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Either We're Too Early & They Can't Learn It, or We're Too Late & They Know It Already: The Dilemma of "Applying Piaget"

Some History

Probably the largest single area of research inspired by Piaget's work has been the study of the genesis of an idea or an "intellectual structure" to see whether its development in the child was really as late as Piaget said it was. Skepticism was understandable. After all, his first discoveries were stunning. A 5-year-old who can count to 29 does not realize that if you take eight eggs out of eight cups and put them in a small pile, there are still as many eggs as eggcups. A child who battles daily with brothers and sisters to get a "fair" share of everything does not realize that if juice is poured from one glass to another of a different shape, the quantity doesn't change.

Even Piaget was skeptical at first. It was with epileptic children that he made his astonishing discovery that "number" is not a natural intuition: The ability to recite numbers in order does not necessarily have anything more to do with quantifying the number of objects than does the ability to recite a nursery rhyme. The situation Piaget first designed to study this phenomenon has come to be known as "the merchant and the pennies." He, the adult, started with a number of objects. The child started with number of pennies. The child "bought" the objects from the adult—one object per penny. After five or six purchases, Piaget stopped, covering his remaining objects and the pennies he had received, and asked the child how many pennies he (Piaget) now had. All the child had to do was to count the number of objects he had acquired through one-to-one exchange. But he did not do this. And when it was suggested that he count his own objects, he did not see how that could tell him anything about the number of pennies Piaget was hiding.

This early experiment, which soon gave rise to the classic egg and eggcup form, produced results that astonished Piaget as much as it did his early readers. In fact, at first he believed that it was specific to epileptics—that he had discovered a new diagnostic tool for epilepsy! As Thomas Kuhn (1962) has made amply clear, and as the later body of Piaget's own work shows over and over again, all of us, from children to scientists, have difficulty accepting data that go against our firmly held beliefs. We have to restructure too much of our intellectual framework to assimilate such surprises. It is far less costly, at least for a time, to keep the framework and deny the fact. Hence, the early skepticism about Piaget's findings and the lengthy attempts by American psychologists to see if they were really true. And, yes, they turned out to be true: "The children in my home town might be a *little* speedier than the children in Geneva, but I have to admit that they do, at some age, act just as Piaget said."

Efforts then turned to trying to see how to teach children the truth about such matters. "Learning experiments" replaced "replication experiments." Piaget's own view was that such development took time and could not be hastened. Simply telling children the truth about something could not make them understand it. This attitude was even more of a shock to the common sense derived from decades of acceptance of behavioral or stimulus-response psychology. One would think that if we can shape pigeons to play pingpong, we can shape children to conserve number. Surely we have only to devise the proper situations, focus the children's attention on the pertinent factors, elicit and reinforce the correct responses, and the job will be done.

Experiments based on Piaget's work have entered a new phase and are still going on. Convinced behaviorists remain convinced. They can now look at the facts and agree that most children are nonconservers when they enter school. The facts now, after four decades, have found common acceptance among psychologists concerned with child development or learning. But these notions can still be accepted by behaviorists without changing their theoretical framework by acknowledging that, on the whole, children in preschool years are simply not put into situations where the correct notions would develop. They still need not restructure their framework if they can show that, with the right training, these ideas can be made accessible to children.

This debate is not over. An instructive example is the interchange between Siegfried Engelmann (1971), on the one hand, and Constance Kamii and Louise Derman (1971), on the other. This particular exchange is not recent, but the issues it highlights remain.

Engelmann, a behaviorist, undertook to teach a number of kindergartners some notions that usually develop much later—among them the idea of specific gravity as an explanation for the floating or sinking of objects. He then allowed Kamii and Derman to assess from a Piaget perspective the extent to which they thought the notions had been learned. Among the rules Engelmann taught the children, the principal one was: "An object floats because it is lighter than a piece of water the same size; an object sinks because it is heavier than a piece of water the same size." Kamii and Derman describe fascinating instances of conflicts between the rules the children were taught and their own intuitions—their common sense. In addition to the rules they often gave other explanations, typical of children their age: "because it's heavy," "because it's little," "because it has cracks in it," "because I pushed it," "because it has air inside"; or, simply, "I really don't know why."

In other instances, the rules seemed to come between the children and their intuitions in ways that led to nonsense not normally encountered in children their age. One child hefted a large candle in one hand and a birthday cake candle in the other, but having seen that they both floated, maintained "they weigh the same." Another child said that a tiny piece of aluminum foil that sank weighed more than a large sheet that floated on the surface. Clearly, these children were trying to apply the rules rather than coming to terms with the objects. A typical 6-year-old's reaction to the aluminum foil, for example, might be to say that the tiny piece sank because it was too tiny, and the large piece floated because it was flat.

