

Chapter 1

The Response to Modern Society

The Conference was fortunate in having as its opening speaker, Professor P. L. Kapitza of the Soviet Union. He set the tone of informality for the whole conference by giving his paper in English, using a Russian text only as notes. His subject was "The General Principles of the Education of Present-day Youth and General Methods of Secondary-School Physics Teaching":

I accepted the invitation to speak to this conference with some reluctance because I am not a teacher and have never taught any secondary-school teachers. But I take great interest in how young people are taught and therefore I have come to speak on general questions of education.

Before talking of teaching and education, you must first of all take account of the social changes which have been happening during these last years. Science and technology have always had great influence on culture. But during the recent years, the most recent twenty to thirty years, this influence has been so great that the scientific achievement has influenced the social structure of the world on a large scale. This influence is now called the scientific-technological revolution. Now, more and more, social phenomena can be regarded as part of the technical-social revolt. This has also had a great influence on education, and two particular effects on physics.

You know very well that the effect of science on social conditions has been the tremendous increase in productive power of the human being. This was mainly due to the fact that manual power was replaced by motors and by big sources of electrical power. When you add automation, you will see that this productive power increased immensely in industry as well as in farming and agriculture. For instance, during the last century 80 to 90 percent of the population was engaged in farming, in producing food; only 10 percent lived in towns. Now only 10 percent of the population in America is engaged in producing food and the others can be engaged in industry and production, and the productive power per person is high. For instance, if you consider a modern automobile factory and divide the number of automo-

biles it produces by the number of all workers in the plant, you will find that the work of one person produces more than one automobile per month.

Our modern economists reckon that only a quarter of the present population of a country is needed in industrial production to supply all of the population with food, clothing, housing, and necessary services. A number of the rest of the population may be engaged in war industry, in helping less developed countries, and in activities like sport, cinema, television, and traveling.

Such a rise in productivity means that we can produce more than we need to live. This is all very interesting and has influenced education very much. In the last century in England, at that time the most industrially developed country, only a very small number of well-to-do people could go to a university and be educated to the age of 20 or 23. Faraday became an apprentice in a book-printing establishment when he was 14. So did most other people go to work early. Education was limited for the general population to 14 years, and the work day very often grew to be 12 or 14 hours long. Now it has become economically possible to educate all the population not only through secondary school up to the age of 17 or 18, but to give them a higher education. Also the number of students in the universities is growing very rapidly. In the United States, in the Soviet Union, and in all the developed countries, the number of students in the universities has doubled in the past 10 years. The numbers are changing all the time but are always growing, and if you extrapolate at this moment you will find that at the end of this century you can expect that all the people of these countries may have higher education. Such a possibility of universal higher education has a big influence on the secondary school, which would come to be regarded only as a preparatory stage for the higher school.

There is another effect of the scientific-technological revolution on education which is much more subtle. During the last century the leading economists reckoned that the increase of production would obviously be accompanied by the impoverishment of the proletariat. However, the scientific-technological revolution changed this prediction. The increase of productivity per person was so great that there was a tremendous increase

of wealth, of income per person in all countries. Unemployment and poverty in some countries is due only to the social structure, but I do not mean that with the present economy's means of production this could be avoided easily. But with this high productivity and high income for most people there arises another problem, the problem of leisure. A very important problem.

To illustrate, you can put this problem in the following way. If at present a person is engaged in his work about 6, 7, or 10 hours a day, and if he sleeps a normal amount of time and uses only about two hours for eating and moving from place to place, he has 7 or 8 hours left for living. What can a man do in this time? Has he ways to spend his leisure reasonably and properly? This is a very important question and a great social problem. Especially because this time of leisure will eventually grow longer and longer. A number of economists predict that the introduction of the computer and all the electronic devices will shorten the working time and increase the leisure even more, and the time of leisure will be longer than the time of work.

