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Development and Learning

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This selection and the following paper were written by two of the most influential developmental psychologists of the twentieth century, Jean Piaget and Lev Vygotsky. Although written at different times and for different forums, these papers are similar in their attention to the relationship between two key psychological processes: learning and development.

Both Piaget and Vygotsky considered learning and development to be important and distinct psychological processes. However, they differed in how they viewed the relationship between these processes as well as the role that each played in organizing and guiding development. While exploring their different approaches, consider the types of educational programs that might be designed from each of these views. Such programs will differ in many aspects, including the ways that teachers and students interact with each other.

In his opening remarks Piaget makes a distinction between development and learning—development being a spontaneous process tied to embryogenesis, learning being provoked by external situations. He proceeds to discuss the concept of an operation as an interiorized action linked to other operations in a structure. Four stages of development are enumerated—sensori-motor, pre-operational, concrete operations, and formal operations. Factors explaining the development of one structure of operations from another are discussed—maturation, experience, social transmission, and equilibration. Equilibration is defended as the most fundamental factor. Commenting on the inadequacy of the stimulus-response approach to understanding learning, Piaget presents evidence negating the effectiveness of external reinforcement in hastening the development of operational structures. These operational structures can be learned only if one bases the learning on simpler, more elementary

structures—only if there is a natural relationship and development of structures. The learning of these structures is held to follow the same basic laws as does their natural development, i.e., learning is subordinated to development. Piaget concludes that the fundamental relation involved in development and learning is assimilation, not association.

My dear colleagues, I am very concerned about what to say to you, because I don't know if I shall accomplish the end that has been assigned to me. But I've been told that the important thing is not what you say, but the discussion which follows, and the answers to questions you are asked. So this morning I shall simply give a general introduction of a few ideas which seem to me to be important for the subject of this conference.

First I would like to make clear the difference between two problems: the problem of *development* in general, and the problem of *learning*. I think these problems are very different, although some people do not make this distinction.

The development of knowledge is a spontaneous process, tied to the whole process of embryogenesis. Embryogenesis concerns the development of the body, but it concerns as well the development of the nervous system, and the development of mental functions. In the case of the development of knowledge in children, embryogenesis ends only in adulthood. It is a total developmental process which we must resituate in its general biological and psychological context. In other words, development is a process which concerns the totality of the structures of knowledge.

Learning presents the opposite case. In general, learning is provoked by situations—provoked by a psychological experimenter; or by a teacher, with respect to some didactic point; or by an external situation. It is provoked, in general, as opposed to spontaneous. In addition, it is a limited process—limited to a single problem, or to a single structure.

So I think that development explains learning, and this opinion is contrary to the widely held opinion that development is a sum of discrete learning experiences. For some psychologists development is reduced to a series of specific learned items, and development is thus the sum, the cumulation of this series of specific items. I think this is an atomistic view which deforms the real state of things. In reality, development is the essential process and each element of learning occurs as a function of total development, rather than being an element which explains development. I shall begin, then, with a first part dealing with

development, and I shall talk about learning in the second part.

To understand the development of knowledge, we must start with an idea which seems central to me—the idea of an *operation*. Knowledge is not a copy of reality. To know an object, to know an event, is not simply to look at it and make a mental copy, or image, of it. To know an object is to act on it. To know is to modify, to transform the object, and to understand the process of this transformation, and as a consequence to understand the way the object is constructed. An operation is thus the essence of knowledge; it is an interiorised action which modifies the object of knowledge. For instance, an operation would consist of joining objects in a class, to construct a classification. Or an operation would consist of ordering, or putting things in a series. Or an operation would consist of counting, or of measuring. In other words, it is a set of actions modifying the object, and enabling the knower to get at the structures of the transformation.

An operation is an interiorised action. But in addition, it is a reversible action; that is, it can take place in both directions, for instance, adding or subtracting, joining or separating. So it is a particular type of action which makes up logical structures.