In another part of the Kamii and Derman assessment, no longer dealing with floating and sinking, the children were asked why the water level rose in a glass when an object was immersed in it. Two of four replied, "Because it is heavier than a piece of water the same size." The other two children, who tended generally to remain true to their intuitions, answered that the object pushed the water out of the way. In general, confronted with a result they did not expect, the rule-bound children hesitated briefly, and then searched their memory for a learned rule that might apply, whether it really made sense to them or not.

Engelmann's interpretation did not, of course, accord with Kamii and Derman's. Engelmann concluded that with more time the job could be better done; the rules could be better designed to cover a wider variety of situations and could be taught to elicit what I presume he would call a higher criterion of performance. Kamii and Derman's interpretation seems more persuasive: The children had learned a verbal overlay, but their deep-seated notions had not evolved.

Behaviorists are not the only psychologists to have undertaken learning experiments based on Piaget's findings. Learning research of a different character was stimulated by *The Process of Education* (1960), a report by Jerome Bruner of the landmark Woods Hole conference. This conference was the point of departure for much of the curriculum reform of the 1960s. Piaget's long-time collaborator, Bärbel Inhelder, participated in the conference, and, according to Bruner, was asked to suggest ways in which the child could be moved along faster through the various stages of intellectual development in mathematics and physics. Inhelder (personal communication, April 16, 1978) reports that in fact there were lengthy debates at the conference on that point. Physicists and psychologists, including Bruner, generally reproached the Genevan researchers for their observational passivity: In effect, they said, "You've done nothing but document the child's unaided development; you don't intervene. Surely each of the notions you have studied is composed of other simpler notions. Surely it is sufficient to decompose each of the complex notions into its simpler parts, to teach the simpler parts, and to aid the construction of the whole notion in this way." The parallels with physics are clear. The world of physics is infinitely manipulable. If one knows the constituent mechanisms, one can unmake and remake a process in innumerable ways, taking it apart and putting it together as one wishes. In contrast, the biologists, on the whole, understood Inhelder's point that a child's thinking was not as manipulable as a physical phenomenon. Biological organisms have their own interrelated rhythms and structures. Inhelder observed that, among the physicists, only Francis Friedman understood that a child's thinking responded with the integrity of a biological organism and not like the separate components of a physical mechanism. Friedman's influence, tragically cut short by his death in 1962, was nonetheless seminal in the early thinking of the staff of the Elementary Science Study—the one U.S. program of the 1960s curriculum reform movement most consistent with the work of Piaget and Inhelder in psychology.

Bruner and psychologists of a similar bent certainly differed from

Engelmann in their attitudes toward learning. For them, learning was not a matter of acquiring verbal rules; understanding remained central. But they too assumed that understanding could be engineered, molded by an outsider. A great number of learning experiments derived from Piaget's findings were undertaken on this basis.

For educators, the Woods Hole conference was important in bringing Piaget to the fore, since *The Process of Education* was widely distributed, and Piaget was the one psychologist discussed. Clearly, his work had great significance for education. But what was it? Almost without exception, educators followed the learning research and sought ways to speed the development of key ideas that, at their natural pace, develop slowly. It was the prevalence of these attempts that gave rise to the supposed dilemma of my title, a dilemma that besets current thinking about the applications of Piaget's work to education.

Genevan Learning Research

An essential part of this story is that in the mid-1950s "learning research" played a central role in Piaget's own Center for Genetic Epistemology. In 1957–1958, it was the main theme of the center. Four volumes were published on the research of that year (Apostel, Jonckheere, & Matalon, 1959; Goustard, Greco, Matalon, & Piaget, 1959; Greco & Piaget, 1959; Morf, Smedslund, Vinh-Bang, & Wohlwill, 1959). None of these books has been translated, and more's the pity. Even now, 30 years later, they still make surprising and provocative contributions to the discussion.

The research was largely undertaken to find the extent to which children's level of understanding sets limits on what they are able to "read" from the environment and, conversely, to see the extent to which encounters with selected data from the environment affect the child's level of understanding. Of the seven research articles in these four volumes, the most exemplary for this discussion is that of Greco in Greco and Piaget's *Apprentissage et Connaissance* (1959). The problem he chose to study was taken from Piaget's *The Child's Conception of Movement and Speed* (1946/1970): three colored beads, black, white, and red, threaded on a stick, are inserted in a tube, from left to right. If red goes in first, which color is at the right-hand end? If red goes in first, which color is at the right-hand end after the tube is rotated 180°? Which color is at the right-hand end if the tube is rotated 180° *two* times? For those of us who do not have to do the experiment to know in advance, our answer to the last question is based on the following reasoning: One rotation results in the opposite order; two rotations result in the opposite of the opposite, which amounts to the original order. The same reasoning allows us to generalize: Any odd number of rotations will result in the opposite order; any even number of rotations will result in the original order.