It is interesting that the first to tackle the problem of leisure was Aldous Huxley in his very interesting book, Brave New World. This is a utopia, and if you have read this book you will remember that he solves the problem in the following way: The general population must use their leisure for sporting entertainment, for all sorts of very elemental shows and for sex. And finally, if they are not easy enough to control a great emphasis is put on narcotics. The government of the "brave new world" was very careful to educate all the working population so that they had no spiritual demands, no spiritual concern for social conditions. For this purpose they were taught by use of the Pavlov reflex and the Freudian subconscious to despise science and culture.

These predictions of Huxley seem to be proving accurate in the most developed countries, like the U.S.A. The change is not in the decline of culture, not in the decline of civilization, but in the rise of crime and in the rise of the use of narcotics. This leisure is most badly used by the very young population. When they reach maturity, some of them—not all—are mostly interested in sports and some very elementary shows and entertainment. There is no barrier for sex and there is easy access to all sorts of gadgets like motorcars, cameras, cinema, and such

things which are used in such a very primitive way that interest in them is very quickly saturated.

These young people think that their parents are well-to-do and that they will never be put in a position of poverty. They have no need to think of their own futures, to think how to increase their own control of what they can achieve through work. The capitalistic society develops in them a selfish individualism. They have no interest in social problems. So they turn to the use of narcotics, which give only temporary relief, poison the nervous system, and actually lead gradually but deliberately to the growth of criminals. It is quite natural that the best part of the young people beginning to protest, try to be hippies; you can see the first symptom of such protest in the hippies and the beatniks, with whom you are familiar. But indeed this is not a serious movement, with social consequence. However it is clear that such phenomena as hippies and beatniks may appear only in an affluent society, because when everybody has to work hard such things cannot happen.

Much more serious and much more important is the student unrest which is appearing now in all countries. This has great political significance. For example, in the United States data show that 55 percent of the schoolboys who finished secondary school last year went to the university, and we now have in the U.S.A. about 5 million undergraduates. This is a considerable political force. It is interesting that the study of student unrest in the U.S.A. shows that the people who take the more active part in this movement come from well-to-do families. Thus this movement cannot be regarded as a protest about economics. It is purely an ideological one. A purely social one. People are simply not satisfied with the state of social conditions, the ideology with which they are surrounded. They have no sense of direction as to where to aim their activities and their energies, these young people. And neither the country nor the social system provides it.

At present there is no definite ideology in this movement. It is purely a general discontent among the students. The ideology comes later. If you study all the revolutions, you will find that the discontent comes first, and then the aims. The students do not yet have the aims, but these are to come. This all shows that our present social structure is not prepared for so much

wealth along with so much leisure. The social structure must change. This general leisure brings its own social changes. The question of leisure is being studied by a number of sociologists, social workers, and other investigators. A number of Americans feel there is no way out. There is no way to stop the growth of productivity, the industrial growth of all countries, and they see in this movement the end of present civilization. They all agree that the question of leisure is as important as the question of peace in atomic war, for the survival of humanity.

I think we have no definite reason to be so pessimistic. There are two ways out of the present position. The first is to develop further the idea of Huxley, giving only a part of the people a reasonable education and keeping the others in a semi-animal state. The animal desires will, in a crude and primitive way, stop them from having a reasonable thinking and cultural life. The other direction is the opposite, to educate all the people to such an extent that they can choose reasonable and useful interests for their leisure. This brings us to the matter of education. Only by means of education can we solve it provided every developed country will indeed choose this way to oppose the wrong social condition now produced by this continuing increase of leisure and wealth resulting from the scientific-technical revolution.

It is clear that we must change education in order to educate people properly in ways to use their leisure. Up to now, we have always approached education pragmatically. We teach a young person to be a good doctor, a good lawyer, a good engineer, a good designer. We teach them for the practical world. Now we must start to teach people to use their leisure. It is much more important to teach people to use their leisure than to do their work. This is as true in secondary education as in higher education. What sort of education must it be, to make a man cultured?

This is a new problem and I cannot deal with its details, but I think I can describe the general direction in which this education must go. I think you have all experienced the idea that the happiest people in America are those who do creative work: scientists, writers, painters, artists, film producers. You know that people working in art who want to do creative work do not divide their time between leisure and work. All is equally interesting and they do not know which is leisure and which is work.