Above all, an operation is never isolated. It is always linked to other operations, and as a result it is always a part of a total structure. For instance, a logical class does not exist in isolation; what exists is the total structure of classification. An asymmetrical relation does not exist in isolation. Seriation is the natural, basic operational structure. A number does not exist in isolation. What exists is the series of numbers, which constitute a structure, an exceedingly rich structure whose various properties have been revealed by mathematicians.

These operational structures are what seem to me to constitute the basis of knowledge, the natural psychological reality, in terms of which we must understand the development of knowledge. And the central problem of development is to understand the formation, elaboration, organization, and functioning of these structures.

I should like to review the stages of development of these structures, not in any detail, but simply as a reminder. I shall distinguish four main stages. The first is a sensory-motor, pre-verbal stage, lasting approximately the first 18 months of life. During this stage is developed the practical knowledge which constitutes the substructure of later representational knowledge. An example is the construction of the schema of the permanent object. For an infant,

during the first months, an object has no permanence. When it disappears from the perceptual field it no longer exists. No attempt is made to find it again. Later, the infant will try to find it, and he will find it by localizing it spatially. Consequently, along with the construction of the permanent object there comes the construction of practical, or sensory-motor, space. There is similarly the construction of temporal succession, and of elementary sensory-motor causality. In other words, there is a series of structures which are indispensable for the structures of later representational thought.

In a second stage, we have pre-operational representation—the beginnings of language, of the symbolic function, and therefore of thought, or representation. But at the level of representational thought, there must now be a reconstruction of all that was developed on the sensory-motor level. That is, the sensory-motor actions are not immediately translated into operations. In fact, during all this second period of pre-operational representations, there are as yet no operations as I defined this term a moment ago. Specifically, there is as yet no conservation which is the psychological criterion of the presence of reversible operations. For example, if we pour liquid from one glass to another of a different shape, the pre-operational child will think there is more in one than in the other. In the absence of operational reversibility, there is no conservation of quantity.

In a third stage the first operations appear, but I call these concrete operations because they operate on objects, and not yet on verbally expressed hypotheses. For example, there are the operations of classification, ordering, the construction of the idea of number, spatial and temporal operations, and all the fundamental operations of elementary logic of classes and relations, of elementary mathematics, of elementary geometry and even of elementary physics.

Finally, in the fourth stage, these operations are surpassed as the child reaches the level of what I call formal or hypothetic-deductive operations; that is, he can now reason on hypotheses, and not only on objects. He constructs new operations, operations of propositional logic, and not simply the operations of classes, relations, and numbers. He attains new structures which are on the one hand combinatorial, corresponding to what mathematicians call lattices; on the other hand, more complicated group structures. At the level of concrete operations, the operations apply within an immediate neighborhood: for instance, classification by successive inclusions. At the level of the combinatorial, however, the groups are much more mobile. These, then, are the four stages which we identify, whose formation we shall now attempt to explain.

What factors can be called upon to explain the development from one set of structures to another? It seems to me that there are four main factors: first of all, *maturation,* in the sense of Gesell, since this development is a continuation of the embryogenesis; second, the role of *experience* of the effects of the physical environment on the structures of intelligence; third, *social transmission* in the broad sense (linguistic transmission, education, etc.); and fourth, a factor which is too often neglected but one which seems to me fundamental and even the principal factor. I shall call this the factor of *equilibration* or if you prefer it, of self-regulation.

Let us start with the first factor, maturation. One might think that these stages are simply a reflection of an interior maturation of the nervous system, following the hypotheses of Gesell, for example. Well, maturation certainly does play an indispensable role and must not be ignored. It certainly takes part in every transformation that takes place during a child's development. However, this first factor is insufficient in itself. First of all, we know practically nothing about the maturation of the nervous system beyond the first months of the child's existence. We know a little bit about it during the first two years but we know very little following this time. But above all, maturation doesn't explain everything, because the average ages at which these stages appear (the average chronological ages) vary a great deal from one society to another. The ordering of these stages is constant and has been found in all the societies studied. It has been found in various countries where psychologists in universities have redone the experiments but it has also been found in African peoples for example, in the children of the Bushmen, and in Iran, both in the villages and in the cities. However, although the order of succession is constant, the chronological ages of these stages vary a great deal. For instance, the ages which we have found in Geneva are not necessarily the ages which you would find in the United States. In Iran, furthermore, in the city of Teheran, they found approximately the same ages as we found in Geneva, but there is a systematic delay of two years in the children in the country. Canadian psychologists who redid our experiments, Monique Laurendeau and Father Adrien Pinard, found once again about the same ages in Montreal. But when they redid the experiments in Martinique, they found a delay of four years in all the experiments and this in spite