This seems simple enough. Most of us would be surprised that children would have any difficulty understanding it, but Piaget's research had shown that they did. Beyond that, most of us would not suspect that "understanding" had much of a role to play in finding the rule. It would seem a simple enough generalization for children to draw for themselves, if they were shown enough examples. This is what Greco wanted to investigate.

He carried out the research with 4- and 5-year-olds who did not at the outset understand the relationship between the number of rotations and the positions of the beads. Various techniques, corresponding to a number of different forms of analysis, were used. Single rotations caused little difficulty. If the rule was not immediately seen, it was easily generalized from a few examples: When you turn, it comes out the opposite. But two rotations were another story, and often the child's rule for one rotation suffered along the way.

Some children needed as many as eight different sessions before they were able to predict consistently what would happen in these two different cases. The data are not "seen" for a long time. For example, in one session, Chal (5 years, 10 months) predicts incorrectly four times in a row, when black has entered first, and the tube has been rotated twice. "Why do you always say red?" she is asked. "Because before [in a single series of rotations] when you turned it, it changed color." "And now?" "Not always." Greco notes that she has just witnessed 14 double rotations in a row (some with black going in first, some with red); but all she has seen is that it doesn't "always" change color (Greco, 1959, p. 117).

Since the data are so simple, all the children finally do manage to get the rule. But for many of them, the rule for double rotation remains just that—a rule. They see no sense in it. The one rule they understand is that when the tube is turned once, the color changes. The double rotation is learned only as an exception to this rule; for some reason, when you turn it twice, it doesn't change. It is not a matter of changing twice, and thus coming back to the original position. It is, for some inexplicable reason, a matter of not changing at all. The rule is formulated and remembered without understanding.

Other children do come to understand, but their understanding is clearly the result of their own struggle to make sense of the data. Dar (5 years, 5 months) makes six wrong predictions in seven items of double rotation. He himself counts his mistakes on his fingers, and he declares, "I still made six mistakes." "You haven't got it yet?" "No, because when you turn once, I know it changes color; but when you turn two times, it's the same color, so I don't get it." At the next session, the whole series is answered correctly, and Dar exclaims: "Oh yeah, when you turn two times it's the same color!" At the end of the session, Greco asks him why. "Because the black that came there [to the left end] comes back here [to the right end] when you turn it the second time" (p. 129).

His words are precisely the same in the two cases. "When you turn two times it's the same color." But the first time he doesn't "get it"; he doesn't think it ought to be that way, so he doesn't give in to it. He sees the generalization, but he keeps predicting the way it *ought* to be, much like the skeptics' reactions to Piaget's early results.

The children who don't have Dar's insight and who are perhaps more willing than he is to accept a rule they don't understand finally gave in to it as an exception to the rule they do understand. They seem to be defeated by the evidence. The difference between those children and children like Dar is clear. Here is an "explanation" from a child who simply gave in to the rule: "When you turn it two or three times [it was never turned more than twice] it stays just the same" (p. 137). Here are some other explanations from children who, like Dar, understood the reason: "It doesn't stay the same all the time, it changes, and then it changes again" (p. 137). "When you do two turns, it changes sides twice; at every turn the black changes sides" (p. 137). In a subsequent posttest, where the number of rotations was increased to three, four, and five, the children like Dar did significantly better than the children who gave in to the rule without understanding it. They did not, however, do as well as those who had known, without needing the learning experience, that a double rotation amounted to the same thing as no rotation.

It is possible, then, for a child's understanding of this kind of necessary relationship to evolve in especially devised situations more quickly than it would spontaneously. But it is not the pressure of data that gives rise to the understanding. It is, on the contrary, the child's own struggle to make sense of the data.

Greco underlines this point by devising four experiments where various kinds of direct help were given to the children—either perceptual clues to help follow the movements of the appropriate end of the tube or a direct statement of the rule during the course of the learning sessions ("See, every time it turns, it changes color; you just have to say, 'red, black' like that" (p. 143). In no case did this outside help, characteristic of the Engelmann type of behaviorist research, speed up the learning process. In those cases where the verbal rule was given, the children conscientiously applied the verbal alternation, "black, red, black, red," but they did so without seeing the relationship between the rotations and the colors. Sometimes when the rotations were stopped they added a term to their alternating series, so it would turn out the way they thought it should. The only accepted part of the rule was the part they understood to begin with: "When it turns it changes color."

Of the situation with perceptual clues, Greco says, "The failure of these methods . . . shows that the discovery of the rule could not be the product of perceptual learning. . . . It is the discovery of the law which makes possible the correct use of visual tracking" (p. 142).

