Course: Foundations of Science Education (8627)
Semester: Spring, 2021
ASSIGNMENT No. 2

Q.1 Discuss the key features and importance of Gestalt theory of learning.

Imagine you're a teacher, and you are standing in front of a class of students. Some of them are doing what they are supposed to be doing, listening to you. Others, though, are talking or misbehaving or staring out the window.

You tell the class an important piece of information. This information is so big, so life changing, that it's important that the students learn it. If they don't, they likely won't succeed in life. How do you know if the students have learned that piece of information? Can you pry open their heads and see the words you just said imprinted on their brains?

Since that's impossible, you will have to make do with some outward signs of learning, like if their eyes light up or if they are being attentive.

Let's look closer at Gestalt, a famous behavioral psychologist, and what his research on learning can tell us.

Remember that you're teaching your students, and some are paying attention, and others aren't. When you want to find out if they've learned what you've just taught, you look for behavioral signs of understanding, like being attentive. You might even ask some questions, and their answers would help you figure out if they've learned what you've said.

Psychologist **Gestalt** was interested in learning and behavior. Like teachers who have to depend on behaviors to tell them what's going on inside a person, Gestalt believed that observing people's behavior was the best way to figure them out.

In Gestalt's branch of psychology, behavioral psychology, **learning** is about changing behaviors. If a student who is talking when he is supposed to be listening to you changes his behavior and begins to listen, he has learned to listen.

Likewise, if you are explaining to students how to add numbers and a student consistently answers with the wrong answer but then begins to answer with the right ones, his behavior shows you that he has learned how to add.

Gestalt believed that people learn two different ways: they learn to avoid negative things and strive for positive things. So according to Gestalt, if you give a child a piece of candy each time he gets an answer right, he will learn to figure out the right answer in order to get the candy because he is striving for positive things.

On the other hand, if you give a child detention every time he gets an answer wrong, he will also learn to figure out how to get the right answer, this time in order to avoid a negative thing (detention).

An important process in human behavior is attributed … to 'reward and punishment'. Thorndike described it in his Law of Effect. It is now commonly referred to as 'operant conditioning' … The essentials may be seen in a typical experimental arrangement. A hungry rat [can be seen] in an experimental space which contains a food dispenser. A horizontal bar at the end of a lever projects from one wall. Depression of the lever operates a switch. When the switch is connected with the food dispenser, any behavior on part of the rat which depresses the lever is, as we say, ‘reinforced with food’. The apparatus simply makes the appearance of food contingent upon the occurrence of an arbitrary bit of behavior … The relation between a response and its consequences may be simple, and the change in probability of the response is not surprising. What is technologically useful in operant conditioning is our increasing knowledge of the extraordinarily subtle and complex properties of behavior which may be traced to subtle and complex features of the contingencies of reinforcement which prevail in the environment …

The application of operant conditioning to education is simple and direct. Teaching is the arrangement of contingencies of reinforcement under which students learn. They learn without teaching in their natural environments, but teachers arrange special contingencies which expedite learning, hastening the appearance of behavior which would otherwise be acquired slowly or making sure of the appearance of behavior which might otherwise never occur …

In improving teaching it is less important to find new reinforcers than to design better contingencies using those already available. Immediate and consistent reinforcement is, of course, desirable but this is not to deny the importance of intermittent or remote reinforcers. The student who knows how to study knows how to amplify immediate consequences so that they prove reinforcing. He not only knows, he knows that he knows and is reinforced accordingly. The transition from external reinforcement to the self-generated reinforcement of knowing what one knows is often badly handled. In a small class the precurrent behavior of listening, reading, solving problems, and composing sentences is reinforced frequently and almost immediately, but in a large lecture course the consequences are infrequent and deferred. If mediating devices have not been set up, if the student is not automatically reinforced for knowing that he knows, he then stops working, and the aversive by-product of not-knowing pile up.