of the fact that the children in Martinique go to a school set up according to the French system and the French curriculum and attain at the end of this elementary school a certificate of higher primary education. There is then a delay of four years, that is, there are the same stages, but systematically delayed. So you see that these age variations show that maturation does not explain everything.

I shall go on now to the role played by experience. Experience of objects, of physical reality, is obviously a basic factor in the development of cognitive structures. But once again this factor does not explain everything. I can give two reasons for this. The first reason is that some of the concepts which appear at the beginning of the stage of concrete operations are such that I cannot see how they could be drawn from experience. As an example, let us take the conservation of the substance in the case of changing the shape of a ball of plasticene. We give this ball of plasticene to a child who changes its shape into a sausage form and we ask him if there is the same amount of matter, that is, the same amount of substance as there was before. We also ask him if it now has the same weight and thirdly if it now has the same volume. The volume is measured by the displacement of water when we put the ball or the sausage into a glass of water. The findings, which have been the same every time this experiment has been done, show us that first of all there is conservation of the amount of substance. At about eight years old a child will say, "There is the same amount of plasticene." Only later does the child assert that the weight is conserved and still later that the volume is conserved. So I would ask you where the idea of the conservation of substance can come from. What is a constant and invariant substance when it doesn't yet have a constant weight or a constant volume? Through perception you can get at the weight of the ball or the volume of the ball but perception cannot give you an idea of the amount of substance. No experiment, no experience, can show the child that there is the same amount of substance. He can weigh the ball and that would lead to the conservation of weight. He can immerse it in water and that would lead to the conservation of volume. But the notion of substance is attained before either weight or volume. This conservation of substance is simply a logical necessity. The child now understands that when there is a transformation something must be conserved because by reversing the transformation you can come back to the point of departure and once again have the ball. He knows that something is conserved but he doesn't know what. It is not yet the weight, it is not yet the volume; it is simply a logical

form—a logical necessity. There, it seems to me, is an example of a progress in knowledge, a logical necessity for something to be conserved even though no experience can have led to this notion.

My second objection to the sufficiency of experience as an explanatory factor is that this notion of experience is a very equivocal one. There are, in fact, two kinds of experience which are psychologically very different and this difference is very important from the pedagogical point of view. It is because of the pedagogical importance that I emphasize this distinction. First of all, there is what I shall call physical experience, and secondly, what I shall call logical-mathematical experience.

Physical experience consists of acting upon objects and drawing some knowledge about the objects by abstraction from the objects. For example, to discover that this pipe is heavier than this watch, the child will weigh them both and find the difference in the objects themselves. This is experience in the usual sense of the term—in the sense used by empiricists. But there is a second type of experience which I shall call logical-mathematical experience where the knowledge is not drawn from the objects, but it is drawn by the actions effected upon the objects. This is not the same thing. When one acts upon objects, the objects are indeed there, but there is also the set of actions which modify the objects.

I shall give you an example of this type of experience. It is a nice example because we have verified it many times in small children under seven years of age, but it is also an example which one of my mathematician friends has related to me about his own childhood, and he dates his mathematical career from this experience. When he was four or five years old—I don't know exactly how old, but a small child—he was seated on the ground in his garden and he was counting pebbles. Now to count these pebbles he put them in a row and he counted them one, two, three, up to ten. Then he finished counting them and started to count them in the other direction. He began by the end and once again he found ten. He found this marvelous that there were ten in one direction and ten in the other direction. So he put them in a circle and counted them that way and found ten once again. Then he counted them in the other direction and found ten once more. So he put them in some other direction and found ten once more. So he put them in some other arrangement and kept counting them and kept finding ten. There was the discovery that he made.

