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LOGOS VIA PRAXIS:
A TENABLE SOLUTION TO THE PROBLEM OF LEARNING

by

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ABSTRACT

This thesis examines the epistemological background and implications of Seymour Papert's work in Mindstorms. The Genetic Epistemology of Jean Piaget is outlined in an effort to clarify Papert's philosophical position, who makes certain claims about the nature of knowledge and learning.

A major assertion of Papert's holds that contemporary social conditions are such that an aversion to mathematics and related forms of communicating ideas is commonplace. He maintains that it is precisely this kind of understanding that will allow individuals to participate fully and successfully in the modern world.

Futhering this idea, he presents the computer and his computer language, LOGO, as a means of counteracting the mathematical deficiency. In doing so, Papert is attempting to provide children, (or any LOGO user), with what he believes to be an appropriate means to generate a new psychological perspective.

The conclusion of this thesis attempts to reveal the degree to which Papert succeeds and where his program is most vulnerable.

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TABLE OF CONTENTS

Introduction

The purpose of this thesis is threefold: 1) to illustrate the major features of the genetic epistemology of Jean Piaget by comparing it to other positions, 2) to relate this to the work on artificial intelligence and children's learning pursued by Seymour Papert, and 3) to illustrate the educational implications of this research. The conclusions will be primarily concerned with the educational claims of Papert's theories as they relate to the learning ability of children and to demonstrate the importance of Papert's work. The main purpose of the paper will be to attempt to reveal the specific nature of Papert's claims about learning, and to point out both the strengths and weaknesses. At this time, when computer technology is making its initial advance in the classrooms, it is important that both educators and those who form educational policy take it upon themselves to carefully examine the theory, the capacities and the literature concerned with these devices before approving either their purchase or their use in the classroom.

While computers may eventually become invaluable classroom teaching aids, they are, at present, only beginning to prove themselves useful. There are a number of alternatives for most classroom applications which are equally or more effective and less expensive. Nevertheless it seems very evident that this technology will have a major role to play in the future of our society. For this reason alone, it is imperative that students become aware of at least the rudimentary forms of these devices and their capacities. This kind of knowledge, however, does not arise from the simple use of these machines, but from their study in a socio-cultural, philosophical context. Without this type of understanding on the part of each student and ultimately each citizen, these machines will remain, to the vast majority, a source of power and influence out of their control, subject to any number of misunderstandings about their purposes and abilities. In human terms, this could lead to profound mistakes in our choice of direction for our society. How should we, for example, prepare our children for the future? Should computers be used to compete with human labour, or should we direct our attention to creating computers that supplement it? How can we best prepare ourselves psychologically for the social impact of these devices?

There is, perhaps, a certain note of urgency that is characteristic of technologically advanced societies in these closing decades of the twentieth century. This sense may be described as an adherence to the belief in the technological imperative: Advances in technology directly correspond to the continuing health and well-being of the human race. From this premise a number of beliefs of potentially dubious value have arisen; that solutions to human problems will be brought about through the use of technology, that the future holds great promise only for those who are technologically aware, that specialized technical knowledge should be the central component in every sound education.(1) A great deal has been said in recent years about the necessity of introducing computers into the classroom. Indeed, many believe that an education without this particular component is less than adequate.(2) While there is little doubt that these instruments, by virtue of their great abilities to facilitate problem solving, to provide assistance with the immense task of storing and retrieving information, and to assist in the alleviation of much human suffering, there are many claims made about computers which cannot be substantiated. Many of these are made in the area of learning and learning ability and in particular, children's learning ability. As educators, we must select the most plausible, and subject them to testing before permitting their classroom application. Educators must examine these alternatives and place them in a carefully considered perspective.

There is another dimension to the problem, however, that deals not with the direct effects of the wholesale acceptence of technology as the classroom mentor, or as the omnipotent benefactor of human kind, but with the possibility that such an acceptance might lead to the neglect of other issues seemingly less spectacular, but perhaps more vital to both children and society.

The speed at which the devices of modern technology become an accepted part of the social fabric is ever increasing. In a similar way, the power and versatility of these machines is also increasing. As they become an integral part of everyday life, traditional habits and patterns are tailored to suit new needs. Instruments such as the telephone, radio and television, and the automobile have each profoundly altered our perspective of the environment by allowing us to interact with it in previously impossible ways.

In this age of scientific achievement, when society is laden with its many gifts, the most awesome of technological creations, the computer, stands apart, not only as a testament to the apparently unlimited power of science, but more importantly, as a device capable of transforming entire dimensions of human interaction. For the proponents of computers, such transformations are envisioned as positive events in which computers have assumed the most tedious roles in the workplace and have offered the most educational and entertaining roles in the home. For the detractors, the computer represents a threat to the unique and irreplaceable relationships created through simple human contact, and presents a challenge to the flexibility and creativity of the human intellect. Of this, the most that can be said is that computers, under intelligent direction may have the capacity to harness a number of hitherto evasive areas of interest to cognitive psychologists, researchers in artificial intelligence, epistemologists and others. These areas include topics such as the nature of intelligence, the mechanisms of the thinking process, methods of storing, retrieving and transmitting information, and the development of cognitive processes to name several. When used within the wider body of society itself, computers are equally capable of assisting in the extending or the curtailing of many individual freedoms.

