6

CONSTRUCTING REALITY

Eysenck (1984) has suggested that experimental psychology has increasingly become synonomous with cognitive psychology and identifies Broadbent's 'Perception and Communication' (1958) and Neisser's 'Cognitive Psychology' (1967) as being seminal influences on the 'booming, buzzing confusion that is contemporary cognitive psychology.'

Neisser (1976), in turn, identifies the developmental studies of Piaget as offering an alternative to earlier behaviouristic models of human behaviour, claiming that 'human nature is too important to be left to the behaviourists....' (p.8). Central to Neisser's position is the concept of the schema, which has been developed extensively by Piaget.

> Although perceiving does not change the world, it does change the perceiver. (So does action, of course.) The schema undergoes what Piaget calls 'accommodation,' and so does the perceiver. He has become what he is by virtue of what he has perceived (and done) in the past; he further creates and changes himself by what he perceives and does in the present. 'Existence precedes essence,' as the existentialists say. (Neisser, 1976, p.53)

Jonassen (1985) sees the present situation as a shift from a behaviouristic, mechanistic psychology of human behaviour to that of an active, constructive psychology, with learners viewed as organized entities actively constructing their own reality. He sees Piaget's theory of cognitive development as being of major importance to the new educational technologies, particularly Piaget's dictum that knowing is a process of constructing systems of transformations that model reality and that mature 'operational' thought is the product of:

> successive constructions, and the principal factor in this constructivism is an equilibration achieved by autoregulations that make it possible to remedy momentary incoherences, to resolve problems, and to surmount crises or periods of imbalance by a constant elaboration of fresh structures.... (Piaget, 1971, p.40)

PIAGET'S CONSTRUCTIVISM

Piaget rarely directed his attention specifically to education. Primarily he considered himself to be a biologist and a genetic epistemologist, indeed, he never really left biology even when he was so occupied with cognition.

For many years Piaget studied the water-snail, Limnaea stagnalis, which in tranquil water has an elongated shell. When moved to lakes where waves beat upon its shell, Piaget found that the young snail changes its shape, it contracts the muscles attaching it to rocks each time a wave breaks and eventually it becomes globular in shape. In time the snail's adaptation to the turbulent waters tends to become hereditary. Piaget moved some back to his aquarium where they retained their globular shape for many generations. For Piaget this is an example of how organisms may adapt genetically to novel surroundings. He does not fully subscribe to the Lamarkian heresy of the inheritance of acquired characteristics, but he disagrees with neo-Darwinian theory which sees organisms as essentially passive and dependent on chance mutation for adaptive change in the fight for survival. For Piaget, the adaptation is a dynamic, on-going process in which the hereditary structure of the organism interacts with the external environment in such a way as to reconstitute itself for better survival. Piaget (1971) identifies Waddington's (1957) theory of genetic assimilation as providing a basis for the mechanism by which such adaptive changes become genetically transmitted. This has led to Piaget's emphasis on the process that brings about progressive states of equilibrium: the dynamic, on-going self-regulating process which he calls equilibration.

His theory of cognitive development was presented in more than a hundred books and articles spanning more than fifty years. Many educationalists have been inspired by these writings, though Piaget has frequently pointed out that his ideas have not always been fully understood by such educationalists. Piaget's book 'The Science of Education and the Psychology of the Child' (1971) represents the fullest account of his thoughts on education. However, in order to understand these writings it is necessary to have a grasp of the basics of his theory.

Assimilation, Accommodation and Adaptation

Adaptation is a biological mode of functioning that characterizes all forms and levels of life. It consists of the dual processes of assimilation and accommodation, which go on continuously. Assimilation is the process of taking in from the environment all forms of stimulation and information, which are then organized and integrated into the organism's existing forms or structures. Accommodation implies modification of the structures of the organism so that it can adapt to the environment.

The young infant investigating his immediate environment, grasps, sucks, explores, probes and absorbs it, assimilating the experiences. But the environment, whether of inert objects or living things, resists, moves, rewards and punishes the infant, compelling him to accommodate, to adjust to new and changing conditions, so that pre-existing patterns of behaviour are modified to cope with new information or feed-back from the external situations.

Piaget states that intellectual growth is propelled by disequilibrium, by a failure of accommodative and assimilative processes to keep pace with one another, by failure of the child's models of the environment to suffice in coping with newly learned complexities of that environment, giving rise to the jest that it is the 'trouble theory of development.'

Assimilation, Accommodation - an example:

If I present you with the following numbers: 2 and 4, and ask you to decide what the next number is, you will probably form the theory that this is a progression of even numbers and therefore that the next number in the series is 6. When I tell you that you are correct you assimilate this information into your theory. The information fits. I now ask you to provide the next number in the series and you will probably surmise that it is 8. However, this time I have to tell you that your answer is wrong and that the correct answer is 10. You are now in a state of disequilibrium, to use Piaget's terminology, and until you accommodate to the new information you will remain in disequilibrium. In order to attain a steady state or equilibrium you must re-organize your theory, in order to reach a balance between assimilation and accommodation. You can see why it is called the trouble theory of development. The progression is achieved by adding the last number to the penultimate number in the series, so the next will be 10 plus 6. We can summarize this cognitive process by saying:

> because of the intellect's organisation it exhibits adaptation, a two-way process comprising accommodation and assimilation.

