Scheme Theory as a Key to the Learning Paradox

Carl Bereiter's article "Toward a solution of the learning paradox" appeared in 1985, was widely read and cited, but did not end the discussion about the "learning paradox". My contribution is an attempt to show that it is in fact a spurious problem and that the paradox springs from unwarranted traditional views of knowledge and conceptualization. A constructivist orientation adopting Peirce's notion of abduction and a particular interpretation of Piaget's scheme theory opens a different and perhaps more promising approach.

Keywords: Abduction, Cognitive Development, Learning, Scheme Theory.

Introduction

Unlike other contributors to this Advanced Course I have not had the benefit of a Genevan education or of doing research under the guidance of either Bärbel Inhelder or Piaget. But I have had the good fortune of a few extended conversations with Bärbel here in Geneva and when she visited the United States. Still, I am in no position to judge how large a part, or what particulars of the Genetic Psychology that was invented here, can be considered Inhelder's personal contribution. To me, the whole is very much a joint venture – and when people work, talk, and think together as intensively and for so long as did Inhelder and Piaget, the question of individual authorship tends to lose importance.

Besides, I am uneasy about the separation of psychology and epistemology. Every researcher – man or woman, psychologist, physicist, or mathematician – is a manifestation of the *sujet épistémic*, and it is one of the characteristics of the 20th century that the researchers in these three disciplines can no longer afford to forget this.

All psychology, empirical no less than theoretical, requires an epistemological position, and the topic I have chosen is a good example of this.

The notion of a learning paradox was introduced in contemporary literature as a late and not always acknowledged reflection of Plato's theory of innate ideal forms.

Piaget never tired to reiterate his opposition to that theory and to any form of preformation in the realm of cognition. The model of the scheme provided him with the source of sensorimotor know-how from which reflective abstraction could derive level after level of "operative" abstract ideas.

In the first chapter of *Le cheminement des découvertes de l'enfant,* Bärbel Inhelder and de Caprona make the distinction between "a general architecture of knowledge" that consists of "the structures of the *epistemic subject"* and, on the other hand, "the vast domain of conducts that rely on a variety of cognitive schemes that are more heuristic" (Inhelder & de Caprona, 1992, p.20).

A few pages later they ask, "is the scheme a structural unit or a functional one?" (p.29). This is a difficult question, but they supply an answer that I find thoroughly convincing:

> Structures are the permanent connective patterns of the cognitive system. They engender its possibilities, that is, its openness, and they also determine what is necessary in it, its closure. … For us, they have above all the sense of a dynamic pattern. (Inhelder & de Caprona, 1992, p.33)

I hope that this definition will be found to cover the scheme theory that I am using to resolve the learning paradox and which I shall explain in the pages that follow.

Preformation: A ruse to avoid research

Anyone who has read some of Plato's dialogues will have noticed that Socrates appears there not only as a wily character but sometimes also as contradicting himself. In one place he says: "I know that I know nothing", in another he describes himself as a midwife, because he helps a young boy to give birth to an important piece of knowledge.

It is, of course, a matter of context. When he said: "I know nothing", he referred to the kind of knowledge that philosophers have tried to capture in the many centuries since then – objective knowledge of a world as it might be before we experience it. Socrates was in fact re-phrasing what Xenophanes and Protagoras had said before him. He could not have meant that he did not know Athens. After many miles of peripatetically philosophizing all day long, he never had trouble finding his way home. Indeed, Socrates knew a lot of practical things, among which at the end, that the drink of Hemlock would kill him.

In contrast, the knowledge he leads a boy to bring forth in Plato's *Meno* had to do with the square root of 2 and therefore was not merely know-how. It belonged to the domain which the Platonic School considered to be a domain of eternal, absolute truths. It was one of those truths which, as he said, "you find in yourself" in the sense that you *remember* it. According to Plato's theory, this kind of knowledge was innate but inaccessible to us *until* we call it forth from the hidden treasury of the soul. Clearly, however, Socrates himself had remembered it long ago. He knew it perfectly well when, step by step, he led the boy to recall it. One could say that it was a little disingenuous for him to say that he knew nothing. But I would not hold this against him. Much as the Zen masters, Socrates liked to shock his listeners into thinking. And

by saying that one simply *remembered* the "true" ideas, he could skirt the problem of how we come to learn them.