Frequent reinforcement raises another problem if it reduces the teacher’s reinforcing power. Money, food, grades, and honors must be husbanded carefully, but the automatic reinforcements of being right and moving forward are inexhaustible …

Strictly speaking, the student cannot reinforce or punish himself by withholding positive or negative reinforcers until he has behaved in a given way, but he can seek out or arrange conditions under which his behavior is reinforced or punished … He can create reinforcing events, as by checking an answer to a problem. He can stop emitting unreinforced responses in an unfavorable situation … for example, he can learn not to read books which are too hard for him so that his inclination to read other books will not suffer … Education has never taught the self-management of motivation very effectively. It has seldom tried. But techniques become available as soon as the problem is understood …

Through a proper understanding of contingencies of reinforcement, we should be able to make students eager and diligent and be reasonably sure that they will continue to enjoy the things we teach them for the rest of their lives.

Q.2 What is Idealism? Discuss key features of this philosophy.

Idealism is the metaphysical view that associates reality to ideas in the mind rather than to material objects. It lays emphasis on the mental or spiritual components of experience, and renounces the notion of material existence. Idealists regard the mind and spirit as the most essential, permanent aspects of one's being. The philosophical views of Berkeley, Christian Science, and Hinduism embrace idealist thought as they relate it to the existence of a supreme, divine reality that transcends basic human understanding and inherent sensory awareness. A well known exponent of this view was Plato, a philosopher in ancient Greece (428-347 B.C.). Plato believed that the physical world around us is not real; it is constantly changing and thus you can never say what it really is. There is a world of ideas which is a world of unchanging and absolute truth. This is reality for Plato. Does such a world exist independent of human minds? Plato thought it did, and whenever we grasp an idea, or see something with our mind's eye, we are using our mind to conceive of something in the ideal world. There are a number of proofs of this ideal world. The concepts of geometry, such as the concept of a circle, which is a line equidistant from a point, is something which does not exist in the physical world. All physical circles, such as wheels, drawings, etc. are not perfectly round. Yet our mind has the concept of a perfect circle. Since this concept could not come from the physical world, it must come from an ideal world. Another proof is that from moral perfection. We can conceive of a morally perfect person, even though the people we know around us are not morally perfect. So where does someone get this idea of moral perfection? Since it could not have been obtained from the world around us, it must have come from an ideal world. Platonism has been an extremely influential philosophy down through the centuries.

George Berkeley was an Anglican bishop from Ireland who challenged the irrationality of the notion that matter exists autonomously outside the mind as Locke and other contemporaneous empiricists speculated. Berkeley's immaterialist ontology maintained material substance cannot be real beyond the confines of the mind because inanimate objects do not have the ability to operate as causal agents. It is nonsensical and foolish to designate the causal qualities of humans, or spirits, to inert matter. Only life forces, such as spirits or souls, are able to function causally through perception and are the only substances that really exist. Knowledge springs from perceptions, and because material objects are not causal agents, they unquestionably do not arouse perceptual activity. Berkeley says that only an infinite being may produce and direct causally the perceptions that humans (spirits) have of physical matter.

"But whatever power I may have over my own thoughts, I find the ideas actually perceived by sense have not a like dependence on my will. When in broad daylight I open my eyes, 'tis not in my power to choose whether I see or no, or to determine what particular objects shall represent themselves to my view; and so likewise to the hearing and other senses, the ideas imprinted on them are not creatures of my will. There is therefore some other will or spirit that produces them," (Principles). Berkeley asserted that man's ideas are emitted from the Divine, and thus all humans are merely ideas in the mind of God. When he thinks of us, we are begotten and our existence activated. Yet, God still remains ineffable as he is beyond our comprehension. It is ultimately

God who causes us to sense the physicality of objects by means of his direct volition. First He will conceive the idea that we humans sense or perceive an object and then we actually do as He thought. Hence, the effect of God's mind on the mind of humans is required for sensation to occur. Berkeley explicates that all physical objects are perceived via sensation. Material objects are merely ideas obtained through perceptual activity and their attributes are sensible rather than being physical properties. Sensation is therefore impossible without the presence of ideas or else anything sensed would be unperceived or unthought. In conclusion, Berkeley asserts that all physical things in this world are ideas of the Divine and specifies this concept as esse est percipi, Latin for "to be is to be perceived." Christian Scientists generally believe that God is a disembodied spirit who is omnipotent, omniscient, and omnipresent. They set all being in His mind. He is and encompasses all aspects of existence as he is referred to as "God is All-in-all." Mrs. Mary Baker Eddy, founder of Christian Science, states that due to God's spiritual nature, humanity (the product of His creation) must also appropriately be spiritual and not material. The concept of additional spiritual deities is excluded because of His "All-in-all" totality. The true universe in its entirety, according to divine metaphysics, or Christian Science, is comprised of ideas that are completely spiritual and fashioned by divine thought, just as Berkeley espouses in his immaterialist views. Therefore, Christian Scientists specify that we as humans are in truth spirits produced by divinity, and in consequence are all incarnations of God. If we ignorantly deny the truth of God's spiritual existence, it is then that we will mistakenly envision the world in the form of material, as it will be an illusion. All ideas hostile to God's infiniteness, permanence, and goodness, such as conceptions of death, hell, and evil, are flawed and wicked hallucinations and are NOT real. God envelops all that is real, and therefore, everything he is (eternal, omni beneficent, etc.) is justifiably real. Everything else is just mortal error.