Physical, Logico-mathematical and Social-arbitrary Knowledge

The concept of equilibration is a dynamic one, and it is therefore necessary to indicate what upsets the organism once it has achieved equilibrium. The first dynamic factor is maturation, the physiological growth of the genetic organic structures. Maturation only opens up future possibilities in Piaget's scheme, experience is also necessary to actualize the potential, experience derived from commerce with the environment. These interactions with the environment lead the child to construct two different kinds of knowledge: physical and logico-mathematical.

Physical knowledge is associated with the results of actions on objects: touching, lifting, throwing, hitting, smelling etc. To construct this knowledge the child must have repeated active experiences in which he carries out manipulations of objects. When constructing physical knowledge the physical properties of the objects themselves correct or reinforce the child's learning. Implicit in Piaget's conception of the development of the child is the idea that children acquire knowledge about the physical properties of objects by manipulating the objects and that all other ways of coming to know objects are qualitatively inferior. Reading about or listening to someone talk about an object cannot provide the quality of physical knowledge that can be acquired by active manipulation, a fact that is acknowledged by Gagné:

> The great value of concepts as means of thinking and communicating is the fact that they have concrete references.... but since concepts are learned by the human being via language, there is often the danger of losing sight of this concreteness. Learning can become over-verbalized which means that the concepts learned are highly inadequate in their reference to actual situations. The learner does not really know the meaning of the word even though he can use it correctly in a sentence. (Gagné, 1970, p.187)

Logico-mathematical knowledge is derived from acting upon objects, but does not come from the objects themselves, it is constructed from the child's actions on the objects. Logical relationships are constructed in the child's mind, such as higher, lower, faster. Mathematical relationships also are not implicit in objects but are constructed by the observing or counting child. Number and number-related concepts are logico-mathematical types of knowledge, but number is not a quality or characteristic of an object, it is an invention of each child.

Of course, physical knowledge and logico-mathematical knowledge develop in an inter-dependent manner, being tied together in their formation.

The third factor contributing to cognitive development is the transmission of social-arbitrary knowledge. Here information is learned from other children or transmitted by parents, teachers, or books in the process of education. Children learn language, values, rules, morality and symbol systems, in fact social-arbitrary knowledge is everything that is handed on from generation to generation, that which constitutes the essential foundation of human society. Piaget believes that when a child hears contradictory statements concerning this realm of knowledge his equilibrium is disturbed, effecting a search for an answer which will reduce the cognitive conflict.

It is the equilibration process which co-ordinates and regulates the three factors of cognitive development (maturation, experience and social-arbitrary knowledge), bringing about progressive states of equilibrium. Equilibration is the organizing factor underlying all biological and intellectual development.

The Relation between Subject and Object

An implicit assumption in behaviourist, stimulus-response psychology is that knowledge is a copy of reality. It is also a frequent assumption of traditional and conventional educational practice.

Piagetian thought provokes the question: is knowledge a copy of reality or is it a unique, individual construction? The traditional view has been that knowledge is a directly acquired copy of reality, the child was thought to incorporate accurate images of the real world directly. The latest ideas in cognitive psychology reject this idea. As Neisser (1967) puts it in his ‘Cognitive Psychology’:

> Whatever we know about reality has been mediated, not only by organs of sense but by complex systems which interpret and re-interpret sensory information. (Neisser, 1967, p.3)

Piaget’s major contention is that each individual constructs reality, and for each child this is a unique construction: and this is what he means when, in ‘The Science of Education and the Psychology of the Child’, he says:

> Knowledge is derived from action, not in the sense of simple associative responses, but in a much deeper sense of assimilation of reality into the necessary and general co-ordination of action. To know an object is to act upon it and transform it.... intelligence consists in executing and co-ordinating actions, though in an interiorised and reflective form. (Piaget, 1971, p.28-29)

For Piaget, children’s conceptions develop from those initially based on limited information - unrefined and frequently inaccurate schemes - to increasingly more accurate and refined schemes. The essential functions of intelligence consist in understanding and inventing, in other words of building up structures by structuring reality.

In relation to the different types of knowledge that may be acquired Piaget (1971) describes two aspects of thinking that are different but functionally related: the figurative aspect and the operative aspect.

Figurative Knowledge

The person looking at a tree sees it figuratively, but in his mind he also conceives it as alive, breathing, having roots, branches etc. These latter aspects are operative conceptions that go beyond the limitations of the former figurative knowledge. Figurative thoughts are perceptions, imitations, mental images, those aspects of thought that deal with states as they appear in the senses. They are the thoughts that occur at the time of perception of external objects, or at the perception of mental images. When we look at an object and our thought produces identification of that object - that is figurative thought.

A child looking at a tree sees leaves, branches etc: what she sees is figurative knowledge about the tree.

Operative Knowledge

Operative thought is the product of perceptions (figurative) and intelligence. Operative knowing is the product of transformations of states resulting from actions. It is the organization, consolidation and interaction of figurative knowledge, and intellectual development can be characterized as the growth of operative knowledge.