Piaget's summary of these four volumes of research includes the following statements: "In the first place, it is incontestable that a certain amount of learning of logical structures can take place" (1959, p. 16). Some children did learn that the result of two rotations is necessarily the opposite of the result of one rotation. "However, in the second place, this learning of logical structures remains very limited" (p. 16). That is, it took a long time and was neither universal nor generalizable. "In sum the learning of logical structures . . . consists of the construction of new coordinations" (p. 16). Here the effect of the second rotation had to be coordinated with the result of the first.

This research was clearly the basis for Inhelder's insistence at Woods Hole that there are limits to the engineering one can do with children's understanding. It is nonetheless of some historical interest that Piaget agrees that "a certain amount of learning of logical structures can take place." Well after the Woods Hole conference, Piaget was understood, by most American educators at least, to believe that children's logical construction could not be "accelerated" at all.

The misunderstanding of Piaget's own position probably arises from his reaction to what he called, in the early 1960s, "the American question," referring no doubt to the debate at the Woods Hole conference: If it is true that children's levels of understanding develop so slowly, what can we do to speed them up? It was Piaget's good-natured mocking of this question that perhaps led to the misconception that he believed nothing could be done to speed them up. But in fact that was not what he meant to convey. He simply meant to question the reason for doing so. A few years later he pointed out that for him the question was not how *fast* we can help intelligence grow, but how *far* we can help it grow.

According to Inhelder, the Woods Hole debate played a role in stimulating another body of learning research. It is much better known to the American audience, since it has been translated into English (Inhelder, Sinclair, & Bovet, 1974), and it is perhaps the most interesting learning research done to date. A dozen years after Woods Hole, Inhelder took up the challenge of the physicists and psychologists and tried to break up a notion into simpler constituent parts to see how children managed to recombine them. But the research took on quite a different

character from that which the conference participants might have imagined. The attempt was to put into relief the conflicts that were engendered when any single child based a judgment on one or another of two different ways of thinking. (Examples can be found in chapters 5 and 9 of this book.) It was an effort not simply to see *whether* specific experiences could make logical understanding easier, as Greco's research did, but to see what goes on when a child passes to a new level of understanding. What conflicts led children to see the inadequacies of their own notions and to modify those notions in order to resolve the conflicts?

Again, it is clear from this research that children's understanding is not infinitely malleable. At certain levels, the children do not even see the conflicts in their own thinking. Conflicting notions are simply compartmentalized, and no need is felt to reconcile them. Only if children recognized and were bothered by a conflict did they sometimes manage to construct a more adequate notion to coordinate the two conflicting ones.

Two points from Piaget's preface to the Inhelder, Sinclair, and Bovet study shed light on this discussion. The first is that for him the interest of these experiments does not lie in whether the acquisition of certain notions can be accelerated, but rather in what research like this can tell us about the process involved in passing from one level of understanding to another. What he found significant is that in every case where acceleration takes place, it results from a conflict arising in the child's own mind. It is the child's own effort to resolve a conflict that takes him or her on to another level. Piaget's second point concerns the effects that outside stimulation might have on the child's initiative. He questions whether, when some notions are facilitated by learning experiments, they will serve as points of departure for new, spontaneous constructions, or whether the child will then tend to depend on outside provocation rather than his or her own initiative in pursuing the relationships among ideas.

This seems to be a critical question for educators. Indeed, in his preface, Piaget puts it directly to educators, not to psychologists. Early in the preface he speaks of the "psychologist" and the "subject"; but in raising this question, he abruptly switches to the "teacher" and the "pupil." His question brings us squarely into the realm of the dilemma posed in the title of this chapter, and it adds another dimension.

Breadth and Depth

It is clear that the dilemma of the title is a false one. The problem lies in the wrong assumptions about what the "it" of education ought to be, as if all knowledge or all intellectual preparation consisted of logical structures and conceptual frameworks. On the contrary, Piaget's work suggests that this is the one area of intellectual preparation that educators need worry least about; left to their own rhythm and given the opportunity, children tend to develop the basic frameworks as naturally as walking.

On the other hand, there are clearly enormous differences among people in what they make of their basic frameworks. By age 7 the naturalist Gerald Durrell was intimately acquainted with the ways of every bug and amphibian in his back yard. A 15-year-old of my acquaintance, skeptical about whether 300 raffle tickets selling from 1¢ to $3.00 would leave much profit beyond the price of the tennis racquet that was offered as the prize, reinvented, as she sauntered down the street, Gauss's formula for finding the sum of numbers from 1 to *n*. My 11-year-old country neighbor has the mechanics of my lawnmower and rototiller down pat. And, from the other extreme, a group of adults I once worked with, intelligent but untrained in science, spent seven sessions experimenting with floating and sinking before it occurred to one of them that floating might depend on a relationship between weight and volume (Duckworth, 1986). Contrary to Inhelder and Piaget's own suggestion (1958), logical structures alone did not lead to a grasp of this phenomenon. What is it that affects what individuals actually do with their basic frameworks? This, surely, is the critical question for educators.