Ultimately, however, it is not the computer itself that directs these changes, but the human forces doing the directing. It may be a truism to state that for whatever reasons, biological or environmental, among the variety of human tempermemts, there are two contrasting types of individuals: There are those who will choose to adopt innovations and use them to their advantage and those who will choose to resist change and remain in standard patterns of thought and behaviour. In terms of the computer, there are those who prefer to program the machine and design programs and those who would rather use preprogrammed packages. There are also those who will choose not to use computers at all. Not all students will want to learn the skill of programming. Nor should they be compelled to do so. Just as our culture needs electricians and welders, so too will it require those who can make computers work. In the same way that most people drive, the future will likely find most people using microcomputers. Not everyone is required to repair cars, however, and it will not be necessary for everyone to understand the intricacies of computer programming.

The final choice concerning the place of computer technology in society is a social choice. As individual members of the society we must take it upon ourselves to assist in making this choice and as educators, seek to counteract the biased viewpoints of interest groups, be they academic or business in orientation, so that the problem can be seen from an unbiased perspective. It may be that the role of the school in the issue of computers and education, is primarily one of developing in students a critical faculty so that they are capable of evaluating the relative worth of these machines. At present, however, the trend appears to be to attempt to impart at least a minimum of technical skills to all students as quickly as possible. One of the major problems with this approach is that the skills the students learn very quickly become outdated and no longer useful in the larger community.

The current perception in society that it is immediately necessary to move in this educational direction may find its origins not in an actual social need, but rather in the board rooms of corporations with vested interests in these kinds of products. As this perception becomes entrenched in the public mind, its veracity, as portrayed by advertising slogans and polished salesmen, seems to become all the more self-evident. The other issues, some of which relate to these machines, but some of which are quite autonomous, become less visible. In the evaluation of this issue, eductors must seek balance and attempt to distinguish actual value from contrived value.

This paper will attempt to bring the claims made by Seymour Papert about enhancing the learning abilities of children through the use of the computer into this type of focus. Papert makes two basic assumptions on which subsequent arguments are predicated: that the elegance and beauty of geometric design and operational computer programs will in themselves be motivation enough to induce children to continue programming and that the knowledge gained through programming a computer will be generalizable to other areas of intellectual and practical concern. The major goal of this exercise is, as seen by Papert, not simply to learn about mathematics or handling computers but to learn about learning.

While some aspects of these theories may be questionable, Papert brings to our attention what may be a fundamental oversight on the part of educators. There is a particular dimension in human learning which is generally overlooked by our school systems. Schools, ironically enough, do not consciously and systematically approach learning as a topic. Although we have any number of subject areas, each with its own set of skills and knowledge, the actual ability to learn is not one of them. It is certainly true, though, that much has been done to bring to the attention of the teacher the various conditions which facilitate learning in children. Indeed, educators are encouraged and even required to attend professional development days for the purpose of increasing their knowledge in these areas. But the study of learning, and of learning to learn, are not required classroom subjects. Exactly what children do when they memorize information, solve an unfamiliar type of problem, create a painting or write a poem is not generally used as classroom material and is certainly not part of any common curriculum. Children are, therefore, not given the formal opportunity to reflect on these processes.

Traditionally, we have understood special talents in academic, musical, or artistic areas as genetic traits passed on from parent to child. Papert challenges these kinds of assumptions. He claims that learning to think, and more specifically, learning to think mathematically, is as much, perhaps more, of a cultural than a biological phenomenon. It is a fact that we can greatly enhance our natural skills and qualities through special physical or mental exercise. The science of cognitive psychology has evolved to a state where mnemonic techniques for enhancing memory could be readily passed on to students. Similarly, the study of formal logic at an early age might assist students in their ability to examine verbal statements and claims. Other systems are available which attempt to present improved methods of problem solving or problem identification. Still others claim to develop the ability to think creatively or critically. Papert's central claim is that his computer language, LOGO, will enable children to develop their capacity to think. While some of these notions, like many of the claims made about the computer, may be greatly exaggerated, the central point is well-taken: Students are not presented with a clear, developed strategy for approaching everyday problems or situations of larger concern. What is needed is a metasystem of understanding through which students can consciously examine their relationship to the environment during their explorations and interactions. It is not enough simply to provide students with skills, facts and a positive self-image.