Now what indeed did he discover? He did not discover a property of pebbles; he discovered a property of the action of ordering. The pebbles had no

order. It was his action which introduced a linear order or a cyclical order, or any kind of an order. He discovered that the sum was independent of the order. The order was the action which he introduced among the pebbles. For the sum the same principle applied. The pebbles had no sum; they were simply in a pile. To make a sum, action was necessary—the operation of putting together and counting. He found that the sum was independent of the order, in other words, that the action of putting together is independent of the action of ordering. He discovered a property of actions and not a property of pebbles. You may say that it is in the nature of pebbles to let this be done to them and this is true. But it could have been drops of water, and drops of water would not have let this be done to them because two drops of water and two drops of water do not make four drops of water as you know very well. Drops of water then would not let this be done to them, we agree to that.

So it is not the physical property of pebbles which the experience uncovered. It is the properties of the actions carried out on the pebbles and this is quite another form of experience. It is the point of departure of mathematical deduction. The subsequent deduction will consist of interiorising these actions and then of combining them without needing any pebbles. The mathematician no longer needs his pebbles. He can combine his operations simply with symbols and the point of departure of this mathematical deduction is logical-mathematical experience and this is not at all experience in the sense of the empiricists. It is the beginning of the coordination of actions, but this coordination of actions before the stage of operations needs to be supported by concrete material. Later, this coordination of actions leads to the logical-mathematical structures. I believe that logic is not a derivative of language. The source of logic is much more profound. It is the total coordination of actions, actions of joining things together, or ordering things, etc. This is what logical-mathematical experience is. It is an experience of the actions of the subject, and not an experience of objects themselves. It is an experience which is necessary before there can be operations. Once the operations have been attained this experience is no longer needed and the coordinations of actions can take place by themselves in the form of deduction and construction for abstract structures.

The third factor is social transmission—linguistic transmission or educational transmission. This factor, once again, is fundamental. I do not deny the role of any one of these factors; they all play a part. But this factor is insufficient because the child can receive valuable information via language or via education directed by an adult only if he is in a state where he can understand this information. That is, to receive the information he must have a structure which enables him to assimilate this information. This is why you cannot teach higher mathematics to a five-year-old. He does not yet have structures which enable him to understand.

I shall take a much simpler example, an example of linguistic transmission. As my very first work in the realm of child psychology, I spent a long time studying the relation between a part and a whole in concrete experience and in language. For example, I used Burt's test employing the sentence, "Some of my flowers are buttercups." The child knows that all buttercups are yellow, so there are three possible conclusions: the whole bouquet is yellow, or part of the bouquet is yellow, or none of the flowers in the bouquet is yellow. I found that up until nine years of age (and this was in Paris, so the children certainly did understand the French language) they replied, "The whole bouquet is yellow or some of my flowers are yellow." Both of those mean the same thing. They did not understand the expression, "some *of* my flowers." They did not understand this *of* as a partitive genitive, as the inclusion of some flowers in my flowers. They understood some of my flowers to be my several flowers as if the several flowers and the flowers were confused as one and the same class. So there you have children who until nine years of age heard every day a linguistic structure which implied the inclusion of a sub-class in a class and yet did not understand this structure. It is only when they themselves are in firm possession of this logical structure, when they have constructed it for themselves according to the developmental laws which we shall discuss, that they succeed in understanding correctly the linguistic expression.

