football game or a Muhammed Ali boxing match, which is a one-time occurrence, right? And he knows, and he uses odds. He accepts that perfectly well, but in his work it's a different life.

Then you have the problem that everything interacts with everything. Let me give you an illustration of how subtle… because we've gotten into the subject of technology assessment, looking at the impact of technology on society, and how subtle this can be. There was recently a study done, very interestingly enough not by a technologist, but a historian. It was entitled *Technology Assessment from the Stance of a Medieval Historian.* That's very instructive. It is instructive to look at the past. In the Middle Ages… let me take the example of mass production of books.

Now, you all know... the first thing that would come to your mind if I asked you, "What were key elements in making the mass production of books possible?" You would say, "The printing press." Gutenberg. I would counter… or this article suggests the situation's much more complex. You needed good paper, and lots of it, to have mass production of books. Now the spinning wheel came to Europe in the 12th-13th century, and if you were an analyst at that time, you would have clearly said, "The mechanical way of looking at weaving should make clothing cheaper." Okay? And if you'd really been a farsighted and total picture analyst, you would have said, "Maybe children's health will improve because poor children can afford to be dressed warmer in a cold winter in Europe, get less pneumonia, less disease because of the spinning wheel." It would have never occurred to you at all to relate this to books. What has the spinning wheel got to do with books? Well, linen was one of the most popular materials in the Middle Ages. Bedding, clothing made of linen at that time. So you were weaving linen, and having cheap linen clothing ultimately meant we were getting cheap linen rags. And now maybe the light lights up. Linen rags is a very good source of high-quality paper. Remember, if you go and buy stationery... say “rag content,” so much. So here you have the spinning wheel having a direct and very significant relation, just as much as the printing press, to the mass production of books.

Another example is the genius who invented the chimney. He had an impact on social stratification. Why? 'Cause in the old days you think of the castle in the winter in Europe; all the cold. Everybody was around a central area with a fire to keep people warm, and you had to live in pretty close physical proximity to keep warm. The man who invented the chimney made it possible to have chimneys all over in different parts of the castle, and of course the first thing that happens is the lord and lady move to their own quarters and don't associate so closely with the servants anymore: the origin of the upstairs-downstairs concept. And that's therefore something which should have been of great significance in regard to technology like the chimney.

With the automobile, how many people in the 1920s concerned themselves with the concept of what does this to the family, what does this do to suburban sprawl, and in the case of the family, does it have any relation to divorce rate? So we're talking about rather subtle things, and as Hardin said, Garrett Hardin, "You can never merely do one thing." This is one of the lessons you learn. If we could have the slide... could you? Let me give you an illustration…. The latest book of the Club of Rome has a very simple such illustration, and this concerns the world food supply. There are lots of people going around saying, "The way to solve the world food supply is to have a three or four percent increase in the economic growth." The question is, can people eat dollars? That's the first box, the economic solution. The second one is a science solution. It's possible to increase the yield substantially in a laboratory… there's plenty of evidence, so that on paper we can feed 30 billion people. 30 billion. Much more than we have today, or expecting even in the year 2000. The only question with the second technological or scientific approach is that you want to bring people together with food. That's one of the problems at least. Just because you have that ability does not mean it's going to be successfully applied.

So, we have the problem of population. Is there the infrastructure to make this work? How much food can be produced in time and for the populations which actually need it, which are very unevenly distributed throughout the world? Okay, you say, that's the whole system. But then you've got to figure if you're going to produce all this food, you're gonna have to start producing a lot of other things. You're going to be using chemicals on a very vast scale, you're going to be reducing the diversity in nature because it'll… simply a lot of crops and other things you'll have to squeeze out to do this. So you'll be eliminating other species in supplying all this food. Now you've got the problem of ecology. And I think this morning you got a pretty good idea of the sophistication of such an ecological system.

Then you've got the question, you say "All right, suppose we are able to include that, isn't that enough?" And the answer is it still isn't because now you'll have to worry about sociopolitical arrangements. Some regions are going to be producing their foods, other regions are going to be using it. The immediate question comes up: how will this food be used as a weapon? As a political instrument? So you've got the sociopolitical context. Is this the whole system? No, because you're also dealing with individuals, not just groups. Dealing with individual values; people have to change their eating habits, people have to change even their religious attitudes to permit this kind of approach. Sacrifices will be needed by some to give more food to the others. So you have the problem of the individual. So that you finally have this large conglomeration as a total system.