Learning to Think

Papert views a large part, but not all, of the ability to learn as an innate quality of human beings. He sees this process as one that does not initially need directing and one that operates as a function during typical, daily interaction. (3) What is referred to as play in children also provides the types of concrete experience necessary for the construction of intellectual models of physical relationships. Cognitive growth is, therefore, considered to be directly dependent upon the type of subject material and the quality of environmental interaction.

It is at this point that Papert diverges from the traditional position of Piaget. Papert suggests that educators tend to over-emphasize the formality(4) of a concept as the major factor in determining the structure of the sequential order in which concepts are presumed to be learned. In this model, advanced by Piaget, cognitive evolution is understood as progressing in a linear direction which is marked by the increasing degrees of formality in concept acquisition, such as the conservation of fluids or combinatorial thinking.(5) Papert suggests that it may not be the formality of the concept alone, but the type and quality of environmental stimuli that encourages intellectual growth and the subsequent acquisition of concepts. The absence of a concept or of a class of concepts in the intellectual stock of an individual is presented, from this perspective, as either a lack of exposure to relevant environmental cues, or to the prevention of the use of those cues after exposure. This viewpoint is also used to offer the possibility of enhancing the process of concept acquisition, thereby setting new standards for rates of development. The educational model of Papert seeks to supply those elements he believes are lacking or inadequate in contemporary elementary schools. Its purpose is to ensure that the child's learning environment is enriched to a point where pleasure is taken in seeking out the conceptual explanation for concrete, physical phenomena. He also believes that prior to the advent of the computer, such an environment was not possible. His recommendation is that in order to support children's learning, one must support their attempts to build their own intellectual structures.(6) While the process by which this is accomplished is believed to be natural and innate, it can also be encouraged.

Papert offers one method of improving the schoolroom environment. He expresses the position that the optimum relationship between the child, his learning ability and his environment is one in which meaning is derived through practical and physical interaction. In expressing this idea, he uses the terms "ego-syntonic" (7) and "body-syntonic" (8) as important elements in the child's ability to grasp an abstract concept. The physical body is actually used to syntonically understand the relationship between the intellectual conceptualization of, for example, a geometric figure, and the physical representation of that mental image.(9)

It is these types of involvement that are frequently absent in the primary, (and higher), grades. Children, so the argument holds, learn most efficiently if they are allowed to relate to the problem in a holistic sense, using physical and perhaps emotional as well as strictly cognitive abilities. Physical participation thus becomes a vital component in the learning process. Understanding at a purely intellectual level can only occur after the child has had sufficient physical experience. Syntonic knowledge of objects in time and space must be developed at the concrete level before the child can reduce that experience to the level of generalization and then use it to construct a purely abstract category. Abstraction is an ability associated with a higher level of cognitive awareness, and its cultivation must precede its appearance. Understanding at the concrete level must precede abstract understanding and the interrelationship between the two appears to be unidirectional. This relationship may be expressed as <u>logos via praxis</u> to indicate that the higher levels of intellectual evolution, such as the capacities of abstraction and generalization, occur only through the child's activity and physical involvement with his environment.

A second dimension of Papert's educational philosophy is his belief that the search for "the aesthetically pleasing" is a necessary component in the appreciation and understanding of mathematics.(10) Mathematics, he claims after Henri Poincaré (11), is not reducible to a knowledge of logic alone. Essentially, the aesthetic component is as important as the logical dimension to mathematical understanding.

Papert seeks to create an environment wherein children have the opportunity to reflect upon their own thinking processes thereby inducing intellectual growth. In an effort to accomplish this, he developed a medium, LOGO, which is a computer language through which children can manifest their conceptualizations. Logo provides the necessary tools for children to bridge the hiatus between mental image and physical reality. The tasks the children cannot do for themselves because of psychomotor limitations, such as the inability to use scale, manipulate drafting tools, rulers or pencils, the computer itself can theoretically accomplish under their direction. The mental process involved in making the computer image a more accurate representation of the child's own conceptualization than could be accomplished with the ordinary classroom tools is the process by which the child learns. This type of programming activity will itself, it is believed, encourage and foster intellectual expansion. The relationship between the child, his learning and the environment may be expressed as one of interaction and exploration. The child is not only involved in applying his knowledge of LOGO to create a computer program, but is also analysing the results of his endeavours, and evaluating them in terms of possibilities for improvements. The child is, then, operating along the full range of Bloom's taxonomy of cognitive processes; knowledge, comprehension and application are considered when the child begins the program, and analysis, synthesis and evaluation are achieved when the child examines the program for flaws.(12) The result of such endeavour is apparently not only to accelerate the development of understanding of certain formal concepts, but also to provide the child with the opportunity to reflect upon the thinking process and to develop a metasystem of understanding through which problems are clarified in terms of available and necessary knowledge. By formulating problems, by using available knowledge and by seeking out new information and procedures to solve these problems and by evaluating the degree of success in achieving these goals, the child can be said to be involved in a system of heuristic learning. Papert claims that this approach to learning can provide the child with a powerful tool- a metasystem of understanding- for interaction with the surrounding environment.