I come now to the fourth factor which is added to the three preceding ones but which seems to me to be the fundamental one. This is what I call the factor of equilibration. Since there are already three factors, they must somehow be equilibrated among themselves. That is one reason for bringing in the factor of equilibration. There is a second reason, however, which seems to me to be fundamental. It is that in the act of knowing, the subject is active, and consequently, faced with an external disturbance, he will react in order to compensate and consequently he will tend towards equilibrium. Equilibrium, defined by active compensation, leads to reversibility. Operational reversibility is a model of an equilibrated system where a transformation in one direction is compensated by a transformation in the other

direction. Equilibration, as I understand it, is thus an active process. It's a process of self-regulation. I think that this self-regulation is a fundamental factor in development. I use this term in the sense in which it is used in cybernetics, that is, in the sense of processes with feedback and with feedforward, of processes which regulate themselves by a progressive compensation of systems. This process of equilibration takes the form of a succession of levels of equilibrium, of levels which have a certain probability which I shall call a sequential probability, that is, the probabilities are not established a priori. There is a sequence of levels. It is not possible to reach the second level unless equilibrium has been reached at the first level, and the equilibrium of the third level only becomes possible when the equilibrium of the second level has been reached, and so forth. That is, each level is determined as the most probable given that the preceding level has been reached. It is not the most probable at the beginning, but it is the most probable once the preceding level has been reached.

As an example, let us take the development of the idea of conservation in the transformation of the ball of plasticene into the sausage shape. Here you can discern four levels. The most probable at the beginning is for the child to think of only one dimension. Suppose that there is a probability of 0.8, for instance, that the child will focus on the length, and that the width has a probability of 0.2. This would mean that of ten children, eight will focus on the length alone without paying any attention to the width, and two will focus on the width without paying any attention to the length. They will focus only on one dimension or the other. Since the two dimensions are independent at this stage, focusing on both at once would have a probability of only 0.16. That is less than either one of the two. In other words, the most probable in the beginning is to focus only on one dimension and in fact the child will say, "It's longer, so there's more in the sausage." Once he has reached this first level, if you continue to elongate the sausage, there comes a moment when he will say, "No, now it's too thin, so there's less." Now he is thinking about the width, but he forgets the length, so you have come to a second level which becomes the most probable after the first level, but which is not the most probable at the point of departure. Once he has focused on the width, he will come back sooner or later to focus on the length. Here you will have a third level where he will oscillate between width and length and where he will discover that the two are related. When you elongate you make it more thin, and when you make it shorter, you make it thicker. He discovers that the two are

solidly related and in discovering this relationship, he will start to think in terms of the transformation and not only in terms of the final configuration. Now he will say that when it gets longer it gets thinner, so it's the same thing. There is more of it in length but less of it in width. When you make it shorter it gets thicker; there's less in length and more in width, so there is compensation—compensation which defines equilibrium in the sense in which I defined it a moment ago. Consequently, you have operations and conservation. In other words, in the course of these developments you will always find a process of self-regulation which I call equilibration and which seems to me the fundamental factor in the acquisition of logical-mathematical knowledge.

I shall go on now to the second part of my lecture, that is, to deal with the topic of learning. Classically, learning is based on the stimulus-response schema. I think the stimulus-response schema, while I won't say it is false, is in any case entirely incapable of explaining cognitive learning. Why? Because when you think of a stimulus-response schema, you think usually that first of all there is a stimulus and then a response is set off by this stimulus. For my part, I am convinced that the response was there first, if I can express myself in this way. A stimulus is a stimulus only to the extent that it is significant and it becomes significant only to the extent that there is a structure which permits its assimilation, a structure which can integrate this stimulus but which at the same time sets off the response. In other words, I would propose that the stimulus-response schema be written in the circular form—in the form of a schema or of a structure which is not simply one way. I would propose that above all, between the stimulus and the response there is the organism, the organism and its structures. The stimulus is really a stimulus only when it is assimilated into a structure and it is this structure which sets off the response. Consequently, it is not an exaggeration to say that the response is there first, or if you wish at the beginning there is the structure. Of course we would want to understand how this structure comes to be. I tried to do this earlier by presenting a model of equilibration or self-regulation. Once there is a structure, the stimulus will set off a response, but only by the intermediary of this structure.