Q.3 Discuss the social constraints for the successful implementation of science for the development.

Science is important to the public because it helps address issues that are of concern to the general population. Scientific principles have been and continue to be applied to address issues, concerns, and problems that people face in the day-to-day aspects of living. Scientific research has value and importance to the layperson to the extent that it helps address problems of a practical nature. How science is taught and learned can determine its relevance to the majority of students, not only to those planning careers in scientific fields.

Elements of Science Literacy

Science education has relevance for the learner, since it enables him or her to understand, in an active way, how the natural world is organized and interrelated, and how it changes and interacts with the human-designed world. There are four elements that when combined holistically define science literacy. These four elements are: conceptual themes, or connectors, which are useful for putting isolated information into a context; process skills, which are necessary to observe, collect, measure, and analyze data; nurtured scientific reasoning skills, which encourage the validation and testing of the reasonableness of information; and the important and specific content of the discipline. These are the new "basic skills" demanded by our scientific-technological society.

These elements lead to the development of the attributes necessary for lifelong learning and the ability to apply what has been learned. Through developed problem-solving skills and nurtured science-reasoning abilities, learners can really understand the content under study. More importantly, they can use these same abilities to understand new and different content that they encounter later. These abilities are increasingly important in this rapidly evolving scientific-technological society, particularly with respect to the benefits and challenges of technology. Technology is neutral in itself. It is the application by humans that can make it beneficial or harmful. Decisions about the use of technology have wide-ranging effects. This factor makes a scientifically literate population crucial in our current society.

In the emerging high-performance workplace, virtually everyone acts as a decision-maker, gathers and sifts information, sets up and troubleshoots systems, organizes workflow and team arrangements, manipulates data to solve problems, and, on occasion, provides direction to colleagues. Modern work is entirely too complex for a small group of managers to possess all the answers and solutions.

Evaluating the use of technology by society, and its impact on society, requires the problem-solving skills and the nurtured science reasoning skills to verify assumptions and consider consequences. For example, in this complex technological society, our quest to supply the necessary energy to meet human demands often runs counter to our quest for a quality environment. Likewise, our search for better methods of providing longer, quality life sometimes collides with value systems. These are complex problems for a complex society, and the old basic skills that focused primarily, and in some cases exclusively, on the need to master content will not suffice. New basic skills founded on the active engagement of the learner with a focus on how to learn are essential in a technological society.

Learning and Access to Information

In this age of communication, an important trend being propelled by technology is the ability to link information resources worldwide. This has profound implications for educators and the future of education. For example, technology is fast demonstrating that schools are one of the many places where learning can and will take place by providing ready access to information beyond the classroom walls. Technology is increasingly blurring the distinction between learner and teacher through the capability of giving all users rapid and simultaneous access to information at decreasing cost. This fact has serious implications for the place called school and is one that educators might well note.

Schools are already beginning to evolve toward Learner-Centered Complexes that will take advantage of global resources both during and after regular school hours. What constitutes schoolwork and homework will become less clear as a result of emerging communications technology. Students assigned to do a report on the solar system have many options through technology. The textbook or reference book can be easily supplemented, through technology, by on-line contact with experts and other resources. In some cases, virtual reality makes it possible to experience trips to planets or to look inside a molecule. Although these experiences are not yet widely available, they will become so, and the ability of the educational system to evolve with this change will determine the system's success or failure.