In such an environment, the concept of body-syntonics can be realized. If the child is using a computerized device, such as a Turtle (13), to draw the geometric designs and patterns already conceptualized, the body can be used to enact the general direction the turtle will be commanded to move. A parallel for the child programmer using body-syntonics to understand and anticipate the turtle's movements can be found in the TV watcher who participates vicariously in a hockey game or boxing match. The viewer "knows" which type of shot to use or which punch to throw, and demonstrates this knowledge by tensing certain muscles at appropriate times. It is at this level of involvement, Papert suggests, that children can best comprehend the instruction set they use to command the Turtle.

Knowledge for Papert appears to be much the same as it is for Piaget. It is not merely a learned response, nor is it an innate understanding and pattern of response to the world. The acquisition of knowledge, for these epistemologists, presupposes an exchange between the individual and his surroundings. The information that is retained is constantly subject to refining and is used to construct intellectual structures of a more complex nature. Piaget refers to his theory of knowledge as "genetic epistemology".

Genetic Epistemology

The necessary task, for philosophical purposes, is to examine the "genetic epistemology" of Piaget, and its contemporary extensions and applications in the work of Papert with the intention of addressing the problem of whether Papert's scheme offers a tenable solution to the problem of providing children with an opportunity to develop their own cognitive processes. It is perhaps through an investigation of knowledge itself that some answers to questions of learning and thinking can develop. The subsequent discussion, then, will outline the epistemologies of instinctivism, behaviourism and apriorism, in order to clarify the position of Piaget through its delimitation.

According to Piaget, intellectual understanding occurs through the conscious exercise of cognitive structures which themselves must be exercised in order to expand. It may be appropriate to think of the development of the intellect as a type of cognitive evolution. Development implies, to some extent, a linear sequence of growth, whereas evolution has the connotation of a quantitative leap from one level of cognition to another. The latter term accurately reflects the position of Piaget and Papert with respect to the description of intellectual growth. It is in an evolutionary manner that the mechanisms of the instinct are replaced by those of autoregulation.

Fundamental to a sufficent understanding of Piagetian epistemology is a recognition of the belief that intellectual evolution is sequential, with each level of cognition fully dependent on previous stages. Understanding is believed to be predicated on the generation of logico-mathematical relationships which, in so far as they are flexible and dependent for their genesis upon the interaction of the individual and the environment, are the ontological center of the ability to understand.(14) These mathematical relationships, he concedes, may even find their source in Kantian-like a priori categories which exist outside the environmental sphere of influence.(15) These categories are not, however, fully developed and require construction. The notion of preformation in the genesis of the logico-mathematical structure, which essentially operates in an organizing and regulatory function, is in this way assigned at least some value.(16) The point is, though, that knowledge is generated through systematic investigation and is neither encountered nor brought forward from within.

Piaget, then, with his emphasis on subject/object interaction and subject/environment exchange has adopted an amalgamatory and perhaps ameliorative position between the rigorous strictures of both instinctivism and behaviourism.

Knowledge, for him, is intellectual conclusion.

The behaviourist's view of human (and animal) behaviour differs radically, in so far as it regards action as a response, rather than as an investigation directed internally. In its most elementary forms, behaviour is relegated to a stimulus/response type of exchange, between the subject and his surroundings. Knowledge is simply assigned the value of learned patterns of behaviour, stored and retrieved under appropriate environmental conditions. It is acquired through trial and error methods of interacting with the surrounding world.

The rival theorists of this position are the instinctivists, who, to varying degrees, take the opposing stance, and regard all actions as responses to genetically acquired prompts. The intellect merely covers the actual determinants of behaviour and does not significantly influence, in an absolute sense, the motivation for the particular type of action to be taken. The common bond between the two views lies in the belief that human behaviour is ultimately predetermined and that intellectual response to environmental situations is not derived autonomously but owes part, if not all, of its conclusions to extraneous factors. (17)

Another view of human behaviour comes by way of the philosopher, Immanuel Kant, who proposed the existence of a moral imperative, which exists as a category of the human psyche, and which supplies direction to questions concerning behaviour. Unlike the behaviourists, who see human response to be primarily motivated by pragmatic concerns, Kant saw this universal moral principle, referred to as the "Categorical Imperative", as a means of supplying a method whereby an individual could find an answer to a moral question. The answer would be one that was intrinsically good, and, because of the nature of the Imperative, necessary in itself without condition. Behaviour would be modelled after this answer.(18) It is important to note, however, that the "will" as an independent agent, was not seen as being compelled to carry out the action presented by the Imperative.