Operative and figurative knowing are related. Figurative knowledge feeds the development of operative knowledge - it is its source. And, of course, changes in operative knowing result in changes in our subsequent perceptions. Thus, the child looking at the tree who realizes that it is alive (operative knowledge) looks at it in a different way and no longer gets the same figurative knowledge.

The Theory of Stages

According to Piaget, the organization of intelligence changes qualitatively in several stages throughout the individual’s life. Similar conceptual processes are thought to account for strategies employed at each stage.

The order of the stages is fixed, each stage being regarded as essential preparation for the next one. In part, the stages are a result of maturation of the nervous system of the growing child. However, maturation is necessary but not sufficient for cognitive development: biological maturation does nothing more than open the way to possible constructions. It is interaction with the environment which actualizes them. Piaget acknowledges that some pedagogical interventions can accelerate and complete development (the American question according to Piaget) but they cannot change the order of constructions. There are also untimely pedagogical interventions such as teaching children to count before they have any concept of number.

Piaget (1970) identifies three principal periods of

Figure 6-1. Piagetian Stages of Cognitive Development.

		MENTAL AGE
I	SENSORIMOTOR PHASE	0 - 1.5 years
II	PRE-OPERATIONAL PHASE	1.5 - 7 years
	(i) Pre-conceptual stage	(1.5 - 4 years)
	(ii) Stage of intuitive thought	(4 - 7 years)
III	CONCRETE OPERATIONS PHASE	7 - 11 years
IV	FORMAL OPERATIONS PHASE	11 years and over

development: a) a sensori-motor period, which lasts until approximately 1.5 years of age; b) a period of representative intelligence which leads to concrete operations, running from 1.5-2 years to 11 years; c) finally, a period of propositional or formal operations, starting at about 11 years. There are, however, various sub-divisions, each of which is identified by particular cognitive characteristics (Figure 6-1).

Sensorimotor Phase

During the initial eighteen months of life the child begins by exercising its inborn reflexes and eventually co-ordinates its actions and perceptions to form acquired adaptations. In later life, in the school, the child will deal with his environment chiefly through his thoughts; the baby deals with it through its senses and motor activity. It is a period of pre-linguistic intelligence which allows, even without the use of language, certain rudimentary constructions, such as learning that objects are conserved and the development of notions of space and time. It is this period of child functioning that enables Piaget to place such emphasis on actions as the roots of logical operations.

> Turning to the question of the relations between language and logical operations, we have always maintained that the origin of logical operations is both deeper than and genetically prior to language; that is, it lies in the laws of the general co-ordinations of action, which control all activities including language itself. (Piaget, 1970, p.722)

Pre-operational Phase

This phase is divided into two stages. During the first, the pre-conceptual stage, the child represents one thing by another, plays games of pretence, plays some constructional games, draws and talks, learns letters and may read and write, but forms no true concepts and is considered to be egocentric. The child makes its first attempts at generalization at this stage, forming 'pre-concepts', which fall somewhere between mental images and true concepts (Pulaski, 1980). A pre-concept reveals the confusion between a class of objects and its members: one man is Daddy, so all men are daddies; one slug is much like the next, so the child will say 'There's the slug' on seeing one, and 'There's the slug again' on seeing another a few yards further on.

The second stage, the intuitive stage, starts at about four years. The child begins to form concepts but only sees one relationship in complex arrays and is dominated by perceptual judgements. The intuitive stage is so-called because it lacks the stable, reversible character of true operational thinking. It is typified by non-conservation in one of Piaget's most famous experiments. One of two glasses is partially filled with a liquid, and the second glass is then filled up to the same level. The child is asked if there is the same amount in both glasses, and adjustments are made until the child agrees that there is the same amount. The liquid from one of the glasses is now poured into another vessel, which is narrower and taller. To the question 'Is there more, less or the same amount?' in the tall, thin vessel, the child will reply that there is more, justifying the answer by focusing on a single dimension, even when the liquid is returned to the original glass.

During the pre-operational phase the child focuses his attention on the separate states or configurations of an array rather than on the transformations by which one state is transformed into another and such mental images as exist move slowly from one static configuration to the next, with no reversibility or flexibility, rather like slides in a projector. These are the figurative aspects of thought, in contrast to the operative aspects which are dynamic, related to transformations and external or internal actions.

Concrete Operations Phase

During the period from seven to eleven years physical actions are replaced by mental operations, the child forms classes and series but still works by trial and error, does not plan ahead and has difficulty with verbal definitions.

The child's mind at this stage is still tied to concrete experiences, even though hypotheses may be formed which go beyond the concrete evidence before them. Conservation, first of substance, followed by weight and then volume, is crucial to this stage. This requires an operational knowledge of reversal and involves the crucial process of decentring.

The child is capable of forming consistent classifications as concepts, rather than the pre-concepts formed by transductive reasoning in the previous stage. Related to classification is the ability to order similar objects according to size or position, a process known as seriation.