Schools have traditionally been places where there has been an emphasis on the accumulation of content knowledge. While content knowledge is important, its importance is not as an end in itself but rather as the medium around which to actively engage the minds of students, thereby developing problem-solving skills and nurturing reasoning abilities. Technology is demanding a move in the direction of "learning how to learn," and technology can be an effective aid in achieving this important goal.

Computer technology is not television technology. Computer technology is changing and will continue to change the business of education . . . with or without professional educators. Hopefully, professional educators, and especially science educators, will be leading the way toward the new basic skills demanded by a rapidly evolving scientific-technological society.

To make it clear how deeply science is interwoven with our lives, just try imagining a day without scientific progress. Just for starters, without modern science, there would be:

No way to use electricity. From Ben Franklin's studies of static and lightning in the 1700s, to Alessandro Volta's first battery, to the key discovery of the relationship between electricity and magnetism, science has steadily built up our understanding of electricity, which today carries our voices over telephone lines, brings entertainment to our televisions, and keeps the lights on.

No plastic. The first completely synthetic plastic was made by a chemist in the early 1900s, and since then, chemistry has developed a wide variety of plastics suited for all sorts of jobs, from blocking bullets to making slicker dental floss.

No modern agriculture. Science has transformed the way we eat today. In the 1940s, biologists began developing high-yield varieties of corn, wheat, and rice, which, when paired with new fertilizers and pesticides developed by chemists, dramatically increased the amount of food that could be harvested from a single field, ushering in the Green Revolution. These science-based technologies triggered striking changes in agriculture, massively increasing the amount of food available to feed the world and simultaneously transforming the economic structure of agricultural practices.

No modern medicine. In the late 1700s, Edward Jenner first convincingly showed that vaccination worked. In the 1800s, scientists and doctors established the theory that many diseases are caused by germs. And in the 1920s, a biologist discovered the first antibiotic. From the eradication of smallpox, to the prevention of nutritional deficiencies, to successful treatments for once deadly infections, the impact of modern medicine on global health has been powerful. In fact, without science, many people alive today would have instead died of diseases that are now easily treated.

Scientific knowledge can improve the quality of life at many different levels — from the routine workings of our everyday lives to global issues. Science informs public policy and personal decisions on energy, conservation, agriculture, health, transportation, communication, defense, economics, leisure, and exploration. It's almost impossible to overstate how many aspects of modern life are impacted by scientific knowledge.

In Southeast Asia, learning in science, more than in any other subject, is considered to be a prerequisite for modernization and national development. Thus, over the past two decades, which have been characterized by movements towards industrialization and accelerated economic development, science education has been at the fore of' curriculum reform movements. During the early years the reforms in science education emphasized science for the development of scientific and technical manpower, since there were (and still are in many places) acute shortages of trained manpower in these fields. Rigorous scientific training was emphasized during those years, mirroring reforms in the West during the post-sputnik era, stressing knowledge in the traditional scientific disciplines and an academic approach to learning. During more recent years, science education in Southeast Asia, once again following cues coming out of the West, has become much more process or discovery oriented, but, in addition, has begun to lay much more importance on relevance to local needs and conditions as well as egalitarian issues, epitomized by UNESCO's "science for all" movements Under these influences, science educators in this part of the world have begun to present science as a promoter of logical thinking and a developer of problem solving skills, not only among the scientific elite involved with complex problems and high technology but also among the average wage earner and homemaker in their day to day struggles to make a living and provide for their families. The current review examines some of the trends related to the general situation described briefly above. It will focus chiefly on primary and secondary education, using material gleaned either from written documents or informal interviews. This paper does not present an historical account of reform movements in science education in Southeast Asia and it is not intended to be comprehensive. Instead it is intended to-cover, in a somewhat impressionistic manner, trends in six of the mostly frequently discussed areas of science education, namely:

1. Curriculum reform
2. School science equipment
3. Teacher training and retraining
4. Non formal science education
5. Research in science education
6. Regional collaboration.