Essentially, the concept of the Categorical Imperative is presented as a universal principle against which all maxims which attempt to direct behaviour can be measured. According to Coplestone, the Imperative is not intended to act in the same way as a premise for purposes of deductive reasoning. Rather it is held as a universal standard which can be consulted by all. There are several formulations of the Imperative, each of which is intended to bring its meaning closer to understanding through our intuition and our feelings. The first and second descriptions are discussed in the following way:

> 1) Act only on that maxim through which you can at the same time will that it should become a universal law. and
> 2) Act as if the maxim of your action were to become through your will a Universal Law of Nature. (18)

In this way, Kant constructs a category which functions entirely as a device to direct behaviour. This structure exists as an attribute of rational being and is therefore prior to and outside the jurisdiction of experience.

The ethologist qua instinctivist, Konrad Lorenz, dismisses Kant's argument in the following way:

> It is hard to believe that a man will refrain from a certain action which natural inclination urges him to perform only because he has realized that it involves a logical contradiction...In reality, even the fullest rational insight into the consequences of an action and into the logical consistency of its premise would not result in an imperative or in a prohibition, were it not for some emotional, in other words, instinctive, source of energy supplying motivation. (19)

Genetic impulse provides the motivating force behind behaviour, for Lorenz, who maintains that the intellect is itself directed by instinctive forces beyond its control.

In this belief, he has a powerful ally in Sigmund Freud, and the psychoanalytic tradition. Freud provides extensive commentary on what he believes to be the specific nature of those underlying, instinctive "urges". As motivators these urges are vital and dynamic forces, which, when left in the natural state, direct human behaviour toward the more base of human actions. When these urges are controlled, however, and sublimated, the result is the ability to create and achieve. In fact, Freud attributes all advances in civilization to successes in the process of sublimation of primary instinctual drives. Of this he says,

> We believe that civilization has been built up, under the pressure of the struggle for existence, by sacrifices of the gratification of the primitive impulses, and that it is to a great extent for ever being re-created, as each individual, successively joining the community, repeats the sacrifice of his instinctive pleasures for the common good. (20)

For Freud, success in diverting these impulses is at best a tenuous issue, always subject to regression. Failure of the individual in this area results in an atavism or in a psychiatric illness. Like Lorenz, he finds the source of human motivation deep in the primordial unconscious of our psyche, whether or not the action itself reflects the intent of the instinct.

The behaviourists, after B.F. Skinner, offer an alternative. In this view behaviour is prompted by environmental cues. If the behaviour is in some way rewarded, it will be repeated in appropriate situations. Of this, Skinner says,

> A scientific analysis of behaviour dispossesses autonomous man and turns the control he has been said to exert over to the environment. The individual may seem particularly vulnerable. He is henceforth to be controlled by the world around him, and in a large part by other men...Man himself may be controlled by

> the environment, but it is an environment which is almost wholly of his own making. (21)

Skinner has people behaving not through response to instinctual drives, not according to a moral imperative and not in response to reasoned judgement but in order to attain reward for demonstrating the correct pattern of behaviour. It has been suggested by the psychoanalyst, Eric Fromm, that Skinner's analysis of the human condition reflects an orientation to the experience of the middle class. He writes:

> In the last analysis, neobehaviourism is based on the quintessence of the bourgeois experience: the primacy of egotism and self-interest over all other human passions. (22)

The biological model of Piaget appears to be, in part, an attempt to synthesize the important elements of each of the foregoing theories. Instincts are seen as general directions of behaviour operative before the intellect is capable of assuming control over behaviour and providing more appropriate responses. He suggests that there may be _a priori_ categories of the mind, but that these have to be developed and supplied with information to operate. These do not exist as _a priori_, preformed, autonomous units and need a component of interaction with the environment to be complete. Finally, the subject must interact with the environment to gain information necessary to construct a viable mental system of logical analysis. His theory, however, appears to be centered primarily around the ontological belief that the world, and everything in it, can be expressed in mathematical terms. It is this belief that supplies him with the system necessary to construct a hierarchical system of cognitive evolution.

Number and the World

The world, for Piaget, is regulated, ordered, and is ultimately expressible in mathematical terms. Of this he states:

> How, in fact, are we to explain the harmony that exists between mathematics and the real world?...It must be emphasized at once that the entire world of reality can be expressed in mathematical terms. There is no known physical phenomenon which has defied expression in mathematical form... (23)

A distinction must be made here between expressing reality in mathematical form and the ability to reduce reality to mathematical form. The former is description while the latter implies some action on the world itself. The Pythagoreans, for example, viewed the world and the universe as consisting of number. The first principle of the cosmos, according to their doctrine, was number. (24) Copleston says of their belief:

> ...the Pythagoreans spoke of the cosmic harmony. But, not content with stressing the important part played by numbers in the universe, they went further and declared that things are numbers. (25)

Piaget, not as radical in his commitment to number as the Pythagoreans, saw number simply as a means to describe the real world. Number is one medium through which the intellect can grasp, comprehend and manipulate images it receives from the world. In this particular aspect, Piaget is more closely aligned with Platonic theory, which holds that behind all material appearance, a pure form or idea exists. The idea is the prototype of the earthly entity. These forms are the substance of all that is real. It is through number, Piaget continues, that the mind can best grasp the notion of form. Numbers, however, are clearly distinct from physical entities. (26) Forms can assume other than numerical shape. Moral forms are one such example. While certain concepts can be most efficiently understood by approaching them through numerical and logical analysis, not all ideas are conducive to such types of descriptions.