There are limitations in verbal reasoning, and when asked to use verbal propositions instead of objects, children at this stage tend to consider one statement at a time, just as children in the intuitive stage consider one relationship at a time when dealing with objects. The result is that concrete operational children have difficulty with such problems as: Edith is fairer than Susan; Edith is darker than Lily; who is the darkest of the three? They reason that Edith and Susan are fair, Edith and Lily are dark, therefore Lily is darkest, Susan is fairest, with Edith in between.

Related to the difficulties experienced with interiorized verbal reasoning is the difficulty in planning, especially in scientific experiments where the child tends to work by trial and error, rather than in a systematic manner.

Formal Operations Phase

The highest levels of thinking found in this phase are only possible when the child can follow the form of an argument without having the concrete materials at hand. This is the stage at which children begin to reason hypothetically, in the absence of material evidence. Hypotheses can then be tested to determine real solutions amongst possible solutions, a process known as hypothetico-deductive reasoning.

There is no higher phase than formal operations, and this represents the peak of human cognitive development, the functioning of the mature organism. Although it may represent the final phase, it does not follow that all adults actually achieve the full potential of this phase, indeed, many adults may remain in the previous stage and fail to show those characteristics associated with formal operations: reasoning increasingly in verbal propositions, making hypotheses which they test, planning ahead, seeking to explain events, considering many possibilities and looking for general laws.

PIAGET AND EDUCATION

Active Methods

In 'The Science of Education and the Psychology of the Child', Piaget acknowledged that direct instruction and imposed labour are a necessary part of education but he emphasized that educational programmes should 'give rise to active manipulation and discovery by the child itself.' Piaget is saying that basic operational structures of intelligence are not acquired through instruction but must be invented by the child. Furthermore, the child must reach an appropriate stage of maturational and intellectual readiness before she will be able to develop new structures of thought. The goal for education, according to Piaget, is to produce individuals who are critical, creative and inventive discoverers. So a major part of the child's learning depends on experimentation and discovery.

Piaget states that an active school is not necessarily a school of manual labour and, although a child's activity at certain levels necessarily entails the manipulation of objects, at other levels the most authentic research activity may take place in the spheres of reflection requiring the most advanced forms of abstraction or verbal manipulations.

A criticism of such methods has been that they inevitably lead to anarchic individualism, but Piaget counters this by suggesting that far from this, they actually help to combine individual work and team work, and encourage self-discipline and voluntary effort.

At the time of writing 'The Science of Education and Psychology of the Child' (1971) Piaget felt that although active methods were gradually becoming accepted, no great progress had been made because of the difficulty of putting them into practice when compared with receptive methods. Active methods require much more varied and concentrated work from the teacher, whereas giving lessons is less demanding and tiring, and corresponds to a much more natural tendency in the adult generally, and in the adult pedagogue in particular.

Also, an active pedagogy presupposes a much more advanced kind of training and without an adequate knowledge of child psychology the teacher cannot properly understand the students' spontaneous procedures and therefore fails to take advantage of reactions that to him seem quite insignificant and a mere waste of time. Piaget claims that 'the heart-breaking difficulty in pedagogy... is, in fact, that the best methods are also the most difficult ones' (1971, p.69).

The active classroom has been associated with the term progressive teaching, which has pupils in an active role, learning predominantly by discovery techniques, with an accent on creative expression. Subject matter tends to be integrated, with the teacher acting as a guide to educational experiences and encouraging co-operative work. External rewards and punishments are seen as being unnecessary, and there is not so much concern with traditional academic standards and testing.

Receptive Methods

Piaget compares active methods with receptive methods, which are also referred to as traditional methods of teaching, in which the child is the passive receiver of information transmitted by the teacher. The danger with such methods, according to Piaget, is that the resulting knowledge will frequently be rote learned and not fully understood. In other words, receptive teaching methods lead to a predominance of figurative knowledge rather than the higher goal of operative knowledge.

Receptive methods place greater emphasis on the creative role of the adult, with a consequent emphasis on the transmission of knowledge by the teacher, rather than the constructive role of action which leads to placing an essential share of importance upon the activities of the student.

The accent is on memory, practice and rote learning, with a concern for regular testing and competitive, academic standards. The pupils are essentially passive and there is little emphasis on their creative expression.

Intuitive or Audio-visual Methods

Periodically emphasis has been placed on the role of audio-visual methods, according to Piaget. He uses the term 'intuitive' for such teaching methods, equating the function of audio-visual aids with the 'intuitive stage' in his developmental scheme, a period before operative thought is established, and during which figurative aspects of knowledge predominate. He accuses well-intentioned pedagogues of using such aids and believing that they have reached the summit of educational progress when, in fact, they are multiplying intuitive figurations in forms that no longer have anything active in them.

Piaget quotes an experiment which illustrates the dangers of these 'intuitive figurations.' He compared the memories that groups of children retain of a grouping of cubes, according to whether the cubes had been:

1. simply looked at
2. reconstructed by the child itself
3. constructed by an adult while the child watched.

Piaget found that the direct experience is superior (Piaget, 1971, p.35), and the demonstration by an adult is no better than the simple observation of the completed grouping. Thus, Piaget concludes, by carrying out experiments in the child's presence, either as demonstrations or on film, instead of making him carry them out, one loses the entire informational and formative value offered by direct action.