And it is therefore very tricky and very dangerous to do what we attempted to do, particularly the United States. We say, for example, if we have to make trade-offs, if we have an energy shortage, you've seen in the press plenty of reports would say, "Well, what you've got to do then, obviously, is relax environmental standards. You've got to take your choice; do one or the other." If you want more gas mileage in the cars, you'd better stop adding onto the safety requirements like bumpers and so on, and drop those standards down.

In many ways, these systems—and I think this was already apparent and I'm sure will be apparent from some of the other talks—behave in what most of us would view as a counter-intuitive manner. I'm reminded of a headline I just saw in the *Oregon Journal* on February 15. The headline says, "Computer Says Ford Plan Ranks with Doing Nothing," referring to the energy economy plan proposed by Ford. Certainly, to a lot of people, that kind of conclusion would be counter-intuitive. I assume it would be to him. What do we do? Well, what we do already ties in with another fallacy. It's called a fallacy of argument from incompetence, which says, "If I cannot see how to solve a problem, it is unsolvable." As German poet Goethe said, "There is nothing more terrifying than ignorance in action."

Let me give some illustration that may be familiar to some of you, at least in one area of system dynamics. The problem of... from the original Jay Forrester work, trying to look at the world as a system. Now, this looks fairly simple. There were originally five variables. Population, capital investment, natural resources, the fraction of capital devoted to agriculture, and pollution. Obviously all important. And the way this kind of thing works just for those of you familiar with the general concept, we have here population in the middle, the rectangular box, and population results in… if you know the normal death rate, you can calculate the number of deaths in a certain time increment. That of course will affect the population in a similar way with the number of births, assuming a certain birth rate will create new population, so you have these feedback loops. Feedback is a very essential element in looking at systems. Now you say, this looks all very simple, where's the complexity? Just keeping in mind those five variables, this is what you get. Just for those five variables. The five variables are these rectangles. This one's population… this is what I showed in the previous slide. So it doesn't take much to develop complexity, and of course people criticize this particular model as being highly oversimplified.

Another thing we find out is that we talk a lot about… well, let me first show you what happens with this kind of thing. Typical kind of charts which are now pretty widely known, and a lot of people are looking into this kind of thing and improving and working in this kind of area of systems dynamics; here you have shown the variables such as natural resources, population, and this goes from 1900 to 2100. In other words, the way the model is derived to take the information which we know from 1900—population, pollution, et cetera—from 1900 to 1970 and make sure that if you started in 1900 and let the model work incrementally through to 1970, you in a sense get a reasonable picture of what's happened over 70 years. Which should satisfy a lot of people; 70 years is a big database. And then you run it on into the future. And you see that you get the province of pollution rises to much higher levels and you get declines; you get this typical complex system behavior, then you say, well we want to use this thing as a learning device. We want to see how to improve it. For example, here, what they defined as quality of life in this particular case peaked; in fact, it's already peaked around 1950 or so. And it's declining; we don't like that, so the question is what do we do about it, and typically we look at certain steps that seem reasonable and seem intuitive, such as let's stop using natural resources up at the rate that we have. If you look at the previous chart, we're talking about this curve here, and that's why today we stop using up the resources at the same rate, so they don't deplete as much and so we have a break in this curve. Instead of going down, it's flatter. We're using up… recycling more, using up at a lesser rate. And lo and behold, that really doesn't help the situation because we get instabilities.

You notice the population is now going through a drastic decline and then goes up again. The first implication is naturally to blame the model. And you say that can't happen, it's never happened before. Of course you're wrong, because it has happened before, and you can go back into history and people have done this. In fact in the transition from the Middle Ages to the Renaissance, and if you include in pollution, disease is a form of pollution, and you remember the plagues decimating cities, a fifty-percent population drop in a very short time in some cities, eighty percent in some. You see that this pattern is not at all unnatural. We did get an increase, in fact showing what shows up here, the increase in the quality of life after this catastrophic situation has happened, and that is what we properly call the Renaissance, following the Middle Ages. So we've gotta be very careful. It points up another thing, that we don't look at the past enough. We don't apply our modern tools to the past. I'll get into that problem in a minute.