Therefore to make a man happy during his leisure, you must teach him to do creative work. Now we must define the word "creative" in a much broader way than is usual. "Creative" means that in any work in which he is engaged a man should be able to find a solution for himself and within himself. If he acts according to a definite instruction from someone else, he is not creative. Present mass production is arranged in such a way that a man cannot do any creative work on an assembly line, but has to work by quite definite instruction, and any small change will produce a negative effect. So the work of mass production is dull and tedious for the worker. If you remember the masterful movie of Charlie Chaplin, Modern Times, you will know what is really meant by mass production.

At the same time, our experience of life shows that it is quite possible to spend our leisure in interesting ways if we do creative work. Only a few people do it now. We have the natural ability to be creative. I know a number of people who spend their leisure very reasonably as artists or painters, but who find creative work also in their environment, in social problems, in traveling. What education must teach the general bulk of people is how to do creative work by themselves and enjoy it.

I should explain that while you are doing creative work with proper education, you will enjoy it. Let us say, you spend your leisure in traveling. A number of people do it. It is very common to travel all around the world, and you come to some town, ancient or modern. You look at it. If you look at it knowing the history of this town, knowing the history of the people who live in this town, you can make judgments very different from what you would think if you did not know all this. It is much more interesting to you. But even further, you can compare the ancient town with the modern, the modern way of life with the old. This is even more interesting. If you are taught how to compare and if it is your natural interest, it is more interesting still.

Another new problem put before educators is how to give a man a large amount of knowledge and ability to develop independent thinking about it, to be able to comprehend the environment in a creative way. The creative ability of a man appears in very early days, in the school, but the period when the most fruitful interests become clear is probably after the age of eight. So the secondary school must provide a general development of the cre-

ative ability of a man, and the university must find the region in which it is to be best applied. The secondary school must help a young man develop creative ability in any subject, physics, mathematics, and all.

This question of developing creative ability in young people interested me long before this problem of leisure appeared. I was interested mainly as a scientist who wanted to have good students and develop science. All you need for your pupils and for your research are people who have been developing creative ability for a long time.

Now we must see what changes must take place in the secondary school if at present most young people are taught to memorize a definite number of facts. The student must be led toward independent thinking, toward creative activity. This kind of education requires you to approach each person individually, not generally. We need an independent teaching system that is much more complicated and much more difficult than the present system. You will soon know which student is interested in natural science and which in art. The school must separate the students and take better advantage of the differences; it must teach the pupil himself.

To focus on the pupils who are to be taught natural science, we see that the teaching of creative ability and independent thinking has three aspects. First you must teach the young people how to generalize phenomena, the method of induction. Second, you must teach how to predict the phenomena of nature from theoretical generalizations, the method of deduction. Finally, you must teach the student how to look at the contradictions in nature and to solve these contradictions, the method of dialectics. The best way to teach these aspects is by means of solving problems and working in laboratories. So we can see at once that the best subject for developing creative thinking in a young man is physics, and this is what makes the role of the teacher-physicist so important in their education.

It is very important to have laboratories and seminars and to solve problems which will encourage independent thinking. The exercises given to schoolboys are not always good for this. Mostly such problems give the pupil the data and he is to put the information into the proper formula to produce the correct answer. The work is to find the correct formula. This is not really independent thinking.

I used to give my students at the university a different kind of problem.¹ I will simplify a few examples for secondary-school levels. (1) The power of a motor necessary to move a pump will give a jet of water large enough to extinguish a fire in a six-story building. With this problem the pupil himself must judge the height of the building and the size of the jet, how far it must reach to the building, and where to put the pump. Each pupil may decide differently on these points, and it is easy to see which is better. (2) What is the size of a convex lens which will focus sunlight in a spot where you will make a furnace. The pupil must find out what heat is necessary and how good the focus must be in determining the size of the lens, and once again he will be thinking out the whole problem. There are other less obvious problems which interested me and on which I would like to advise you.