Put bluntly, the "learning paradox" is the paradox of how one might know something one does not yet know. In times and places where science has not been weaned from metaphysics, Plato's theory of metempsychosis may have seemed a satisfactory resolution. But the notion that the gods instilled all "real" knowledge into the first human beings and that it is transmitted with their souls from generation to generation, seemed too fanciful to most modern philosophers. Yet, Chomsky succeeded in launching an analogous theory, replacing the gods with the principle of genetic determination. According to the new version, abstract knowledge is supposed to lie dormant in the human genome, waiting to be triggered by experiential stimuli. How such knowledge came to evolve in the first place, remains no less mysterious than divine providence. Therefore the question how individuals might come to possess it, once more intrigues a good many people.

The Source of the Paradox

In 1985, Carl Bereiter published a paper with the title "Toward a solution of the learning paradox". It became famous and served as basis for countless discussions. But it did not lead to a solution. In my view, this was due to the fact that Bereiter unquestioningly accepted the problem as it had been formulated by Fodor ten years earlier at the unfortunate meeting of Piaget and Chomsky at Royaumont in 1975. I call this meeting unfortunate, because the 25 authorities who took part in it – all experts in cognition and communication – managed to talk past each other in a manner that was both spectacular and tragic.

The learning paradox was presented by Fodor as follows:

… it is never possible to learn a richer logic on the basis of a weaker logic, if what you mean by learning is hypothesis formation and confirmation. … There literally isn't such a thing as the notion of learning a conceptual system richer than the one that one already has; we simply have no idea of what it would be like to get from a conceptually impoverished to a conceptually richer system by anything like a process of learning. (Fodor, 1980, p.148–149)

Fodor claimed – and Bereiter followed him – that hypothesis formation is an *inductive* process. This is a technical expression of the wide-spread view that researchers who create new knowledge spend considerable time collecting "data", and that the examination of these data then induces the hypotheses they set up. This induction, Fodor asserts, is only possible if the logical structure of the hypothesis was in some form already present in the researcher.

Les Steffe has politely but effectively argued against this contention by presenting a number of careful microanalyses of children's generation of novel conceptual structures in the context of counting and elementary arithmetic (Steffe, 1991, pp.26-44).

As a radical constructivist I could take a much cruder and more "radical" path and begin by saying that, far from being *given*, what is called "data" can be seen as the result of the experiencer's own construction. From that perspective, conceptual

learning begins at the very outset of the child's cognitive career, at least at birth, but probably already in the womb. And instead of remembering innate "true" ideas, the child has the innate tendency to search for "Rhythms, Regulations, and Groupings" (Piaget, 1947, title of Conclusion) and to test its constructs for their viability in actual experience. But I will not pursue this line of argument here.

Instead, I shall try to show, first, that forming hypotheses does not have to be an inductive process; and second, that every induction (and generalization) requires a conceptual jump that is not *given* by the data but constitutes a small but genuinely creative act on the part of the observer.

The Notion of "Abduction"

The logic of creative acts has been studied and clarified by Charles Peirce, who coined the term "abduction". He added it as a third kind of inference to the traditional logical patterns of induction and deduction. In induction, thought moves from a plurality of experienced cases to a rule. In deduction, it moves from a rule to a case at hand. In abduction, a hypothetical rule is generated from a single case. Peirce described this novel pattern as follows:

• The surprising fact C is observed
• But if A were true, C would be a matter of course
• Hence, there is reason to suspect that A is true

(Peirce, 1931–35; 5.189)

In Peirce's formulation, "A" stands for a hypothetical rule invented at the spur of the moment. To become viable as explanation and for making predictions, this new rule must then be tested in the course of further experience – a kind of induction in reverse. If it turns out to be false, other abductions have to be made, until one is found that fits the experiential facts. In principle, this is not unlike natural selection in the theory of evolution. The big question, then, is: *how are such hypothetical rules invented?*

At the end of his initial presentation at Royaumont, Chomsky referred to "the principles, now unknown, that underlie what Peirce called 'abduction' ... I see no reason to doubt that here, too, there are highly specific innate capacities that determine the growth of cognitive structures,..." (Chomsky, 1980, p.52). Saying that he sees no reason to doubt such highly specific innate capacities, implies that he starts by assuming them. This is where we disagree. Assuming a capacity to be innate is a quick way to avoid further investigation. No one doubts that any theory of cognition has to assume *some* innate capacities, but the *less specific* these capacities are, the more powerful the theory will be.