Now, if you think that this kind of thing is kind of a doomsday situation, first of all, let me say that the reason one does this is not to have this kind of self-fulfilling forecast; you want to have a self-defeating forecast. You want to make sure this doesn't occur. And that of course is the essence of the whole idea of looking at these same systems, the same discussion that you heard earlier this morning on making the system more safe-fail. One of the things that makes this, in a sense, conservative is the fact that the population's actually—from 1650 on—has been increasing at a faster rate than what is normally used in these. We always talk now about exponential growth. Doubling in a given time period. Turns out, if you look at world population data from 1650 to 1700, world population increased at 0.27 percent per annum. 0.27 percent. From 1850 to 1900, 0.62 percent. From 1960 to 1970, 1.97. 1971 to '72, over 2 percent per year.

So we've gone from an annual rate of .27 percent to over 2 percent. That's not exponential. You can call it hyper-exponential, or in fact it's called hyperbolic. If you continue that trend, this is what it actually looks like, the… you come out with an infinite population in the year 2026. And there's been a recent study looking at this. I think one of your studies earlier came out with a very similar conclusion… what was it? 2025. [*response from audience off microphone; audience laughs and applauds*] Now, you know, this is not going to happen on Friday the 13th in whatever month it is in 2025 or 2026. You know it's not going to happen, but it also suggests that the trends can continue and that we are in fact in a kind of a phase change today. In other words, the kind of tool you're most used to using… in fact, even this model is in a sense the system dynamics model I showed you before, it is a trend extrapolation because you assume the basic nature of the model, the structure of the model will remain the same. And it cannot remain the same in this kind of situation. That's where you could say it does not really reflect the true, realistic situation. You don't let it go to these extreme situations. You try at least to provide ways to avoid this.

So that you have a very serious type of problem, a type of problem where the typical forecasting tool which is used—if anybody does forecasting at all most of the time, trend extrapolation—it becomes more hazardous. And you can't… you really have to go to a kind of systems concept modeling simulation other ways, including non-quantitative ways to assess what is happening and what can be done. Let's go back to the problem of resources. You say well it's a matter of finding… using shale oil, for example, instead of oil directly. We not only have a problem of depletion, we have a problem of dispersion as you go towards, and of course increasing expense in getting to the more subtle and more, let's say, deeper layers of the shale oil extraction, use up more energy, until the problem becomes self-defeating. You use as much energy to generate the energy that you want to use so that you don't have a net gain at all.

Now if you think that isn't… I was always amused… in talking to technologists, the typical claim that is made is that agriculture is an outstanding example of the effectiveness of technology. Because after all in the United States today, less than 4 percent of the population are producing more than 100 percent of the food requirements. This is a tremendous gain in efficiency. Well, yes and no. If you think about it, you're also using fuel, and in fact you're using a great deal of fuel to produce one BTU of food, you may be using 5 or 10 BTUs of energy to produce one BTU of food. All you've done is switch from human energy to fossil fuel energy. And using it with extreme abandon. So there's a question of efficiency here. Now you might… the Chinese wet rice agriculture, for example, is a different story. For one BTU of food input, you get many BTUs, some calculated 25, 50 BTUs of output in terms of food energy. Now it just gives us here some food for thought.

The other problem we get to and a very significant one is discounting: discounting of the future. If you take something like that first standard curve in population that I had from the system dynamics, that's shown here on the left hand side. This is simply—it's from basically the same type of data, this curve here, and that's population—all that I've done is essentially normalized it, so that 1970 becomes unity. So that it goes up to three times that value in 70, 80 years. Fine. What I'm suggesting here is what we're actually doing. Remember, I've talked about long lag times to solve problems; what we're actually doing is looking at the future as shown in the second and third slides. We use essentially a discount rate. The second slide uses one percent per year, we're all used to doing that with dollars; a dollar that you get in 1980 if you give it to any businessman even without inflation, that is not worth to him the dollar that he gets next year because he can reinvest it; put it in a savings account or do something with it to make more money. So that even without any inflation you have some kind of discount rate; in business we tend to use some kind of capital. Might be 10 percent a year.