I should like to present some facts. We have facts in great number. I shall choose only one or two and I shall choose some facts which our colleague, Smedslund, has gathered. (Smedslund is currently at the Harvard Center for Cognitive Studies.) Smedslund arrived in Geneva a few years ago convinced (he had published this in one of his papers) that the develop-

ment of the ideas of conservation could be indefinitely accelerated through learning of a stimulus-response type. I invited Smedslund to come to spend a year in Geneva to show us this, to show us that he could accelerate the development of operational conservation. I shall relate only one of his experiments.

During the year that he spent in Geneva he chose to work on the conservation of weight. The conservation of weight is, in fact, easy to study since there is a possible external reinforcement, that is, simply weighing the ball and the sausage on a balance. Then you can study the child's reactions to these external results. Smedslund studied the conservation of weight on the one hand, and on the other hand, he studied the transitivity of weights, that is, the transitivity of equalities if A = B and B = C, then A = C, or the transitivity of the equalities if A is less than B, and B is less than C, then A is less than C.

As far as conservation is concerned, Smedslund succeeded very easily with five- and six-year-old children in getting them to generalize that weight is conserved when the ball is transformed into a different shape. The child sees the ball transformed into a sausage or into little pieces or into a pancake or into any other form, he weighs it, and he sees that it is always the same thing. He will affirm it will be the same thing, no matter what you do to it; it will come out to be the same weight. Thus Smedslund very easily achieved the conservation of weight by this sort of external reinforcement.

In contrast to this, however, the same method did not succeed in teaching transitivity. The children resisted the notion of transitivity. A child would predict correctly in certain cases but he would make his prediction as a possibility or a probability and not as a certainty. There was never this generalized certainty in the case of transitivity.

So there is the first example, which seems to me very instructive, because in this problem in the conservation of weight there are two aspects. There is the physical aspect and there is the logical-mathematical aspect. Note that Smedslund started his study by establishing that there was a correlation between conservation and transitivity. He began by making a statistical study on the relationships between the spontaneous responses to the questions about conservation and the spontaneous responses to the questions about transitivity, and he found a very significant correlation. But in the learning experiment, he obtained a learning of conservation and not of transitivity. Consequently, he was successful in obtaining learning of what I called earlier physical experience (this is not surprising; it is simply a question of noting facts about objects)

but he was not successful in obtaining a learning in the construction of the logical structure. This doesn't surprise me either, since the logical structure is not the result of physical experience. It cannot be obtained by external reinforcement. The logical structure is reached only through internal equilibration, by self-regulation, and the external reinforcement of seeing the balance did not suffice to establish this logical structure of transitivity.

I could give many other comparable examples, but it seems to me useless to insist upon these negative examples. Now I should like to show that learning is possible in the case of these logical-mathematical structures, but on one condition—that is, that the structure which you want to teach to the subjects can be supported by simpler, more elementary, logical-mathematical structures. I shall give you an example. It is the example of the conservation of number in the case of one-to-one correspondence. If you give a child seven blue tokens and ask him to put down as many red tokens, there is a pre-operational stage where he will put one red one opposite each blue one. But when you spread out the red ones, making them into a longer row, he will say to you, "Now, there are more red ones than there are blue ones."

Now how can we accelerate, if you want to accelerate, the acquisition of this conservation of number? Well, you can imagine an analogous structure but in a simpler, more elementary, situation. For example, with Mlle. Inhelder, we have been studying recently the notion of one-to-one correspondence by giving the child two glasses of the same shape and a big pile of beads. The child puts a bead into one glass with one hand and at the same time a bead into the other glass with the other hand. Time after time he repeats this action, a bead into one glass with one hand and at the same time a bead into the other glass with the other hand and he sees that there is always the same amount on each side. Then you hide one of the glasses. You cover it up. He no longer sees this glass but he continues to put one bead into it while putting at the same time one bead into the other glass which he can see. Then you ask him whether the equality has been conserved, whether there is still the same amount in one glass as in the other. Now you will find that very small children, about four years old, don't want to make a prediction. They will say, "So far, it has been the same amount, but now I don't know. I can't see anymore, so I don't know." They do not want to generalize. But the generalization is made from the age of about five and one-half years.