There has been much interest in the Soviet Union and in other countries in developing schools for the most gifted young people. We collected the most talented in physics, biology, and mathematics and tried to teach them together in order to produce much better scientists. I have found that this is an absolutely wrong idea, often difficult, and never good. If you take an able schoolboy from a school, you at once lower the level of teaching because he is the first assistant to the teacher in that he helps his schoolmates. More than this, when the boy teaches his friends, he teaches himself. The best way to learn something is to explain it to someone else. In a special school the able student loses this opportunity and thus he himself does not develop as quickly as in an ordinary school. Since boys in such a school also soon become conceited, things are even worse.

The second point to consider is the teacher. To teach creative physics in a secondary school, the quality of the teacher must be very high, and it is difficult to find enough good teachers. This problem is still possible to solve if its gravity is recognized. We have to see that in teaching school it is not enough to

1. Typical problems of this sort have been published by Kapitza; for example, see Nauka i zhizny 33, 1967. The problems are stated in the January issue, p. 122. The solutions are given in February, p. 156, March, p. 144, April, p. 140, May, p. 125, and June, p. 130.

educate the students, the undergraduates, but we must teach the teacher as well. The teacher need not be a professional teacher. He must be a scientist himself and then he will grow together with the students.

With these ideas, we organized a university and a high school in Moscow in which all these undergraduates got the general courses over the first two years, but then went to different institutes where they joined different laboratories and were taught with the research students themselves. Each research worker was given two or three students whom he taught, and for this he received a good salary. All this took more than one day a week, but it proved a great success. This institute produced a great number of academicians, and this program now exists in all our universities.

In the history of science it is curious that most of the great discoveries were made while the scientist was teaching people. Mendeleev found the periodic system while he was trying to arrange the elements in a way which undergraduates could understand easily. Lobashevsky in mathematics gave a course in elementary geometry to adults and was trying to explain to his own satisfaction the a priori evidence of the postulate of two parallel lines when he discovered non-Euclidean geometry. Stokes never proved his famous theory but gave it to his undergraduates in a collection of examples. When we refer to Stokes we refer to this collection he made for students. In a more modern illustration, I have a story told me by de Broglie himself. He was asked to explain his work to some research students at the Technical University in Zürich. When he tried to explain it in a reasonably simple way to undergraduates, he discovered his famous fundamental formulation.

You can see how it would be if the teachers in all the secondary schools were young research students. It is difficult to organize education in this way, because you have so many students. A pupil-research student contact may last more than one day at a time, but this cannot disturb the research work and the teacher will grow with his pupils. Creative ability in physics must be educated in the final stages not by professional teachers but by some device such as ours, which is not easy to arrange but which I think is very important.

I think what I have told you may be helpful in your work, but

remember that all these things can begin only when you recognize the importance of educating creative ability in the young people. I would like to underline the idea that to teach today's young people you must approach them according to their abilities to develop their own creativities, and this must be done in the secondary schools as well as in the primary schools. This is really not just a small problem. This is a big problem, on which depends the future of our civilization. Our future generally depends upon the education of young people, but in the present state of society, when they have access to wealth and leisure, the people must learn to use them properly. Without this, we will have a catastrophe like an atomic war. All of us, scientists, teachers, and people in general, must approach this task very seriously and regard it as one of the most important problems of our civilization.

Kapitza's paper stimulated a great deal of discussion throughout the whole Conference on how secondary-school teaching could be made responsive to the new needs of modern society. Statements on the subject were made on a number of occasions, sometimes as part of a panel discussion which was arranged specifically on the subject, and sometimes as part of general discussions after some of the invited papers. To illustrate the wide range of statements on this subject, we have abstracted a number of these as useful contributions toward finding solutions to this all important problem. B. R. Chapman (U.K.) said:

I think we have during the last one hundred years concentrated in our curriculum reform on the content of science and on the process of science. Sometimes the balance has been toward content, at other times toward the process of science. In times of great technological change it seems to me that we push the content. At times when we have problems with our supply of scientists, we say: "Ah, it's because we have given too much content, let's give them process and that will change the situation." And we oscillate between the two. There is also a third element which seems to me to be vital importance to contemporary society, and this is the interaction between science and society, the way science influences society, the way society influences science, and the whole interaction between the two. The complex

decisions that society has to make when technological changes are involved, the problems you have when you decide to build the Concorde, the problems you have in society when you decide whether or not to join in with the rest of Europe to accelerate a program of one sort or another, these are the sort of problems which have aspects that can be termed sociological and aspects that can be termed scientific.