While Piaget endorses a natural realist's (27) ontology, he agrees that number permits, through enabling a logical, mathematical approach to interpreting the world, an intellectual, rational understanding of the world.

Although Piaget does not doubt either the reality of sensual perception or the qualities of the objects of perception themselves, he maintains that perceptions alone will not generate new knowledge or contribute to the evolution of the logico-mathematical stucture itself. It is only through some form of activity which, he maintains, by its nature involves all dimensions of human capacity, that cognitive evolution can occur. Perception portrays its object not as an isolated entity, pure and abstract, but in relation to the subject's possible future action. Perception, then, is viewed not as a phenomenon isolated from acts of intellect and will, but as one dimension of a unity, divisible from intention, direction and action only theoretically. Perceptions, as functions in themselves, imply actions, and are predicated on the existence of actions. (28)

In the initial stages of the psychogenesis (29) of knowledge, the subject, necessarily a child, relates primarily to events occuring at the moment. With increased knowledge, acquired through practical action and experiment, the events themselves become categorized and reduced to abstract ideas and placed in the logical framework to be used as components of that structure. At this point, the child has begun to "interiorize" (30) experience and therefore becomes further removed from the necessity of concrete experience. The cognitive structure that has developed does not merely house images of the real world. Rather, the images have been stripped of their concrete form and reduced to elementary components. The psyche now has an intellectual component, which, as a system of abstract relationships, adds the new dimensions of possible and probable results of behaviours. (31)

The foregoing description of the acquisition of knowledge offers an insight into the linear, sequential nature of Piaget's genetic epistemology. Due to the nature of biological processes, the elements of perception, interpretation, intention and response are intertwined and mutually dependent. For this reason activity itself and neither perception, analysis or habitual response, is considered the fundamental point of contact between the subject and the environment.

Comprehension, then, during the initial stages of intellectual advance, as in the case of children, is not possible according to Piaget, without physical interaction with the environment. It is specifically this type of body contact with the surrounding world that permits the individual to acquire the fundamental mathematical knowledge necessary to construct the various components of the logico-mathematical structure.

The individual using this structure has the capacity for self-analysis and self-modification.(32) Newly internalized knowledge is placed in relation to something. It is not merely stored waiting to be retrieved after an environmental stimulus but is an active part of the cognitive structure which is continually processing new information. Without such a structure, intellectual knowledge could not exist. As a human construction, the logico-mathematical framework serves a basic purpose: it extends the human range of action and sphere of influence in the world.(33)

If intellectual growth does in fact occur in the manner suggested by the model, it is incumbent upon the educator to provide appropriate environmental conditions for syntonic understanding to occur in the class. Traditional educational policy may deny this opportunity. Classroom orientation may be primarily directed toward propositional rather than procedural knowledge. According to Piaget, the ability to use propositions to acquire understanding of the logico-mathematical structure occurs only in the latter stages of intellectual development. The learning which does occur without a history of praxis in the stages of growth prior to formalized thinking must then be premature and necessarily flawed and incomplete. An example of this kind of learning is learning by rote. For the information in memory to assume meaning, it must be placed in context and for a child at the concrete operational level of cognition, this can only happen, according to the theory, through physical involvement. It should also be mentioned that it is believed that while some items must be committed to memory, not all problems can be solved through simple recall of fact. Environments without opportunities for physical and emotional involvement have the potential to slow, perhaps arrest completely, certain dimensions of future intellectual growth.(34)

It may be that the existential condition of the individual currently considered normal in the classroom is in reality one of stunted growth. Further, this situation may be inherently prone to resisting remedy. Each of the blocks of the logico-mathematical structure operates in cooperation with the others to provide a foundation for the assimilation (35) of new knowledge, thereby enlarging the entire framework, and enhancing the individual's ability to interact with his surroundings. If some of the initial blocks of the structure are absent or flawed, reflective thinking may not reveal either new component blocks or the source of the inability to perceive new correlations.