I once had what struck me as a great insight, derived from Piaget's work: "All the rest of the world passes us by unless we think of thinking about it in that way." What brings us to think of thinking about parts of the world in new ways? The question applies at all levels. Nobody until Einstein thought of thinking about space and time as interdependent variables, though once he had done so, other physicists were able to think that way too. Nobody until Freud thought of thinking about the power of the unconscious in human activity. Nobody until Piaget, for that matter, thought of thinking about how children thought about conservation problems. Until he did, that whole part of the world passed all of us by.

It was actually in the context of sensorimotor intelligence—the practical intelligence that infants construct before the development of language—that I was struck by this image. I thought of a baby girl lying in her crib with the whole of the universe, or at least some part of it, around her. But, for lack of knowing what to do to this universe, all of it passes her by except for the little that responds to what she knows how to do. She has only to push, and this part of the world will swing; she has only to shake and that part of the world will jingle; she has only to let go, and some other part of the world will fall down and bang on the floor. But since she has not yet come to invent these actions (which, for infants, is a better way of saying that she has not yet thought of thinking about the world in these ways), all of that entertainment passes her by.

I was thinking, of course, of Piaget's own studies of infants. *The Origins of Intelligence in Children* (1936/1966) is the only one of his books in which he studies the child's practical use of what he or she already knows. This research is so closely related to my theme that I would like to quote in full one short example of how one kind of action that a child knows how to effect gives rise to a new action (a new scheme, in Piaget's terminology), providing the infant access to another part of the universe.

> For Laurent, the scheme of hitting came into being in the following way. At 4 months, 7 days, he looks at a letter opener tangled in the strings of a doll hung in front of him. He tries to grasp [a scheme he already knows] the doll or the letter opener but each time, his attempts only result in his knocking the objects [so they swing out of his reach]. He then looks at them with interest and starts over again.
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> The next day, same reaction. He still doesn't hit intentionally, but after trying to grasp the letter opener, and failing each time, he then only sketches out his grasping gesture, and so simply keeps knocking one end of the object. The next day Laurent tries to grasp a doll hanging in front of him; but he only manages to make it swing, and not to hold onto it. Then he shakes his whole body, waving his arms [another scheme he already knows]. But in so doing he hits the doll by accident; then he starts over on purpose, a number of times. . . . At 4 months, 15 days, with another doll hung in front of him, Laurent tries to grasp it, then shakes himself to make it swing, knocks it accidentally, and then tries simply to hit it. Now the scheme is almost differentiated from the preceding ones, but it does not yet have an independence of its own. At 4 months, 18 days, Laurent hits my hands without trying to grasp them, but he started by simply waving his arms around, and only afterwards went on to hit my hands. The next day, finally, Laurent immediately hits a doll hung in front of him. The scheme is now completely differentiated. Two days later he hits some hanging rattles, making them swing over and over again. Starting at 5 months, 2 days, Laurent hits objects with one hand while holding them in the other. (Piaget, 1936, Obs. 103; my translation)

It is this level of analytic description that is the fascination of *The Origins of Intelligence*. A new procedure is developed from old ones, and leads to yet other new ones. Note that Laurent's knowledge is broadened, in the sense that he can conceive of (which means that he can act on) the world in more varied ways; it is deepened, in the sense that he can know more aspects of one given object or situation. His repertoire is greater; he sees the pertinence of his repertoire to any one situation.

More situations now make sense; any one situation makes sense in a greater number of ways.

In the companion volume, *The Construction of Reality in the Child* (1937/1986), Piaget analyzes the way various schemes are coordinated into structures, forming the framework of a child's understanding of space, time, causality, and the permanent existence of objects. It is this level of analysis that he pursues in all his subsequent work, and in all of his work with older children. Never again has he looked at the detail of how one child's actions or thoughts evolve.

Piaget's emphasis on structures has been very fruitful for epistemology, which is his field of interest. But for educators it is the detail of a single child's broadening and deepening knowledge that is the important thing. The lesson we can take from *The Origins of Intelligence* is that knowledge is always based on other knowledge—a refinement and a reintegration of the knowledge one already has. How does this work with older children? How does a child or an adult mobilize capacities? Whatever the state of development of his or her notions at a given moment, the child may or may not even think of bringing them into play. That is why the dilemma of the title is so much beside the point. The real question for educators should be when and how does anyone think of bringing ideas into play?