Piaget goes on to suggest that an additional reason why active methods have not been taken up is the confusion that sometimes occurs between active and intuitive methods: that they are either equivalent or at least the intuitive methods produce all the benefits that can be derived from the active methods. This arises from two confusions:

1. that any activity on the part of the student or child is a matter of physical actions. This is only true at the elementary levels, not in the later stages when a student may be totally active in the sense of making a personal rediscovery of the truths to be acquired, even though his activity is being directed toward interior and abstract reflection
2. a belief that an activity dealing with concrete objects is no more than a figurative process, in other words nothing but a way of producing a sort of precise copy in perceptions or mental images of the objects in question.

In other words, some audio-visual theorists believe that a mechanical copy of an object or situation, as in a film or still picture, enables the child to gain knowledge of the object or situation. This is not so, as the experiment with the blocks revealed, knowledge is not at all the same thing as making a figurative copy of reality for oneself, it invariably consists of operative processes leading to a transformation of reality, ie. knowledge goes beyond the surface appearances.

Piaget is complaining about the rote-learning aspect of education, whereby the student makes a figurative mental copy of, for example, the stages of Piagetian theory, which are then duplicated in the examination or essay, without attempting to fit this information into previously acquired knowledge and experience in order to transform the old and new information in the process of thinking which leads ultimately to understanding.

Thus, intuitive methods merely provide students with speaking visual representation either of objects or events themselves or of the result of possible operations, but without leading to any effective realization of those operations. Piaget says that these methods are traditional methods which are continually reborn from their own ashes.

He concedes that they do certainly constitute an advance in relation to purely verbal or formal techniques, but they are totally inadequate in developing the child's operative activities and it is only as a result of a simple confusion between figurative and operative aspects of thought that it has been believed possible to pay tribute to the ideal of the active methods while at the same time giving concrete form to the subject matter of education in this purely figurative guise.

He relates this to the use of Cuisenaire rods, which are capable of being used in diametrically opposed ways:

1. a genuinely operative method, in which the child spontaneously manipulates the rods and forms configurations which lead to true operative understanding

2. intuitive or figurative methods, in which the teacher demonstrates and explains configurations laid out by the teacher rather than the child.

He also describes the use of a film to demonstrate geometrical concepts, including an illustration of Pythagoras's theorem in which the 'relations involved acquired visual clarity worthy of the highest praise.' But, Piaget asks 'Is this really training the child in geometrical reasoning and in operative construction in general?'

Pedagogy based on the image, even with the apparent dynamism of the film, remains inadequate for the training of operational constructivism, because intelligence cannot be reduced to a series of images on film. Piaget suggests that it might more correctly be compared to a series of cybernetic mechanisms ensuring a continuous flow of images by dint of auto-regulating and auto-correcting processes. This in turn leads to the conclusion that computer simulations with interaction between student and the machine may be more acceptable to Piaget.

Programmed Methods

Piaget's views of the figurative, rote-learning aspect of education are developed more fully in his criticisms of behaviouristic psychology, particularly as applied as an educational psychology. Piaget has this to say about behaviourism:

> This empty box conception of the organism, as it has been called, thus deliberately thumbs its nose at all kind of mental life, human or animal, and confines itself solely to behaviour in its most material aspects, ignoring any possible search for explanations in order to concentrate exclusively on the broad laws revealed by scrupulously detailed experimentation.
> This being so, Skinner, already in possession of the laws of learning he had personally verified or evolved, and freed of any theoretical preoccupations that might have hampered his testing of their general or practical application, observed in the first place that his experiments always worked much better when the interventions of the human experimenter were replaced by efficient mechanical apparatus. In other words, the pigeons produced much more regular reactions when dealing with teaching machines capable of applying the stimuli with greater precision and fewer minute variations. Skinner, a teacher by profession as well as a learning theorist, then had the brilliant idea that this observation of his would be equally valid when applied to humans, and that teaching machines, provided they were sufficiently well-programmed, would produce better results than an oral method of teaching susceptible of great variation in its application. And since the empty box conception of the organism renders so many preliminary considerations of the internal factors of human learning unnecessary, it was sufficient to be familiar with the general laws of learning and with the subject matter of the branches of knowledge to be taught, in order to construct programs at least equal in content to the body of knowledge commonly acquired.
> The experiment was tried and proved a total success. And it goes without saying, if we confine ourselves to the usual methods of teaching by means of verbal transmission and receptive processes, that it could not fail to succeed. (Piaget, 1971, p.76-77)

Piaget does have some good words for Skinner's machines because they 'provide evidence of good psychology in that they make use exclusively of positive reinforcement and dispense totally with negative sanctions or punishments.' Further, he is not saddened by the fact that school teachers can be replaced by machines because this demonstrates the mechanical nature of traditional teaching methods, which merely require the repetition of what has been transmitted. The machines may even demonstrate the failure of traditional methods to accomplish their rather limited aims.