This is in contrast to the case of the red and blue tokens with one row spread out, where it isn't until seven or eight years of age that children will say

there are the same number in the two rows. As one example of this generalization, I recall a little boy of five years and nine months who had been adding the beads to the glasses for a little while. Then we asked him whether, if he continued to do this all day and all night and all the next day, there would always be the same amount in the two glasses. The little boy gave this admirable reply, "Once you know, you know for always." In other words, this was recursive reasoning. So here the child does acquire the structure in this specific case. The number is a synthesis of class inclusion and ordering. This synthesis is being favored by the child's own actions. You have set up a situation where there is an iteration of one same action which continues and which is therefore ordered while at the same time being inclusive. You have, so to speak, a localized synthesis of inclusion and ordering which facilitates the construction of the idea of number in this specific case, and there you can find, in effect, an influence of this experience on the other experience. However, this influence is not immediate. We study the generalization from this recursive situation to the other situation where the tokens are laid on the table in rows, and it is not an immediate generalization but it is made possible through intermediaries. In other words, you can find some learning of this structure if you base the learning on simpler structures.

In this same area of the development of numerical structures, the psychologist Joachim Wohlwill, who spent a year at our Institute at Geneva, has also shown that this acquisition can be accelerated through introducing additive operations, which is what we introduced also in the experiment which I just described. Wohlwill introduced them in a different way but he too was able to obtain a certain learning effect. In other words, learning is possible if you base the more complex structure on simpler structures, that is, when there is a natural relationship and development of structures and not simply an external reinforcement.

Now I would like to take a few minutes to conclude what I was saying. My first conclusion is that learning of structures seems to obey the same laws as the natural development of these structures. In other words, learning is subordinated to development and not vice-versa as I said in the introduction. No doubt you will object that some investigators have succeeded in teaching operational structures. But, when I am faced with these facts, I always have three questions which I want to have answered before I am convinced.

The first question is, "Is this learning lasting? What remains two weeks or a month later?" If a structure develops spontaneously, once it has reached a state of equilibrium, it is lasting, it will continue throughout the child's entire life. When you achieve the learning by external reinforcement, is the result lasting or not and what are the conditions necessary for it to be lasting?

The second question is, "How much generalization is possible?" What makes learning interesting is the possibility of transfer of a generalization. When you have brought about some learning, you can always ask whether this is an isolated piece in the midst of the child's mental life, or if it is really a dynamic structure which can lead to generalizations.

Then there is the third question, "In the case of each learning experience what was the operational level of the subject before the experience and what more complex structures has this learning succeeded in achieving?" In other words, we must look at each specific learning experience from the point of view of the spontaneous operations which were present at the outset and the operational level which has been achieved after the learning experience.

My second conclusion is that the fundamental relation involved in all development and all learning is not the relation of association. In the stimulus-response schema, the relation between the response and the stimulus is understood to be one of association. In contrast to this, I think that the fundamental relation is one of assimilation. Assimilation is not the same as association. I shall define assimilation as the integration of any sort of reality into a structure, and it is this assimilation which seems to me fundamental in learning, and which seems to me the fundamental relation from the point of view of pedagogical or didactic applications. All of my remarks today represent the child and the learning subject as active. An operation is an activity. Learning is possible only when there is active assimilation. It is this activity on the part of the subject which seems to me underplayed in the stimulus-response schema. The presentation which I propose puts the emphasis on the idea of self-regulation, on assimilation. All the emphasis is placed on the activity of the subject himself, and I think that without this activity there is no possible didactic or pedagogy which significantly transforms the subject.