In certain of these areas some countries will be featured and others not. This is not necessarily because those countries are particularly representative of the area. It is because their programs are especially interesting or innovative or well known. Inevitably certain of the most interesting innovations will be overlooked simply because I, as a layman in this field, simply did not have access to the appropriate information. 1. Curriculum Reform a. Integration. Critics of science education during the 60's and 70's found it to be dull, overly academic and fragmented. It was one of the most unpopular subjects among students, partly because of the way it was presented and because it generally had very' little to do with their everyday experiences. The integrated science movement, strongly supported by organizations like UNESCO, was developed to make science more problem and society oriented, and thus, presumably more interesting and less intimidating to children. Two kinds of integrator were advocated, that among sciences (ta counteract fragmentation) and that between science and social studies (ta promote social relevance). Examples of this abound in Southeast Asia. 2 In Malaysia, for example, a phased primary school curriculum reform introduced in 1982 will present to pupils in primary 4 a new course entitled "Man and his environment," an integration of various sciences and social studies. The main purpose of that course is to establish an appreciation of science in the modern world, a goal consistent with a recent regional UNESCO conference call for science education which above all would establish and maintain a positive attitude towards science and technology. Malaysia also offers an integrated lower secondary school science course, which is social problem oriented, emphasizing themes liter environmental pollution, energy conservation and consumerism. In Thailand, the Royal Thai government's Institute for the Promotion of Science and Technology (IPST) has developed an integrated science approach for elementary schools which combines health education with science and social studies.

b. Relevance.

Advocates of indigenous curriculum reform have insisted that science must be presented in such a way that it is relevant to a country's needs and resources. The position has also been advanced that for science to be attractive and meaningful to most children it must impinge on their daily life experiences and be geared to their level of cognitive development. Besides those who call for relevance to national problems and content, there are those within nations who call for adaptations to local environments and conditions, particularly in nation’s liter Indonesia and the Philippines, where there is wide regional variation. Examples of this movement are perhaps most plentiful in the Philippines, where the official national curriculum states that science education must be connected to the needs of the country and development goals. The prestigious Science Education Center at the University of the Philippines (UPSEC) has conducted numerous community surveys and made profiles of students and teachers in an effort to develop science learning modules with materials relevant to local problems, needs and resources to supplement national textbooks. Perhaps the best single example of this is a joint UPSEC/UNICEF project called "survival of the family," which started with a community needs assessment and ended with villagers experimenting with different types of traditional medicine and ways of salting fish.

Q.4 Discuss several implications of constructivism in Science Laboratory.

Constructivism has roots in philosophy, psychology, sociology, and education. But while it is important for educators to understand constructivism, it is equally important to understand the implications this view of learning has for teaching and teacher professional development.

Constructivism's central idea is that human learning is constructed, that learners build new knowledge upon the foundation of previous learning. This view of learning sharply contrasts with one in which learning is the passive transmission of information from one individual to another, a view in which reception, not construction, is key.

Two important notions orbit around the simple idea of constructed knowledge. The first is that learners construct new understandings using what they already know. There is no tabula rasa on which new knowledge is etched. Rather, learners come to learning situations with knowledge gained from previous experience, and that prior knowledge influences what new or modified knowledge they will construct from new learning experiences.

The second notion is that learning is active rather than passive. Learners confront their understanding in light of what they encounter in the new learning situation. If what learners encounter is inconsistent with their current understanding, their understanding can change to accommodate new experience. Learners remain active throughout this process: they apply current understandings, note relevant elements in new learning experiences, judge the consistency of prior and emerging knowledge, and based on that judgment, they can modify knowledge.

Constructivism has important implications for teaching. First, teaching cannot be viewed as the transmission of knowledge from enlightened to unenlightened; constructivist teachers do not take the role of the "sage on the stage." Rather, teachers act as "guides on the side" who provide students with opportunities to test the adequacy of their current understandings.

Second, if learning is based on prior knowledge, then teachers must note that knowledge and provide learning environments that exploit inconsistencies between learners' current understandings and the new experiences before them. This challenges teachers, for they cannot assume that all children understand something in the same way. Further, children may need different experiences to advance to different levels of understanding.

Third, if students must apply their current understandings in new situations in order to build new knowledge, then teachers must engage students in learning, bringing students' current understandings to the forefront. Teachers can ensure that learning experiences incorporate problems that are important to students, not those that are primarily important to teachers and the educational system. Teachers can also encourage group interaction, where the interplay among participants helps individual students become explicit about their own understanding by comparing it to that of their peers.