Now on the right hand side you see that with 5 percent a year the crisis has disappeared. And what I'm saying here is that it's a problem of perception. The crisis hasn't disappeared, our view of the crisis makes it shrink. It's like looking through the wrong end of a telescope. A problem that's far in the future we tend to say… or not look at it with a similar seriousness as something which occurs very soon. The best illustration I have is with the oil problem. In the 1950s, there were plenty of studies done; 50s, 60s about forthcoming oil shortages. They end up as reports to the president, like the Paley Commission report, and they're promptly briefed and filed away. You can't arouse interest. When you can't get gas at your gas station, it's a different story. Because one looks like a crisis 30 or 40 years away, the other one is an immediate problem.

We have here another kind of Gresham's law, namely that short-range problems drive out long-range planning. That's true in all organizations; business, government. After all, an elected official has to worry about reelection and what he can do immediately. The electorate tends to ask, "But what have you done for me lately?" So that we have this kind of situation occurring not only in population; this is the same kind of thing with pollution, taken with a zero discount rate using 1950 as unity, and the tremendous rise in pollution, the topmost curve, and by the time you get to 5 or 10 percent discounting, you're like the cartoon character in *Mad Magazine*. What, me worry? It's too far in the future.

Now here you have some I just took out of a new book, and then worked on it to draw the other curves. This first curve here is out of the Mesarovic-Pestel book on *Mankind at the Turning Point*, where he looks at the problem of providing aid to the poor countries to reduce, not close, but reduce the gap in economic wealth between the two; per capita GNP or something of the sort that’s say, three to one with respect to Latin America, five to one respect to Asia, or South Asia, or Africa. All right, this means we're putting aid from the developed countries into less developed countries. And we have three alternatives. The first one is that you start a program in 1975 and carry it out to the year 2000. And this is the annual rate, this is the annual expenditure here. The second alternative is you don't do anything now, but start at the year 2000 and let it go on for 25 years until the year 2025. So each of these two are 25-year programs. This one starts now and it's a slower program that lasts for 50 years.

Now, anybody would conclude that the cheapest program, and therefore the most preferable one, is to begin immediately and do this alternative here. Now on this chart, we've discounted at an annual 5 percent. Here you're actually discounting dollars. Notice that this… the difference between starting in the year 2000 and starting now has virtually disappeared. In other words, it just looks practically as good if we waited and did nothing. And if we discount 10 percent a year, we see that waiting 25 years is actually better, it's cheaper. It looks cheaper because of the discounting. So then in a sense we would have come up with different preferences. So we're talking here about what I consider one of the most fundamental blocks of effective planning. The fact that a) we're dealing with complex systems, which are not easy to change... and yet because of discounting, it's very hard to come to grips and get the popular support, even if we know solutions or we know improvements to these problems. The implementation of any alleviative steps is extremely difficult.

You can give other examples of this trend. If you look, I think you see it in the papers today, you look at arguments between doing something for the economy and doing something for the environment. If you ask the average man, which should we do? If in one case it endangers your job, which is immediate, as opposed to… but in that case you may live several years longer because of improved environment, or do the opposite. Most people will vote for doing the economy at the expense of the environment. One of them has long-range effect, one has short range. If you ask people… and medical people have done this in terms of trying to get people to stop smoking to reduce the chance of cancer. There are still a lot of people smoking. And you see, the idea is that lung cancer takes some time to develop, maybe 10 years. They found that if they make the argument that their sex life is going to be adversely affected by smoking, it's much more effective.

It's the same kind of situation; evidence is all over the place. And as long as we do that, we've got a very difficult problem in addressing some of these world problems and some of our own planning problems at home. So one of the things we need is a long-range perspective, a future orientation; we need global scope; we need to take a holistic view rather than tossing out the bits and pieces. We have to be, in a sense—I wouldn't even say “interdisciplinary” is the right word—Jantsch used the word "transdisciplinary." We have to stop… we have to actually break down the barriers. For example, even in business today, there's already a beginning in the sense that you no longer… you begin to talk about transportation companies rather than vehicle manufacturers, and in the future we may be talking about combining the idea of transportation and communications. There are alternatives, in many ways alternatives, and they need to be looked at together. One's just a matter of transporting people and the other—or goods or material things—and the other's transporting ideas.