Piaget also appreciates the greater intensity of motivation found with machines than that found in many traditional lessons and questions whether the teacher's affectivity always performs a desirable function. He is, in fact, much more positive about teaching machines than may be anticipated from some of his earlier remarks:

> In a time of great increase in student population and the scarcity of teachers they (teaching machines) are able to render undeniable services, and, in general, save a great deal of time in comparison with traditional methods of teaching. They are used not only in schools but also in commercial concerns where, for one reason or another, a necessity exists for rapid instruction of adults.
> Generally speaking, since every discipline must include a certain body of acquired facts as well as the possibility of giving rise to numerous research activities and activities of re-discovery, it is possible for a balance to be struck, varying from subject to subject, between the different parts to be played by memorizing and free activity. In which case, it is possible that the use of teaching machines will save time that would have been needlessly wasted by more traditional methods and therefore

> augment the number of hours available for active work. So that, particularly if the periods of active work include team work, with all that such work entails in the way of mutual incentives and checks, while the machine pre-supposes an essentially individualized kind of work, then this balance would at the same time be realizing yet another necessary kind of balance: that between the collective and individual aspects of intellectual effort, both so essential to harmonious school life. (Piaget, 1971, p.78-79)

Thus, according to Piaget, there is room for programmed instruction, provided it is realized that it will be useful only in terms of acquiring facts (in a figurative manner). There must also be opportunities for activities and particularly manipulations which will lead to acts of discovery or re-discovery for the development of operational knowledge of a subject. But, such activities should not be misconstrued as being related to the use of audio-visual aids, which are perceptually dominated intuitive methods, producing figurative knowledge rather than true operational processes.

Research and Evaluation of Piagetian Theory

Piaget's contribution to cognitive psychology offers a considerable challenge to educational technology, because it personifies an alternative 'world-view' of educational matters. The emphasis is not on mechanical copies of reality as the basis of knowledge and understanding, but on active, or rather inter-active, processes of construction. Hence the choice of his 'cybernetic' analogy for intelligence in opposition to the mechanical film analogy. Piaget's view offers, in many ways, a richer framework for viewing cognition because it is based on a more complex model, which in turn has benefitted from richer conceptualizations and analogies than those available to the early behaviourists.

There have, however, been many criticisms of Piaget's theories and their educational applications, and it is necessary to take these into account before reaching a final evaluation of the potency of Piagetian ideas for educational technology.

It is necessary to point out that the age ranges given for the various stages are subject to substantial variation, predominant culture having a particularly strong effect. Shayer's (1978) investigation demonstrated the degree to which pupils in London comprehensives attained formal operations according to Piaget's time-scale. In fact, only 5.6% of 11 to 12-year-olds had reached the initial stages of formal operations, although many of the tasks demanded of students in the science classes were based on the assumption that a majority of pupils were in early formal operations, and could only be completed satisfactorily by the tiny minority of formal operational thinkers in this age range.

Clearly, the physical manipulation of objects and concrete experiences made available throughout the period of concrete operations, should also be available beyond the early years of secondary schooling and may even be required throughout the final years of schooling for many students.

There is some evidence to support the effects of manipulation rather than mere observation of manipulation by a teacher or instructor. For example, Macbeth (1974) found that the direct first-hand manipulative experiences in the development of process skills in elementary school science supported the theoretical literature that pre-operational children must operate on concrete objects, though such manipulations may be more important for younger rather than older elementary school children.

There is also some evidence in secondary school science provided by Gabel and Sherwood (1980). In this case students who manipulated molecular models made greater progress than those merely observing teacher manipulation of the models.

However, although there is some support for Piaget's emphasis on the need for manipulation and active involvement in learning, his ideas concerning heuristics or discovery learning have received little empirical support.

Certainly, advocates of discovery approaches, such as Shulman and Keislar (1966), have claimed that discovery motivates more effectively than receptive learning approaches, and Suchman (1961) claimed that:

> The need for improvement is great. Current educational practice tends to make children less autonomous and less empirical in their search for understanding as they move up the elementary grades. The schools must have a new pedagogy with a new set of goals which subordinate retention to thinking. (Suchman, 1961, p.151)

Whereas others, such as Skinner (1968), have pointed out that discovery learning is highly inefficient because it involves a relatively high degree of trial and error responding. Wittrock's review of research (1966) offers no conclusive evidence for assuming any advantage for discovery approaches. He suggests that as a way to learn a few specific associations, discovery learning may be inferior to more highly directed procedures, but with the learning of concepts and hierarchically ordered subject matter, discovery may fare better, as Gagne and Brown (1961) had found.

Brainerd (1977) in a sustained critique of Piagetian theory reviewed alternative learning approaches to the acquisition of conservation. According to Piaget teaching children concepts that have not spontaneously developed is completely useless, and he asks, is it good to accelerate the acquisition of these concepts anyway? Brainerd accuses Piaget of being transparently Rousseauian and suggests that Piaget's proposal 'all but trivializes learning research.' Further, he feels that Piaget's collaborators merely aim to confirm existing

Piagetian laws, rather than the discovery of new ones and this makes it difficult to become enthusiastic about experiments 'whose horizons are so limited.' What Brainerd calls 'tutorial methods', which includes all familiar procedures from classical learning theory and social learning theory, were universally condemned by Sinclair (1973) and early evidence (Smedslund, 1961; Wohlwill and Lowe, 1962) certainly showed no evidence for learning effects on conservation tasks. However, other methods have been devised, including simple correction, rule learning, observational learning and conformity training, all of which yield positive results. Conformity training places a non-conserving child with a group who are conservers. The group is asked to observe a conservation experiment and to discuss each question and comment on the result, but they are restricted to formulating a consensual answer.