But we are in danger of letting our children leave school with a simplistic idea of what science is. We ought to let them see that the decisions scientists make, decisions that economists make, which are affecting them both at present and when they grow up, are related to science and that they do not in fact have clear-cut answers.

M. Y. Bernard (France) felt that the decline of interest in physics in favor of such subjects as social science, sociology, psychology, and so on might well be due to the very mathematical nature of their physics, and that physicists were not trying hard enough to counteract this tendency. But, more generally, he pointed out that the young people were so accustomed to airplanes, television, the telephone, and so forth that they were not the least interested in them. On the other hand the modern mass media brought home to them that everything was not right with the world and that the real problems of the world were the struggle against pollution, against poverty, and the social relations between people and that these things appeared to be made worse by technology. He felt that if we did not make physics more interesting and more exciting we would find ourselves in the position of the professors of Latin and Greek who have no pupils because none of the children are interested in these subjects. Professor Bernard went on to propose that it was essential that all students be taught the basic elements of physics, not only those who were enthusiastic but those who were poor at it—even those who were bored, because in the modern world you could never tell who was to become the director of a company, a minister of state, a social worker, or even a revolutionary. He felt that it was essential for everybody to know that the laws of physics are rigid, that science obeys strict laws, and that one cannot find these truths by just reading philosophy.

A. Harashima (Japan), after pleading for creativity and flexibility, since the world was changing so fast that you could not

tell what particular areas of physics might be the most relevant at any particular time in the future, said that he felt that through the medium of television one could keep both teachers and students up to date with the rapidly changing priorities of society.

In amplifying this idea, I. Bukovszky (Hungary) went on to say:

Students must have their say, but that is not enough; I think that the general public must be given the opportunity to take an interest and have their views known about school work and about the process of education. In the first place, knowledge about school must go to the parents and through them to the general public. I would like to refer to the reform movements that are taking place in Australia. They are organizing summer courses for teachers and pupils, and these courses arouse larger and larger interest from year to year and get publicity in the press, radio, and television. The full program is televised twice a day, in the morning and the evening and is being carried on under the watchful eye of a public of three and a half million people. This is a real way to raise the interest of the pupils and through them the general public.

A number of people addressed their remarks to the question of why students were avoiding science and turning to other areas of specialization:

Mrs. M. B. Palma-Vittorelli (Italy): I think that perhaps the main reason why the young generation is now running away from scientific education is that they are of the opinion that science has contributed to increasing rather than solving the problems of society. Up to now scientific education has been mainly concerned with the problems of preparing more physicists, more engineers, more people for the technological needs of society. If the new generation now does not believe in the technological society, it rejects science. So what I think is the main aim of science education at the moment is to give the young generation the kind of preparation that tells them what the fundamental point of science is: how to state problems clearly, how to make observations and to make use of them, how to work from observations to their consequence, how to interpret facts, and so on. We can really reach this goal in teaching science, and it will be useful for the minis-

ter of state, and the revolutionary as well as for the social worker.

E. Nagy (Hungary): Why is it that so many young people are turning away from physics and finding interest in humanistic studies? I think it has a lot to do with time. If somebody wants to be an experimental physicist, he must master a lot of laboratory techniques to be properly knowledgeable in his subjects. By the time he is through he will have reached an advanced age. It is much easier to be a theoretical physicist. An experimental physicist may not be able to master all his techniques until the age of 40 to 45. Pure theoretical physicists will have important results much earlier, say at age 25. But for humanistic studies, the young people feel results can be had at a much lower age, say 18 to 20. I think that the full productive capacity of a scientist must be shifted toward a much earlier age. Unfortunately we try to cram much of the old material into high schools in order to save some time in the university education. I think this cannot be done. The whole problem must be looked at in quite a new way, and fundamentally we must arrive at a way so that a young scientist can reach his full capacity at a reasonably early age.