The first computers that were able to carry out complex mathematical operations had some "innate", i.e. built-in, capacities. They were three extremely general ones: recording binary digits, reading binary digits, and comparing them. I prefer to start theory construction with such simple assumptions and not to add more specific ones unless I get hopelessly stuck.

In abduction, where it is a case of inventing hypothetical rules, it has been suggested that analogy may be one possibility. This seems to me a reasonable suggestion. Let me give an example.

How did people come to have the notion that the sun goes *round* the earth? I do not think that this is much of a mystery. It may have happened long before the invention of the wheel, when we were still living in caves. In that non-technological world, there were not many rotational motions to be seen – eddies in streams, perhaps, and a whirlwind here and there. But the cave dwellers' children sometimes rushed out in the morning and played among the trees. One who felt particularly lively would pick up a dead branch and swing it round and round, as the chimpanzees occasionally do in their famous "rain dance". And when this happened, any observer could see the end of the branch coming up at one side, moving in a semicircle, and disappearing in the high grass on the other side. – Every day, the sun appears in the East, moves up in the sky, and disappears in the West, setting at a point opposite to where it rose. To see this movement as a rotation, requires the conception of an analogy. What has to be assumed *innate,* therefore, is no more than the capacity to remember experience, reflect on it, and to make comparisons.

The Generalizing Abduction

There may be other ways of intuiting a rule on the strength of a single observation, but I would suggest that the conception of analogy can explain a great many such intuitions (especially in the acquisition of language). *Which* aspects of the experiences are to be compared and found to be analogous, is not *given* – it is a conceptual step of generalization.

This brings me to a point where I may diverge from Peirce. He said that both abduction and induction differed from deduction because neither of them could produce logical certainty. And he also held abduction to be "entirely different" from induction, because the second involves probability, whereas the first does not. Yet, he also held that generalization could be the outcome of an abduction that is then tested inductively (Fann, p.34). I want to go a step further and suggest that every inductive inference contains an implicit abduction.

Take the notorious example of an inductive generalization: "All swans are white". How would you come to make it? The obvious answer seems to be that you look at a certain number of swans, notice that they are all white, and conclude that probably all swans you are going to see in the future will also be white. Why did you pick whiteness as the generalizable property? There are many others you could have chosen. The first swan you actually saw had a head and two feet, a long neck, a dark beak, a nicked tail feather, and many other properties, that you might have looked for in the swans that followed. But you chose color as a candidate for a common feature. This choice, I would say, was a kind of abduction, because at some point along your swan-experiences you must have decided to check whether all of them were white.

An Interpretation of Scheme Theory

You may be wondering what all this might have to do with scheme theory. I was reinforced in making the connection by Inhelder's remark that schemes can be procedural "in that they employ procedures of invention and discovery, heuristics that assure innovation." (Inhelder and de Caprona, 1992, p.42). This fitted perfectly with my conception of the scheme.

As I see it, a sensorimotor scheme consists of three elements. There is a *perceptual situation*, an *activity* associated with it, and the *result* the activity is thought likely to obtain. Piaget derived this pattern from the traditional notion of the reflex which is usually described as consisting of two elements: a stimulus and a fixed response. He was struck by a couple of things about this. First, in order to explain the phylogenetic development of reflexes, it was necessary to consider the result of the activities they trigger. To fit reflexes into the theory of evolution, their results had to favor survival or procreation. Second, he observed that the infant's reflexes were not nearly as immutable as they were said to be. Most of them are amenable to some modification, as the child grows up. He concluded that the three-step pattern of the reflex could be applied to sensorimotor action in general. All that had to be added, was the actor's expectation of the result. The pattern of the scheme therefore, in my view, looks like this:

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     1                    2              3
PERCEIVED  → ACTIVITY  →  EXPECTED
SITUATION                 RESULT
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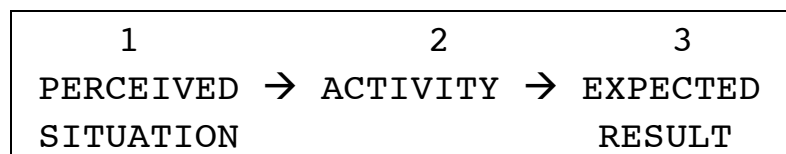
Having thus become a goal-directed phenomenon, it provided a perfect context for the functioning of assimilation and accommodation. As in the reflex, every implementation of an action scheme requires the acting subject to recognize a triggering situation. Such a recognition is of course an assimilation, because no two situations in a subject's experience are ever quite the same.