Finally, and this will be my last concluding remark, I would like to comment on an excellent publication by the psychologist Berlyne. Berlyne spent a year with us in Geneva during which he intended to translate our results on the development of operations into stimulus-response language, specifically into Hull's learning theory. Berlyne published in our series of studies of genetic epistemol-

ogy a very good article on this comparison between the results of Geneva and Hull's theory. In the same volume, I published a commentary on Berlyne's results. Now the essence of Berlyne's results is this: our findings can very well be translated into Hullian language, but only on condition that two modifications are introduced. Berlyne himself found these modifications quite considerable, but they seemed to him to concern more the conceptualization than the Hullian theory itself. I'm not so sure about that. The two modifications are these. First of all, Berlyne wants to distinguish two sorts of responses in the S-R schema. First, responses in the ordinary, classical sense, which I shall call "copy responses," and secondly, what Berlyne called "transformation responses." Transformation responses consist of transforming one response of the first type into another response of the first type. These transformation responses are what I call operations, and you can see right away that this is a rather serious modification of Hull's conceptualization because here you are introducing an element of transformation and thus of assimilation and no longer the simple association of stimulus-response theory.

The second modification which Berlyne introduces into the stimulus-response language is the introduction of what he calls internal reinforcements. What are these internal reinforcements? They are what I call equilibration or self-regulation. The internal reinforcements are what enable the subject to eliminate contradictions, incompatibilities, and conflicts. All development is composed of momentary conflicts and incompatibilities which must be overcome to reach a higher level of equilibrium. Berlyne calls this elimination of incompatibilities internal reinforcements.

So you see that it is indeed a stimulus-response theory, if you will, but first you add operations and then you add equilibration. That's all we want!

Editor's note: A brief question and answer period followed Professor Piaget's presentation. The first question related to the fact that the eight-year-old child acquires conservation of substance prior to conservation of weight and volume. The question asked if this didn't contradict the order of emergence of the pre-operational and operational stages. Piaget's response follows:

The conservation of weight and the conservation of volume are not due only to experience. There is also involved a logical framework which is characterized by reversibility and the system of compensations.

I am only saying that in the case of weight and volume, weight corresponds to a perception. There is an empirical contact. The same is true of volume. But in the case of substance, I don't see how there can be any perception of substance independent of weight or volume. The strange thing is that this notion of substance comes before the two other notions. Note that in the history of thought, we have the same thing. The first Greek physicists, the pre-Socratic philosophers, discovered conservation of substance independently of any experience. I do not believe this is contradictory with the theory of operations. This conservation of substance is simply the affirmation that something must be conserved. The children don't know specifically what is conserved. They know that since the sausage can become a ball again there must be something which is conserved, and saying "substance" is simply a way of translating this logical necessity for conservation. But this logical necessity results directly from the discovery of operations. I do not think that this is contradictory with the theory of development.

Editor's note: The second question was whether or not the development of stages in children's thinking could be accelerated by practice, training, and exercise in perception and memory. Piaget's response follows:

I am not very sure that exercise of perception and memory would be sufficient. I think that we must distinguish within the cognitive function two very different aspects which I shall call the figurative aspect and the operative aspect. The figurative aspect deals with static configurations. In physical reality there are states, and in addition to these there are transformations which lead from one state to another. In cognitive functioning one has the figurative aspects—for example, perception, imitation, mental imagery, etc.

Secondly, there is the operative aspect, including operations and the actions which lead from one state to another. In children of the higher stages and in adults, the figurative aspects are subordinated to the operative aspects. Any given state is understood to be the result of some transformation and the point of departure for another transformation. But the pre-operational child does not understand transformations. He does not have the operations necessary to understand them so he puts all the emphasis on the static quality of the states. It is because of this, for example, that in the conservation experiments he simply compares the initial state and the final state without being concerned with the transformation.

In exercising perception and memory, I feel that you will reinforce the figurative aspect without touching the operative aspect. Consequently, I'm not sure that this will accelerate the development of cognitive structures. What needs to be reinforced is the operative aspect—not the analysis of states, but the understanding of transformations.

Questions

1. What, according to Piaget, are key differences between learning and development?

2. According to Piaget, what role do other people play in fostering cognitive development in children?

3. Suppose that you are asked to consult at an elementary school about children's understanding of scientific concepts, such as the conservation of weight and volume. Several second and third graders at this school are having difficulty with these concepts. What would you advise the teachers to do to help the children develop the skills needed to understand these concepts?