Going Beyond the Dilemma

Some Genevan research addresses this question. This work of Inhelder and her collaborators with children from 4 to 12 years of age is strikingly similar to Piaget's observations of infants years ago. Children are called on to put their knowledge to use in a practical situation, where "the knowledge is not already organized in a way that can be applied as is, but . . . must be created (or recreated) . . . during the solution procedures" (see Ackermann-Valladao, 1981).

Blanchet (1977), in a paper dealing with the methodology of this kind of research, writes, "A good experimental situation . . . must permit the child to establish plans to reach a distant goal, while leaving him wide freedom to follow his own routing" (p. 37). I am struck by the fact that Blanchet's statement could as easily be said of all the best curriculum programs I know. The opening phrase might just as well be "a good learning situation."

What Inhelder and her collaborators look for is what a child notices about a situation, what the child does, how the first acts develop, how the results of these acts modify what is noticed, and how all that is

noticed becomes integrated into a broader and deeper understanding of the situation as a whole. It is worth developing one example.

The researchers (Blanchet et al., 1976) spent two years analyzing a videotape of a 6-year-old boy, Didier, as he worked with a set of five Russian dolls of the kind that can be separated at their middles to nest inside one another. Videotape was a relatively recent technology in Genevan research and it was used here to full advantage. Every gesture, expression, hesitation, swift action, and glance was taken into account as an indicator of the thought that might be guiding Didier's actions. It is significant, also, that the analysis was done by a group. It would be only too easy for one individual to become caught up with a single possible interpretation of the various indicators. When several observers are doing the analysis, they are more likely to "think of thinking about" the situation in a variety of ways, and to be obliged to confront their various ideas to see which seems most appropriate.

The dolls are first presented to Didier with each one assembled as a separate doll. He is given no specific problem. "You can play with these however you want. Do what you want." He starts immediately by trying to nest them, but he starts with the big ones first. He opens the biggest, and goes to put the next one inside it. But he stops, looks at the smallest, and then slowly reverses his procedure, and starts from the smallest.

Starting from the smallest, he succeeds easily. But he is still perplexed because the dolls cannot be nested from biggest to smallest, as open boxes can be. What is it about these things that is so like a set of different-sized open boxes, and yet so different? This becomes the question that keeps him going. Twice more he tries to nest them from biggest to smallest, as if trying to understand why it won't work. Each time, he ends up nesting them from smallest to biggest.

The general idea of "doing the opposite," which first appears here in the smallest-to-biggest, biggest-to-smallest contrast, is carried out in other ways. At one point, he groups the dolls into big ones and little ones, and then he inverts their positions, by crossing his hands, picking up two, uncrossing his hands again, and putting them down on the "opposite" side. When the smallest doll falls over by accident, he places it on its head, and then nests them all again, but putting each one *upside down* into the next.

He starts working with the bases separately. He places each one upside down, which is one way of doing the opposite; and at the same time he places them, at last, from biggest to smallest. This time he no longer has a nest. He has a tower. Rapidly, he does the same thing with the heads—turns them over, and works from biggest to smallest. But this time, to his surprise, he doesn't get a tower. He gets a nest again. As a next step—and the observers believe he is still trying to make a tower—he changes two things. He places the heads right side up and works from smallest to biggest, which gives him another nesting, the other side up.

At this point his universe has become rather complex. He has two procedures—from biggest to smallest and from smallest to biggest, and two positions—right side up and upside down. These also must be coordinated with the fact that, in one case, upside-down means that the opening is up, while in the other case, upside down means that the opening is down. Given this complexity, which now has produced two surprising results (his actions have twice created nests rather than towers), Didier takes apart his two constructions and tranquilly goes back to his very first procedure. He redoes the complete nesting of the dolls, then takes the nest apart, builds his tower with the bases, and, finally, with no false moves, builds the tower with the heads.

Two themes emerge in the numerous studies undertaken to date by this group, and both find support in the example of Didier. The first is the constant presence of alternation between trying to achieve a certain result and trying to understand the situation. At the outset, Didier did not seem to concern himself with understanding the relationships among these dolls. He seemed satisfied with his understanding of things that could be nested and set out simply to achieve this result. It was when he found to his surprise that one of his ways of nesting things—biggest to smallest—didn't work that he started to be interested in understanding what was special about these particular nestable objects. In the course of exploring them, he simply happened to build a tower with the bases, just as Laurent happened to set the letter opener swinging. Building a tower with the heads then became another task—a new result to be achieved. But it coexisted with the goal of understanding their characteristics: Witness the fact that in the case of both of his unsuccessful attempts to build a tower with the heads, he saw his procedure through to the end, as if he were interested in seeing what its outcome would be. His last nesting sequence was carried out for reasons very different from the first nesting sequence. It was not a goal in itself this time: It was a consolidation of what he understood, subordinated to the last remaining goal of constructing a tower with the heads.