Assimilation plays a role also in the third part of the scheme. If a scheme is to be considered successful, the actual result of the activity must be such that it can be assimilated to the expected one. If it is not, this is likely to cause a perturbation which may be disappointment or, if the unexpected result is in some way interesting, it may be a pleasant surprise. In both cases, the perturbation may lead to a focusing of attention on the initial situation. If, then, a formerly disregarded characteristic of the triggering situation is taken into consideration, this may bring about a modification of the conditions that determine the triggering of the scheme; or it may bring about the formation of a new scheme. Both are instances of accommodation; and if the accommodation were done consciously, it would be an abduction, because, at the moment the changes are made, they are hypothetical in the sense that their usefulness has not yet been tested in further experience.

Children accommodate their action schemes by means of fortuitous choices quite some time before they begin to reflect on them consciously. However, the adult observer, who can and does reflect on the choices children make, can see in them the same abductive pattern as in later steps of cognitive development. Steffe cited the creation of non-Euclidean geometries as example, and many others can be found both in the historical and the individual development of mathematical thinking. I would therefore say that those who claim that non-inductively derived cognitive structures must be considered innate, owe us an explanation why some mathematical ones took so long to surface.

In his paper "L'épistémologie des regulations", Piaget discusses the developmental transition from the most primitive regular behavior patterns of biological organisms to "the self-regulation and self-organization of cognitive systems

that are able to engender their own programs and to create new ones" (Piaget, 1977, p.III). Only from the end of this development can it be seen as a "transition", because then the patterns can be "thematized" by reflection and considered qua "patterns" or "cognitive structures" irrespective of their individual content.

I would suggest that the pattern of abduction can be considered a mechanism (if not the principal one) that pervades cognitive development and makes it a relatively homogeneous progress. It appears in accommodations of action schemes on the sensorimotor level as well as in accommodations on the subsequent levels of concrete and formal mental operations. In my view it is the mainspring of creativity.

Conclusion

The point I want to make in the present context, is that it makes no sense to claim, as Fodor, Bereiter, and others have done, that because hypothesis formation is an inductive process, there is a "learning paradox" concerning all theoretical conceptual structures that cannot be gleaned directly from experiential data. As I hope to have shown, every inductive inference involves the spontaneous creation of an idea that may turn out to fit the "data" but was not actually inherent in them. The same is true of conceptual accommodations and even of many elementary accommodations on the sensorimotor level. In both cases there is a conceptual step that fits the pattern of abduction, a step that generates new knowledge whenever the abduction proves viable.

More important than all I have so far said may be an epistemological consideration. Scientific structuralism – that is, the attempt to analyze cognition, its processes and development in terms of mental structures – is neither a doctrine nor a philosophy, but, as Piaget put it, "essentially a method, with all this word implies with regard to technicality, obligations, intellectual honesty, and the progress of successive approximations" (Piaget, 1968, p.117–118). Consequently, we may conclude that the "learning paradox" springs from the technical assumptions that the formation of hypotheses is an inductive process and that induction cannot be the source of novel conceptual structures. I claim that these assumptions are unwarranted and as inappropriate in the domain of scientific explanation as they would be in philosophy or art.

Let me end by expressing my personal indebtedness to Bärbel Inhelder. Not having had the chance to talk with Piaget himself, I found in her an irreplaceable evaluator of my ideas. She was wonderfully open-minded and ready to discuss another's conceptions even if they did not always agree with her own. We are all constructivists, she once said, and we construct our own view of the world – what matters is that we try to be consistent in our thinking and that we are honest about it. The theory of schemes, she remarked, can be interpreted in more than one way – and this greatly encouraged me. I only hope that she would have considered what I have presented here as one of the possible interpretations.

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