Several members of the Conference gave their ideas concerning the general problem of the interaction of science and society.

D. Sette (Italy): The subject is not so much what we can do to increase the number of people going toward science, or how to try to change the training which we now have. There are needs of another kind, needs to prepare a new generation. Recall what Professor Kapitza said. He advocated an education in which creativity of each individual is made important. One should, I believe, stress what science education may contribute to the basic formation of a person. We are speaking here about the secondary-school level, not about the university level. Here contributions may be made to the formation of character, intellectual honesty, and the possibility to make a certain set of assumptions and yet to be ready, if somebody else proves these assumptions wrong, to change them. These are what the study of science can show.

J. A. Rodriguez (Venezuela): Many years ago it was relatively easy to be a successful teacher. The teachers taught some

truths and it took such a long time to change that the pupils did not notice any change during their whole lives. The truth was good enough to assure a successful way of living and to do successful professional work. Today progress is growing so fast that what the teacher teaches is in danger of being overcome by progress in a year or two. When this happens, the pupil begins to doubt the teacher, and it is for this reason that there is a shortage of faith among the pupils today. If we want to contribute to solving the problem, we must try harder to change ourselves, be less dogmatic in our education, and keep the teachers up to date.

E. M. Rogers (U.K.): The young person asks "What use is physics to me? What value does science have for me?" and we find young people ignorant of those values. But I think we must blame ourselves. We need to be advertising men. Remember that a capable advertising man can make families wish to buy two refrigerators when they do not even need one. We do not advertise our physics. In reply to the question, "What use is this to me?" we say to students, "We will drill you in Newton's laws of motion" which will not help him drive a car or understand television. We need to review the content of our physics teaching very carefully and to look for those things which we can tell young people will be relevant. The samples that we offer in school lack advertising value. I think we need to put our own thoughts in order about what we teach, as well as on the broader scale of the relevance.

A. V. Baez (U.S.A.): I think it is necessary, before we can proceed to answer the question "How can secondary-school teaching be made responsive to the new needs of modern society," to specify what we think are the needs of modern society. Only then may we ask what secondary-school teaching can do in this situation. I call the serious problems of modern society the four P's: Population, Pollution, Poverty, and Peace. What is the relevance of education in general to these problems? I think it is because our young people sense intuitively, rightly or wrongly, that physics does not seem to have any relevance to these problems that we are in trouble, or perhaps it is that the relevance has not been pointed out to them. I think that for this reason young people are rebelling and dropping out of the study of science in general, and physics in particular.

I was a little disappointed that some people say, "What we have to do is to increase enrollments in physics and therefore we have to sell physics." I believe that this is not the direction young people are seeking. Actually the young people are using the experimental method and are exemplifying some of the best features of science, even without being scientists. They exemplify what I have called the human qualities of science, that is, the longing to know and to understand. They are questioning many things, including the validity of teaching physics, searching for data and the relationships to give them meaning, the demand for objective verification, respect for logic, consideration of premises and consequences—all these are human values of science.

What is the relevance of physics to these particular qualities which I have called the human values of science? I think that this deserves much more thought than we can give it here, and I suggest therefore that it be put on the agenda for some future conference. In such a conference we must try to define the problems of modern society and then to ask what is the role of physics and physics education vis-à-vis these problems.

The first of these problems lies in the tradition that the scientist should not concern himself with the details of society. But now the pendulum has swung, and there is considerable sympathy for a more active participation by the scientist in society. This needs to be elaborated, in particular by finding examples which arouse interest in the subject and alert students to the impact of science on society.