Piaget refers to these two types of procedural knowledge- the ability to reflect on one's own thinking process and the ability to perceive new relationships- as interiorization and exteriorization. (36) The ability to use these together presumably permits the analysis and redirection of actions that were environmentally unsuccessful, on the basis of past experience. The problem is to discover if this reflective capacity can be modified, and if so, how and at which points. Piaget suggests certain approximate ages for the development of fundamental cognitive structures. This means that there are age barriers which essentially predetermine the cognitive growing process.

The Assimilation of Social Knowledge

In the Piagetian scheme, the growth of the intellect seems to be made possible by the movement in a positive direction resulting from the tension in the individual between instinct and the will to self-determination. The tension is a result of the individual's recognition that survival demands an extension of instinctual abilities, and this extension takes the form of environmental control and understanding. Essentially, the subject is impelled to shed the instinctual harness by replacing those types of responses with development of the logico-mathematical structure. This initially serves primary interests such as the need for food and protection, but later it serves cognitive needs as well.(37)

There are two processes by which the individual becomes involved in environment extending functions. The first is play. Play does not have a particular motive. The child at play is not trying to discover something special but is simply involved in an exploratory process. This kind of activity is common not only to humans, but also to other mammals. It finds its origins not solely on an instinctive plane, but on a general level which includes all possible types of activities. (38)

The second process through which we learn how to learn is during non-playful exercise. These behaviours have specific purposes and result in the acquisition of specific understandings. (39)

In the final analysis, it appears that these specific acquistions- the items of knowledge themselves- will depend upon environmentally available resources. In the case of humans, and some animals, (40) this will include the social transmission of knowledge. Certain cognitive relationships, then, will be formed as a result of the nature of the society and through the particular environmental circumstance. Conversely, other intellectual acquisitions will be denied. The individual is capable of autonomy, Piaget implies, only in relation to instinctive behaviour. The human being must move beyond the instinctive response to survive, and is therefore reliant upon the individual evolution of the cognitive function. This can occur only in relation to the manifestation of the collective will of society. It cannot happen outside the social order and in this sense, our destinies are viewed as being at least partly determined. And so Piaget states:

> "The great man who at any time seems to be launching some new line of thought is simply the point of intersection or synthesis of ideas which have been elaborated by a continual process of cooperation, and, even if he is opposed to current opinions, he represents a response to underlying needs which arise outside himself."(41)

It is as the epicenter of attention that the "great man" fulfills on a macroscale that which the individual achieves on the personal level. In each case, the role is necessary and dictated by biological compulsion rather than individual choice. In the latter case, the individual synthesizes localized information so that a more comprehensive degree of environmental participation is possible. The "great man" accomplishes a similar purpose for the society as a whole.

Piaget continues by expressing the idea that both individual and social evolution occur as a result of the continual processing of information. While this particular claim is not difficult to accept, he enlarges upon it and enters into an area somewhat more controversial. There is not, he says, a fundamental difference between the systems of logic in an individual and in the society. (42) These systems are "open" and involve perceptual and cognitive operations which through time provide alternatives to the logic and understandings derived from the hereditary mechanisms.(43) The society, like the individual, is viewed as a biological entity, subject to the same natural laws. It follows, then, that the degree to which the society can evolve is determined by the degrees of freedom from the instinct the citizens possess.

The movement away from genetically determined responses and into social interaction is refered to as the adoption of interindividual capabilities. Piaget sees this movement as paramount to the development of intelligence. (44)

Piaget's theory of the evolution of the intellect is one of progress toward order, efficiency and the autonomy of the psyche. The individual is viewed as engaged in activities which increase the ability to reason logically. This skill is placed at the forefront of human capacity. There are stages of cognitive development, which, while influenced by the surrounding world, are ultimately determined by biological development. There are general age categories which roughly correspond to these biological stages (45) and specific psychological abilities which accompany each level. It is here that the ramifications of this theory for educational policy and curriculum become evident. If these categories are not immutable, as Papert suggests, and if their development can be hastened, then the standards that have been set may need altering. It may be that there are more appropriate structures on which to base a curriculum. What we have accepted as "normal intellectual growth" may simply be a reflection of adult or social expectations rather than an indication of true potential.

Questions concerning the ability to reflect upon the actual mechanics of thinking and problem solving as a stimulant to the genesis of knowledge have been raised, no doubt inadvertently, ancillary to a rigourous belief in biological structures which rule the level of cognitive ability. It is through the environment that Papert hopes to provide the cueing system necessary for children to enhance their own cognitive evolution.