Fourth, if new knowledge is actively built, then time is needed to build it. Ample time facilitates student reflection about new experiences, how those experiences line up against current understandings, and how a different understanding might provide students with an improved (not "correct") view of the world.

If learning is a constructive process, and instruction must be designed to provide opportunities for such construction, then what professional development practices can bring teachers to teach in student-centered ways?

First recognize that construction in learning is not just the domain of children but of learners, all learners. Constructivist professional development give teachers time to make explicit their understandings of learning (e.g., is it a constructive process?), of teaching (e.g., is a teacher an orator or a facilitator, and what is the teacher's understanding of content?), and of professional development (e.g., is a teacher's own learning best approached through a constructivist orientation?). Furthermore, such professional development provides opportunities for teachers to test their understandings and build new ones. Training that affects student-centered teaching cannot come in one-day workshops. Systematic, long-term development that allows practice - and reflection on that practice - is required.

It is also useful to remember the educator's maxim, Teachers teach as they are taught, not as they are told to teach. Thus, trainers in constructivist professional development sessions model learning activities that teachers can apply in their own classrooms. It is not enough for trainers to describe new ways of teaching and expect teachers to translate from talk to action; it is more effective to engage teachers in activities that will lead to new actions in classrooms.

Constructivism represents one of the big ideas in education. Its implications for how teachers teach and learn to teach are enormous. If our efforts in reforming education for all students are to succeed, then we must focus on students. To date, a focus on student-centered learning may well be the most important contribution of constructivism.

Q.5 Determine the prospects of science education as an emerging field of Educational Research.

After the Second World War, a small technical elite arose in developing countries such as India, Pakistan, Brazil, and Iraq who had been educated as scientists in the industrialized world. They thought that by pushing for Manhattan project-type enterprises in nuclear energy, electronics, pharmaceuticals, or space research they could leapfrog the dismally low level of development of their countries. India, for example, started a nuclear energy program that mobilized thousands of technicians and cost hundreds of millions of dollars but failed to meet power demands.

What my scientist colleagues and national leaders alike failed to understand was that development does not necessarily coincide with the possession of nuclear weapons or the capability to launch satellites. Rather, it requires modern agriculture, industrial systems, and education. The technical elite naïvely believed that spin-offs from their nuclear energy or space programs would somehow convert their countries to 20th-century industrialized states. Instead, there were heavy economic and political costs. In India, for example, such programs led to the development of nuclear weapons—which only encouraged Pakistan to do the same—while many basic human needs such as health and education were not given the support needed.

In my view, this scenario means that we in developing countries should not expect to follow the research model that led to the scientific enterprise of the United States and elsewhere. Rather, we need to adapt and develop technologies appropriate to our local circumstances, help strengthen education, and expand our roles as advisers in both government and industry. In this way, we can prevent the brain-drain that results when scientists are not in touch with the problems of their home countries or when they face indifference—and poor financial support—from their governments.

In Brazil, the use of ethanol as fuel is one example of how this approach can work.**1** By encouraging the wide use of ethanol produced from sugarcane—a traditional crop in the country—as fuel to replace gasoline, the government of Brazil was able replace half of the gasoline used by automobiles in the country (about 200,000 barrels of ethanol per day) with a renewable energy source. In so doing, Brazil became a pioneer in an area that had been neglected by industrialized countries. The entire technology, from the agricultural to the industrial phase, was developed or improved upon by local scientists and technologists. I and other Brazilian scientists first had to convince the government that this approach was technically feasible, even though it had been ignored in industrialized countries. To do this, we had to address questions regarding motor technology, environmental concerns, and the trade-off between raising crops for food versus fuel.

In general, the misconceptions held by the technical elite are derived from an idea cherished by many in the developing world that pure research leads to technological development and then to products that open new markets or conquer existing ones (see figure, model A). This naïve "linear theory" or "cradle-to-grave" approach to science and development served as the blueprint for the establishment of the National Science Foundation in the United States and was widely copied throughout the world.**2** But that model fails to stress the interaction that should occur among the phases. As one moves from pure research to technological development and then to production and marketing, unanticipated problems arise that require reexamination and adaptation at the earlier stages.