A second working group at such a future conference might devote itself to the invention of problems and questions for textbooks that lay emphasis on the needs of society.

Physics education journals could be encouraged to devote a section to the problems of the social responsibility of science. It might also be worthwhile to consider ways in which the image of physics might be improved in the world at large.

These are but some of the ways to infuse education with the idea of social responsibility.

F. Watson (U.S.A.): The prime purpose of this conference is to consider suggestions, additions, and modifications for the development of physics teachers. If the nature of the science to be taught in a classroom is to be modified significantly in future,

then we had better get going. We at Harvard Project Physics are already encountering great difficulty with teachers who have no background in the history of science, in the philosophy of science, and have a confused idea about the nature of the laws of technology and science. The teachers we now have in high schools are the product of the educational system which we have been running. If in our countries we find that the students are unaware or confused about the relationship between science and technology, the world of thought and philosophy, it is because we have not communicated properly with the teachers. So I would like to direct the attention of the audience to the need for focusing as closely as we can on broadening the pattern of instruction for the formation of someone who will become a science teacher. It is necessary not only to know a great deal about mathematics or physics. The teacher is going to be working with students concerned with the world, and the teacher has to see the relevance. That means that the designers of course materials as well as the teachers must have a knowledge and sympathy not only for the student but for his concern for the world.

N. Joel (UNESCO): I would like to discuss the concept of transfer of knowledge or attitude from one field to another. I believe that in the past there has been no such problem as relevance because the objective for teaching physics was to form physicists. So there was no transfer problem from one set of circumstances to another. But as the contemporary objectives of teaching science must now also contribute to the general education of people and to be a tool for life in general, this question can no longer be neglected. Even in those cases where teaching of physics is well done, there is no guarantee of transfer to other fields in life. Let's take the following situation: Suppose we want to teach somebody to be very, very patient. What do we do? We teach him how to fish. When we have taught him how to fish, have we created a patient person? Of course not. If you want to create a patient person, you have to make him work through different situations. He has to be patient in situations where he is probably not going to be patient, and he must understand what it is to be patient. In the same way, if we want to make physics teaching relevant to life in general, we have to introduce elements into the teaching of physics situations that pertain to real life, not just physics. We keep saying that physics

develops independent judgment, helps to see things objectively, and by studying it we learn to recognize the range of the validity of physical laws. But many people who are excellent physicists go out into life and generalize and extrapolate quite crazily. It seems to me to be evident that physics teaching would become more relevant only if it gets a bit more integrated with other subjects. If we are supposed to generate more rational people who would be more understanding of other people, who would be able to live peacefully, and who recognize the difference in people without disliking them, we cannot do so through teaching physics. So perhaps, unless the structure of education changes a lot, there is no answer. Maybe the whole system of adults being treated like children in our schools makes the whole thing irrelevant. By adults I mean people of the ages 18 or 19 or 22 who sit in schools like children. Maybe in future there will be a system by which people sometimes spend their time in one school, sometimes in another school, then they go to work, then back to school, then back to work, and so on. I think as long as we limit ourselves to present conditions, things will remain pretty irrelevant. Perhaps I am a pessimist!

F. Watson (U.S.A.): The things that have been underlying our concern for relating physics as a historically very ancient and admirable example of the sciences have been not only the technological applications but rather the intellectual overtones that have shaped our literature, strongly influenced our art, influenced our poetry, have been at times in the past in conflict with theological views, and are right now in conflict with philosophical views about the variety of ways by which the world may be described. There is a certain naiveté on the part of scientists when they seem to assume that the only way to describe the world is in terms of their particular set of premises. But there are other ways to describe the world — for example artistically — which are just as good a description of the world as any that a physicist creates. The trouble is that we don't honor it, yet we expect them to honor ours. This is the conflict of values which is occurring throughout the world. Students are now alerted to this possibility of alternate ways, yet we keep insisting that we have the only way.