This hypothesis is explored in a number of excellent studies (Ackermann-Valladao, 1977; Karmiloff-Smith & Inhelder, 1975; Kilcher & Robert, 1977; Montangero, 1977; Robert, 1978; Robert & Sinclair, 1974). One of these studies, published in English, has the suggestive title "If You Want to Get Ahead, Get a Theory" (Karmiloff-Smith & Inhelder, 1975), and it sheds light directly on the Greco study—the difference between simply succeeding in a task and understanding what is

going on. Children from 4 to 9 were asked to balance a variety of boards across a narrow bar. Some of the boards were plain, some were visibly weighted at one end, some were invisibly weighted at one end. A child does not need much of a theory to succeed in balancing a board; trial-and-error and readjustments suffice. But, then, each case is seen by the child as separate: Understanding is no better at the end than it was at the beginning. From the moment any theory arises—and the first one usually is that to balance a board you should put it in the middle—each particular result can be seen both as an instance of a practical success or failure and as a confirmation or invalidation of one's reasoning. Balancing a board by putting it near one end is a practical success, but it is an invalidation of the "to balance it put it in the middle" theory. It is only if a child *has* a theory that a result can contribute to the development of his understanding; he can pay attention to results that contradict his theory and try to figure out some other theory that would take them into account.

The simple fact of a success or a failure does nothing for his understanding—just as it did nothing for the understanding of Greco's children—unless the child has some guiding idea that he is testing as he tries to achieve his practical aim. Until he thinks of thinking about the role of the distribution of the weight, the data provided by the successes and failures simply pass him by.

This brings us to the second theme of the Inhelder group's work. In a given situation, what is it that sets us reaching for elements that are already part of our knowledge, and which elements? What determines whether the infant Laurent will hit an object, reach for it, suck it, drop it, or shake it? What determines whether an adult will think of putting weight in relation to volume?

The hypothesis of Inhelder and her associates is that our knowledge has three lines of access. One is perceptual: Something about the way things look connects to something about how things looked before. Another is action: Something about what we do calls up what we have done before. The third is conceptual: An idea, a word, or a formula is the link. In any given situation, it is the interplay among these three that determines our understanding of it and what we do with it, not our conceptual knowledge alone and still less our logical structures.

> These three types of knowledge each gives rise to a very different accounting of the situation, since they break it up and put it back together again according to different units and transformations. The problem then becomes one of coordinating these forms of knowledge to allow for a real understanding of the situation. We believe that no one of these modes of knowledge alone allows for a complete understanding of the problem. . . . One could even define different depths of understanding by the number of

> modes brought into play. A real understanding could be characterized by the free passage of information from one type of knowledge to another, of any given element of the problem. (Blanchet et al., 1976, p. 5)

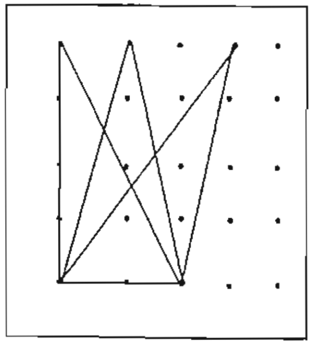
Depending on the situation, either the perceptual aspects of knowledge, the actions it can give rise to, or the ideas, words, and formulas it evokes may have relatively greater importance. None of the three is, a priori, more valid. Words and formulas are useful summaries of a collection of relationships; on the other hand, their apparent simplicity is misleading. They leave out a lot, and they are slippery. Attaching them to the other access routes keeps them honest.

In Didier's case, the perceptual aspect was important at the very beginning: The dolls looked like nestable things. Then an idea, "the opposite," guided his approach to the dolls for most of the session. More than once he actually said he was trying to do "*le contraire.*" But it is unlikely that he was even aware of the various senses of "opposite" that came into play—biggest to smallest or smallest to biggest, upside down or right side up. "Opposite" really took on meaning in this specific situation only through his actions and their effects on the dolls. Similarly, after Didier had built a tower with the bases of the dolls, he set out to do "the same thing" with their heads. But did "the same thing" mean "build another tower" or "work from big to small" or "turn them over?" Until he actually went to work with the heads, he seemed to think that it meant all three of these operations.

It is much too easy for all of us to think we understand a situation simply because we can apply to it a word or a formula. If notions like "the opposite" and "the same thing" are slippery, how much more so, for most of us, are "air pressure" or "cultural deprivation." It is all too easy to get carried away into worlds of our own invention that may or may not have any connection to the full complexity of real situations.