So we have to break down these barriers, and from an academic point of view… oh, let me go over here a minute. From an academic point of view, it means that you have to... that systems involves a great deal. It involves not just mathematics or economics; there are aspects of philosophy and aspects even of art. For example, I talk about holism. Artists are particularly good at transmitting, at communicating total images, because if the total is not the sum of its parts, then there are aspects of it that are not going to be possible to communicate in the ways in which we are used to doing. So, much of this gets in here and much of it is… you can't use even a philatelic approach. There's a few other things left out here that come into the picture.

But let me go back and at least suggest… when we talk about, for example, the need to address problems, the need to form teams to address some of these complex issues. One of the obvious things is that one has to start now; the delay, because the lag times in these systems can be very, very tough. I'm not saying it's suicidal for mankind or for a city, but it may make a transition that much more difficult because as we have seen, you go from one state of stability to another state of stability. It's a question of how much do you want to be in charge of the transition, the instability, in doing so? Or if you try to avoid it altogether? That's the question.

Let me backtrack and suggest for example, in this case of discounting, some of the ideas I want us to look at. Now, when we have the situation of a distant crisis or opportunity, our planning horizon is here. We're here, this is time, and this is physical space or distance. And most people are interested in the here and now, that's down in this corner. We have a crisis here; one way to bring about action, to in a sense get it within our planning horizon, is to bring the crisis in. Now we do that by creating a mini crisis. Now you might say, "Well, that's unethical." In some cases, it may be. But also let me remind you that it's considered perfectly ethical in some situations. Unions create a threat of a strike. That's creating an artificial crisis in the near term to… as opposed to seeing a continual deterioration in a much worse situation later on. That is one example. In a sense, you might even put the oil embargo in this situation, and it brought a distant... not intentionally, let's say, but it brought a distant problem near. So people gain awareness.

There are other ways to do this, and in looking at complex systems, not only… we used this analogy with a telescope; not only do we have the habit of looking through the wrong end of a telescope, but we don't even move the telescope around. We keep looking in one direction. By that, I mean situations that we think of as being future situations for our case may actually be already existing situations somewhere else. You have today situations of overpopulation, of tremendous urban deterioration, which we fortunately don't yet have here, so you have these kinds of situations, and you can… one thing we're very good at, if we have a distant spatial crisis or situation, we can bring it very close in by telecommunications. Technology is very good at this. You take a man landing on the moon, you show it in your living room. Very distant event, very close.

Now, an interesting possibility—this has only recently been really focused on—is to take a distant temporal problem and see if we have an analogy somewhere today. One of the points that's been raised is that you have the situation of... the United States today is rather similar to Sweden twenty years from now, because Sweden is almost a precursor situation; healthcare was done there first, women's liberation was 15 or 20 years ahead there, and so forth; you can give a whole number of situations. So there are things we can do in this area. So, another one of the things that we have to worry about is that we're dealing with unsolved problems, and unfortunately our brainwashing in the educational system tends to say that all problems are solvable. Otherwise you wouldn't be given the problems; the answers must be somewhere in the back of the book. I suggest it's high time we focused in the classroom talking about unsolved problems than about solved problems.

The question of communication: we're dealing here with a situation where communication is extremely essential and communications between different types of individuals in different types of areas. This is the essence of interdisciplinarity; if we cannot communicate, we have trouble. So the communication becomes a very key aspect. Finally, let me mention that we can learn to live with complexity, we can train ourselves to do some of the things you'll be hearing about, you heard about this morning, and you'll be hearing about further. The question is, to what degree, for example, our educational institutions take the lead. And I always have this vision of the cartoon where there are a bunch of people running into the distance, and there's one guy running behind them, waving his hands madly and shouting, "There go my people. I must follow them, for I'm their leader." And I think there's a lesson in there for our educational systems today. So the opportunity is there, and the question is whether we are willing to grasp the nettle. Thank you. [*applause*]

We have to leave this room, unfortunately, right now, because there's a 12 o'clock meeting in here, and there will be opportunity for discussion following lunch. I will try to be in room 329... and we will see you, let me just check… Professor Church will be talking at 1:15 in the ballroom.

[*program ends*]