If we are going to make any response at all to the growing awareness in the society, and try to indicate that we are not anti-

humanists, that we are people among people, we have to be willing to be a little more objective, a little more modest, and a little more realistic about the sciences we are representing. So I see a fundamental conflict in designing the pedagogy. It is relatively simple to want to maintain the presentation of the theoretical structure of physics, evolving but in a way sacrosanct. This is what we have done in the past, and we are continuing to do at the present time. But, except for a small fraction of the people who end up as physicists, we are relatively unsuccessful by this approach; this is the basis of much of the social crisis.

An extreme alternative would be to propose that we abandon what is called the logical, formal structure of physics—as has been tried in some schools—and start with the problems of the world. You start with problems of population or pollution, and try with great difficulty to work backward from that into the kinds of information which are at the moment seemingly relevant to the solution of the problem. Part of the difficulty there is that the problems will change faster than our insights will change. I think that it is probably not a highly productive model, but I suggest it to you simply to show the range of alternatives.

E. W. Hamburger (Brazil): I think we are lingering on a misconception. To me it is quite clear that the problems of the four P's are not scientific problems, not technological problems—they are social and political problems. Maybe in twenty or forty years the problems of the world will be scientific, but that is not the situation now. We do not need any more scientific progress at present; of course we need it in the long range so that it is good that there will be some, but the essential problems of humanity now are not in this area. I do not know a single country where the real problems are in the physical science; they are all of a social, political, and economic nature. Therefore I think we must accept the fact that physics is not as important as it once was.

Another thing which I think must be quite clear to us is that, throughout history, science and technology have always been for sale. Scientists and technologists have always been servants. They have been servants sometimes to the most horrible regimes, they have rarely refused to do things which we now think were very bad. If a certain regime has lacked scientists at some time it has always been able to import them at any time. There-

fore it seems to me that what the students are feeling is exactly the problem of power. When changes are necessary in society, basically the problem always tends toward the power structure of society.

I think that science has some relevance to society in the following way: at the beginning of history man was a slave to nature, a slave to superstition, but during the last two thousand years he has become ever more a master of nature and in principle is now the master of his destiny. I do not think there is any question that the scientific method is indispensable if man wants to determine his own destiny, but I think that is the only real relevance that science and science teaching have to the problems of today.

S. G. Bronevshuk (U.S.S.R.): As in many countries, so also in the Soviet Union education is determined by the social needs of society. We teachers have the duty to fulfill this need as well as we can. What are really the social needs today in the period of rapidly developing technology? A greater percentage of our youth comes in close contact with technology and with science physics, chemistry, and biology than ever before, and therefore it is extraordinarily important to adjust the level of science teaching to the social needs of society.

In the Soviet Union there are 50,000 secondary schools and about 50,000 eight-year schools. Together these are 100,000 schools involved with the first period of education. I would like to emphasize that with such a big number of institutions, any small problem can grow enormously. I think you will all agree with me that the solutions of all small problems are alleviated by a central government system. For instance, for new experiments we need much new equipment and many measuring devices. Our ministry of higher education has its own industry for producing such equipment. This industry is independent of all other institutions, so it makes it easy to cooperate with the main educational departments.

At the moment we have some special difficulties we would like to overcome, and therefore we have investigated very deeply the development of cultural enrichment in education in Japan and the U.S.A. Also, we recently obtained information about rural schools in France and in other countries. Although we find the information we get from these discussions with our colleagues to be useful, there are still unsolved problems.

We feel that it is impossible not to study physics; it is the basic science concerning nature. We must teach physics not only to prevent a loss in the essential content of general education, but also because physics is connected with the formation of a basic ideology. Physics affects philosophy, and therefore all members of society must learn the main problems of the physical world.

During this conference we really have not talked at all about the significance of physics to the students while they are in the process of learning it. But we must do this, if not now then in the future, in order to give the pupils a precise view of the world. We should proclaim the objectivity of the natural and physical laws, to convince the pupils of the greatness of man, so that by learning the laws of physics he is able to take possession of nature and does not have to wait for the generosity or goodness of nature to make progress. This really has to do with the philosophy of physics, which is a matter of great importance and perhaps should be the subject of the next conference.