Murray (1972) the originator of the technique found that 80% of pre-test non-conservers learned five conservation concepts and transfered these to two untrained conservation concepts. More recently Murray (1983) has commented on the fact that although shifts have generally been in the direction of conservation, there is no reason why the shift should not be in the other direction, according to social learning theory. However, although small numbers of conservers yield their position in the conformity situation, none revert to non-conservation on further tests, which means that there must be a powerful interactive effect between organismic maturation and the learning conditions.

There is no easy resolution of the two competing approaches because, as Murray (1983) concludes, 'each debater sees the child's deficiency or errors as due to a factor the other sees as tautological and non-falsifiable.'

On a different scale the Piagetian ideals of the active, discovery approach to teaching, have had a turbulent history when comparisons have been made with more traditional approaches. But, once again, there are different expectations associated with the two approaches. Lavatelli's 'Early Childhood Curriculum' (1970) concentrated on many concrete-operational concepts but did not show that a Piagetian programme produced a deeper understanding than any other system. Weikert (1973) found similar results, which were repeated in the purest of the Piagetian programs, the University of Wisconsin's 'Piagetian Preschool Education Programme' (Bingham-Newman, 1974).

Results from comparisons of approaches adopting many of the features associated with Piagetian methods have also been disappointing. Bennett (1976) ranged teacher styles along a twelve point continuum, from informal/progressive to formal/traditional, and identified a large group of teachers who closely matched the characteristics of the three major groupings: formal, mixed and informal. Data were collected for pupil performance at the start of the school year and then one year later on standard tests for reading, maths and English, together with measures for creative writing, punctuation and spelling, pupil behaviour and pupil personality.

The results indicated that pupils taught by formal and mixed styles show significantly superior progress as compared with those taught by informal styles, with the effect being more noticeable in average and above average achievers. In maths the formal style was superior to both mixed and informal, with the superiority existing at almost every level; and this result was confirmed in the English test.

The most difficult result for the progressive camp was not the fact that the more formal the teaching, the more time the students spent working on the subject matter at hand, hence the better the performance in reading, maths and English, but the fact that pupils in progressive settings did not perform at a higher level in their creative writing than their formally taught colleagues. Bruner (1976) who in much of his early writing had supported the discovery approach (Bruner, 1961) felt that the results indicated that 'common sense and technical inquiry are finally catching up with the romantic excess' and that 'new studies are now pointing to the critical role of the adult tutor, in social and intellectual development.' He did, however, urge caution in interpreting the results:

> The progressives' fallacy was the assumption that you arrive at the terminus immediately - self-directed from the start and not just later. Now we know better. Self-direction is wasteful if one does not know where one is going or why. But to swing back to a Prussian model of authoritarian teaching will only assure that the pendulum will keep going through its dull, historically repetitive trajectory. (Bruner, 1976, p.225)

In fact, Bennett's book encouraged a great deal of debate about the issue of progressive versus traditional teaching, and also about the actual techniques of data collection and analysis in such studies. Bennett undertook a re-analysis of the original data using more appropriate procedures (Aitken, Bennett and Hesketh, 1981) as did others (Gray and Satterly, 1981) and the results led to the conclusion that:

> First, the differences between teachers within styles were far greater than the differences between styles. Thus, one found 'effective' and 'ineffective' teachers, no matter which teaching style they adopted. Second, differences between teaching styles were so small as to be overwhelmed by differences between other systematic effects. And third, the direction of the differences between teaching styles did not consistently favour more 'formal' approaches over 'informal' ones. (Gray and Satterly, 1981, p.187)

These conclusions indicate that there is no easy answer to the progressive-traditional dilemma, certainly there seems to be no good evidence to support the superiority of traditional methods in reading, English and maths, and equally no more support for activities such as creative writing in the progressive classroom.

Aspects of this controversy are now emerging in the application of computers in education, in particular in the ideas of Seymour Papert and the ways in which the computer language LOGO should be used in the classroom.

PAPERT AND LOGO

Piagetian theory continues to exert an influence on teaching and the most recent form this has taken is the computer language LOGO developed by Seymour Papert, who describes in his book 'Mindstorms' (1980) the motivation which led to its creation:

> I take from Jean Piaget a model of children as builders of their own intellectual structures. Children seem innately gifted learners, acquiring long before they go to school a vast quantity of knowledge by a process I call Piagetian learning or learning without being taught. (Papert, 1980, p.7)

However, he does differ in some ways from Piaget, and takes maths as an example of a case where Piaget would explain the slower development of a particular concept by its greater complexity or formality; Papert sees the relative cultural impoverishment in those materials that would make the concept simple and concrete, as the major element. In the case of mathematics this leads to mathophobia! Papert argues that since it is easier to learn French in France, then it should be easier to learn maths in mathsland. LOGO has been developed to provide a mathsland where children encounter and solve fundamental mathematical problems while achieving simple goals like drawing a house or snail.