More realistic are models B and C.**3** Model B corresponds, generally speaking, to present practices in the United States, where some overlap exists between the successive stages. Model C illustrates the Japanese practice of having the three phases completely superimposed. These are the more realistic models that developing countries should follow. In models B and C, practical needs—that is, demand—influence supply, namely, the type of pure research that is done. For example, after solid-state devices such as transistors made possible the expansion of switchboarding in telephone services, industrial laboratories such as Bell Laboratories lavishly financed solid-state physics.

In developing countries, government goals and the "demand side" pull are often lacking. As a result, universities and research centers have become isolated from the rest of the country in an ivory tower, more connected to research centers in Europe or the United States than to the obvious needs of industry, agriculture, and education in their own countries. Science and technology budgets receive little support from the private sector and instead depend on the national treasury.**4** Heavy government bureaucracies wind up cultivating whatever science and technology is fashionable in the developed countries, waiting indefinitely for the time when such competence would trigger development in a manner that resembles the wait for Godot in Beckett's play.

What, then, is a realistic view of the role of basic science in developing countries? After all, many outstanding scientists born and educated in developing countries have contributed significantly to the advancement of science. Talent exists everywhere. What can they do to help their countrymen in solving the problems of development? The answers, in my view, are the following:

1. Help adapt technology to local circumstances. Even when technologies are imported from abroad, research is necessary to make them work. Rather than insisting on developing indigenous technologies, when abundant and well-proven technologies exist, scientists can help choose the right ones, given the local environment and available raw materials, and learn how to use them. An example is given by the "green revolution." Despite its shortcomings, this "imported" technology, when applied properly in the developing world, helped eradicate hunger. Problems with the use of pesticides and fertilizers arose because of abuses by commercial interests and because, owing to a lack of knowledge, users and local scientists failed to provide the expertise or make the adaptations necessary to make the best use of the imported technology.

2. Incorporate new science into education. Development requires a well-trained work force; therefore, high-quality education must be put in place early in development. The teaching of modern science in engineering or medical schools cannot be restricted to the same old classical textbooks but has to be done by active scientists who read the current literature and are capable of conveying the latest advances to their students. This approach worked well in the 19th century during the Meiji restoration, which brought Japan into the modern world.

3. Be involved in government. Science and scientists are an important element in choices and decisions made by governments and can make a difference. For example, at one time the Brazilian government had to set the reservation boundaries for the Yanomamis, a primitive group of some 10,000 indigenous people living in the mineral-rich Amazonia. The issue was whether to set up one large, or several small, reservations. The military and the mining groups favored small reservations, as Indian reservations are "out of bounds" for them according

to Brazilian law and could restrict their movements in that region. But anthropologists advised that this solution would destroy the Yanomami civilization, because these Indians were accustomed to long-distance migrations. As the federal Secretary for Science and Technology, I argued for one large reservation, a solution that was adopted.

I also helped to mediate a conflict in Brazil between multinational enterprises that had computer technology and wanted free access to local markets, and local entrepreneurs who wished to preserve the markets for themselves. In the 1980s, the local entrepreneurs convinced the government to establish high import barriers, virtually isolating the region and condemning it to use obsolete technology. I helped resolve this issue by convincing foreign companies and local enterprises to set up joint ventures in which the technology came from abroad but the manufacturing was local.

Scientific research is motivated not only by curiosity or love for science, but also by fashions and the perception that some areas of research are more rewarding than others. The current emphasis given to costly therapeutics for the treatment of AIDS is counterproductive in developing countries, where a vaccine against the disease is the only real hope. It is important that developing countries avoid the allure of costly but ineffective programs and establish a system that rewards solving practical problems. Although that emphasis may seem to stray from the tradition of academic research, the truth is that many seemingly mundane problems require very sophisticated tools and technologies. And science can accelerate progress. This has occurred in agricultural research, which is highly advanced in developing countries such as Mexico (corn), Brazil (soybeans and sugarcane), and the Philippines (rice).

In conclusion, my experience has shown that the transition of a country from developing to developed is a complex process that requires facing up to the established interests in society. The impetus for this has to come not only from scientists but from other sectors of society as well. In a world where globalization and competitiveness are the rule, progress requires that developing countries find areas in which they are significantly better than their competitors because of a better trained work force, favorable natural resources, or scientific and technological capabilities. Science and scientists can play an important role in determining those choices and implementing development strategies.