Furthermore, when we have learned something only in the form of a word or a formula, we may not even recognize situations where this knowledge is pertinent. Marion Walter (personal communication, October 24, 1972) gave a rather stunning example of this, arising from a teaching methods course she gave to adult students who all had degrees in mathematics. The students were working with geoboards. Each student had a board with a 5-by-5 array of nails and a number of rubber bands with which to make various shapes on the nails (Figure 3.1). Taking a small square of four nails as the unit of measurement, one student had set herself the problem of calculating the area of a triangle constructed on a base of three nails in the bottom row, having as an apex the first nail of the top row. Having calculated the area of that triangle, she moved the

Figure 3.1



apex over one nail. To her great surprise, she found that the new triangle had the same area as the first. She then moved the apex over two more nails. Amazement—it was still the same area and it remained the same area for all triangles on that base with apexes in the top row. Excited by her discovery, she announced it to the whole group. After considerable discussion, one member of the group realized that her discovery was none other than a "fact" that they had all "known" since elementary school: that the area of a triangle is half the base times the height. There was a sense in which they did already know it. But since the formula had been without adequate ties to how things look, or what one can do with them, the knowledge was not evoked by a pertinent situation.

Beyond the False Dilemma

The study of Didier seems almost sufficient in itself as a response to the dilemma of my chapter title. One of the "basic logical structures" to which that dilemma has been applied is precisely the structure of seriation—systematic ordering of objects according to size or some other variable. Note that one does not even know whether Didier has developed that structure. Nothing in this situation enables us to say whether he would be able to order objects whose size differences were not so striking, or whose baseline was not already given by the fact that they stand up on the table. Furthermore, that is quite beside the point. It is neither too early nor too late for him to be engaged in these activities, which call on him to make use of whatever knowledge he has in a new situation.

I would like to linger a bit on this point, because another current interpretation of Piaget (mentioned in chapter 1) is that one should diagnose children's intellectual levels and tailor individual instruction accordingly. This has always seemed to me an impractical aim. To begin with, in any one class we can assume there are 30 children. A minimum number of Piaget notions that are pertinent to teaching at any age would surely include number, length, area, volume, causality, time, spatial coordinates, and proportions. This is only a beginning, but let's say modestly that a dozen tasks might serve to diagnose a child's intellectual level. That adds up to 360 tests for one class of children. And, of course, tests should be carried out periodically to assess progress during the year—let's say 360 tests, four times a year. Even with a full-time school psychologist assigned to each teacher, this pace could probably not be maintained.

But, again, this problem is significant only if our emphasis is on developing specific notions. If our emphasis is on broadening and deepening the child's use of the notions he or she has, such diagnoses lose much of their interest. The only diagnosis necessary, then, is to observe what the children in fact do during their learning. This is not a diagnosis of notions: It is an appreciation of the variety of ideas children have about the situation, and the depth to which they pursue their ideas.

What one can assume, without any diagnostic tests at all, is that in any one group of 30 children—no matter how much one has tried to homogenize them—there will be enormous variations in levels of understanding and in breadth and depth of knowledge already developed. Certainly we would want each child to have the occasion to work at his or her own level. The solution for the teacher, however, is not to tailor narrow exercises for individual children, but rather to offer situations in which children at various levels, whatever their intellectual structures, can come to know parts of the world in new ways. It is not an easy job, but how much more interesting a human enterprise it is. And how much more to the point it is to think of a child's education as knowing and learning about how the world works than to attempt to resolve the dilemma in the title.

I return to Blanchet's thumbnail characterization of a good experimental situation in order to propose it again as a criterion for a good learning situation: It "must permit the child to establish plans to reach a distant goal, while leaving him wide freedom to follow his own routing." If we can create situations like this, then differences among children are by definition taken into account—without our having to diagnose in advance each child's level in a dozen domains. We can also be sure that children will take their own individual notions further as they strive to make sense of any situation, without our having to be obsessed with relating a particular activity to any one of the notions highlighted by Piaget.

Finally, I would like to refer again to the two themes brought out in the current Genevan research: the interplay between the child's attempt at a practical result and his or her efforts to understand, and the interplay among the various access routes to knowledge—perceptions, actions, and words or formulas. Both these themes suggest that practical situations, which are the ones that correspond most to children's natural activity, are not only sufficient, but are also the best kinds of learning situations. In the course of trying to solve practical problems, children spend time reorganizing their levels of understanding; in real situations, children develop multiple access routes to their knowledge. Learning in school need not, and should not, be different from children's natural forms of learning about the world. We need only broaden and deepen their scope by opening up parts of the world that children may not, on their own, have thought of thinking about.