Papert observes that children learn to speak naturally and easily, but they do not acquire equal competence in mathematical activities. He suggests that the difference lies not in innate differences nor even in the amount of learning, but in the nature of the learning process itself: it consists of learning the manipulation of symbols in a manner alien to the child's experience, using an unsuitable technology (paper and pencil). With the right dynamic technology children can become real mathematicians, and the right technology is a computer with LOGO programming language. The computer can provide an interactive relationship, giving immediate feedback when errors occur, leading to meaningful learning of concepts in maths and other areas.

The method advocated by Papert is based on Piaget's learning by self-discovery, LOGO is a 'tool to think with' and the natural processes of learning should not be upset by teachers taking control. He argues (Papert, 1972) that the skills acquired during the design and debugging of programmes will be generalized, eventually being used to design and debug conceptual representations of problems. Papert feels that LOGO is capable of inducing general problem-solving strategies, rather than the 'domain-specific strategies induced from examples given by the teacher' (Howe, O'Shea and Plane, 1980).

There are many different ways in which any particular medium can be used in teaching, as Piaget (1971) noted, and LOGO is no exception. The Piagetian approaches adopted by Papert are 'horticulturalist' (Brainerd, 1978), with an emphasis on total intellectual growth derived from discovery learning, rather than traditional receptive methods which can only produce specific skills. Howe and his colleagues (Howe, O'Shea and Plane, 1980) adopt a more structured approach towards the use of LOGO. Howe (1979) has described his method as learning by model building, a process which enables students to learn about the underlying structure of an entity by building a model of it. Real learning is accomplished when the modeller can define a set of general principles which model a variety of entities. The structured approach developed by Howe is based on the following guidelines:

1. The teacher should always try to build on the child's existing knowledge.
2. The use of familiar materials (toys, pictures, apparatus) as manipulable models or metaphors makes teaching and learning more manageable.
3. Classroom teaching ought to be a partnership between teacher and child, with the child being given as much responsibility as possible for choosing, formulating and solving problems within the broad aims or objectives laid down by the teacher, in contrast to the very formal, rigid control used by many teachers.
4. Feedback of information to the learner is crucial, to check what has been done and to suggest what should be done in the event of failure.

There are many conflicting reports concerning the successes or failures of LOGO, and this arises from the different approaches to the nature of evaluation. Many studies have adopted an observational or case-study approach, following the pattern set by Piaget's method for obtaining data. Papert advocates taking a small group of pupils and working with them exclusively for the time required to test the new method, even in the face of protests from headmasters, teachers and school authorities. He claims that such a method would yield results so qualitatively different that the question 'How do you measure that?' would be meaningless, or the results would be so poor that it would be unnecessary to even ask the question. The Edinburgh group (Howe, O'Shea and Plane, 1980) disagree and have adopted a more formal assessment procedure, for as they say:

> .... we cannot ignore cost considerations, nor objections by educational authorities. In our experience, the most important constraint is the examination diet. (Howe, O'Shea and Plane, 1980, p.5)

Most of the research has concentrated on problem solving and the learning of mathematical skills, but in general results have been disappointing. Michayluk (1986) concludes that, methodology aside, there is little evidence of LOGO influencing such skills. In 1969, Feurzig taught algebra and arithmetic to 13-year-olds using LOGO, but with no overall improvement in their mathematics and Howe, O'Shea and Plane (1980) reported similar findings with bottom stream 11 to 12 year-olds, although they did find that the children became more self-confident and keener to discuss mathematics with teachers.

For many groups the lack of traditional experimental research data does not appear to cause any concern, their descriptive data leads them to the conclusion that LOGO does improve pupils' reasoning and problem-solving, and that the powerful ideas do generalize and transfer (Noss, 1983 and 1984; Hoyles, Sutherland and Evans, 1985). Hoyles and Sutherland's research indicates that LOGO can act as a catalyst for change in the classroom, but do caution that LOGO alone cannot make a poor learning situation into a good one: good organization is crucial. They conclude that LOGO is a powerful new tool for provoking reflection in pupils and that pupils learn to make use of the feedback that the computer provides. The emphasis is on the pupils having freedom to test out their conjectures and to develop their own styles of learning.

However, these are still early days for LOGO research, and it will be many years before a full appraisal will be possible.

Constructivism and Educational Technology

Structured or unstructured, there is a qualitative difference in the approach adopted by both practitioners when compared with behaviouristic methods. The purpose of education is the development of operative mental structures, rather than mere figurative, rote repetition, with children having much greater control over their learning activities. Educational technology must respond to the challenge of investigating these methods and the role such structures play in the development of the creative, innovative aspects of intelligence.

Behaviouristic and neo-behaviouristic methods may establish optimum learning of what is already known, but it is other methods, such as those advocated by Piaget and Papert, which may ultimately lead to the qualitatively different aspects of cognition associated with the invention of the presently unknown. Following the launching of the first man-made satellite by the U.S.S.R., on 4th October 1957, it was for just these reasons that Jerome Bruner's 'The Process of Education' (1960) became a best-seller in the early 1960's, in the U.S.

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