The current social condition in North America, according to Papert, is one in which there is a pronounced fissure between the Humanities and the Sciences. The scientist C.P. Snow has characterized this rift in terms of a dichotomy. The polarized positions of the two groups is responsible for the prevention of the flow of ideas and information between strictly observed boundaries.(46)

The obsession by both parties, to demark and protect certain territory, has had the effect of creating a belief in two specifically different types of thinking processes which can be characterised in a very general way as the difference between the rigors of strict scientific analysis on the one hand and the intuitive, holistic approach to problems on the other. Papert suggests that while a biological root for individual preference in thinking style cannot be ruled out, a more likely cause is the social transmission of attitudes toward the two categories, by parents to children. In this view the child's options, if they are indeed restricted by this bipolar scheme, are not limited by biological determinants alone, but also by the cultural constraints of the immediate environment. As a solution to the problem of the child who has been culturally induced to endorse an unfavourable view of the scientific method, and hence mathematical and logical reasoning, Papert suggests treating the study of number as the study of language in an effort to make number a "natural language".(47) The implication is that because the concept of number is fundamental to human understanding, it is ultimately the most basic of languages. Utilizing this knowledge in the educational framework is the task Papert has assigned himself. While Piaget attempted to observe and to record the formation of basic intellectual structures, Papert has decided to intervene in this process, and has attempted to improve the process by making number, and the organization of number, visible, accessible and usable. It is through the application of this process in educational systems, he believes, that the rift between the scientific and humanistic communities will be healed and cognitive development will be enhanced.

In the appropriate environment, Papert maintains, cognitive development can proceed more rapidly than Piaget's theory would allow. If this is indeed the case, what educators have been regarding as "normal" intellectual development, because it corresponds with their understanding of the Piagetian time scheme, may in fact be retarded. While

Piaget's conception of "biological time barriers" to the evolution of the intellect may be fundamentally correct, Papert's work may indicate that the barriers are not nearly so rigid as has been assumed. The suggestion is that classroom environments created on certain premises should not remain immutable and unquestioned but open and subject to periodical re-examination. In this way, the process by which children develop their powers of cognition will be less likely to be viewed from a deterministic stance and more probably from an environmental position.

Intelligence- Biological, Artificial and Machine

Before embarking on a discussion of Papert's theories of cognitive development, it is appropriate to examine the area of research through which he arrived at a number of his conclusions- the study of artificial intelligence. While Piaget was a biologist and psychologist as well as an epistemologist, Papert is a mathematican and researcher in the field of artificial intelligence. It is through these sciences that he investigates the problems of human knowing. Having been associated with Piaget for many years, he has the additional advantage of having been exposed to a biological perspective on the problems of cognitive development, thus adding credence to his speculations about the problems of knowing and learning. Papert combines expertise in mathematics and his experience with children to bring to the attention of educators and observers a number of conclusions that, if verified, may have the capacity to alter our perspectives concerning certain aspects of learning and teaching. These conclusions are grounded in theories about the nature of human intelligence and the ability and motivation to learn.

The technique of designing computer programs which enable machines to respond to environmental cues in ways dictated by the human mind necessitates an interdisciplinary approach. While the programming aspect itself is specifically associated with the computer sciences, many of the ideas and formatting for these programs are a result of work accomplished in the fields of logic, cybernetics, cognitive psychology and epistemology. The creation of computers made possible the linking of ideas contained in these subjects, which added a material dimension to an otherwise purely speculative topic. Through the computer, ideas concerning the nature of the learning process can be tested, albeit imperfectly, and refined.

One of the requirements for using computers for a particular task, is to define the role it will be expected to play. This is equally true for educational uses as it is for scientific or managerial tasks. In the first instance, the limitations of the machine must be noted. At present the "brain" or central processing unit of a computer cannot be equated, in any adequate manner, with the human mind. While this machine excels, for example, at tasks requiring mathematical accuracy and speed, perfect memory, and repetitive processes, and while it can possess an extremely large memory, any part of which is accessible virtually instantaneously, it "thinks" in a linear manner and it cannot diverge from this pattern. Thus, while the human mind is slow by comparison, it has alternative thinking patterns at its command, and it can make intuitive and associative leaps denied to a computer. There are, then, differences in the thinking structures of men and computers, and, correspondingly, differences in task suitiblity. The essential purpose of study in the field of Artificial Intelligence is to better understand these differences and to clearly delineate the nature of mentation, in all its configurations.

It is important to remember that while both the human mind and the computer can perform similar, even identical tasks, and that both systems may even be capable of operation on the same types of logical structures, there are points at which each system will either fall dramatically short of task suitability or not function at all. This fact has certain implications which are illustrated in the following quotation:

> The difference in "thinking" talent- the computer being good for ultrafast sequential logic and the human being capable of slow but highly parallel and associative thinking- is the basis for cooperation between man and machine. It is because the capabilities of man and machine are so different that the computer has such potential. It is important to use the machines for jobs that humans could not do. However it is equally important that system designers and those managers and other persons who think about computer usage do not try to make the computer compete with man in areas in which man is superior. There has been an unfortunate tendency to date on the part of the popular press and by many persons in management to overly anthropomorphize the computer and its capabilities. (48)

This last comment leads to an important consideration largely ignored by those in the discipline. Artificial intelligence is a term which refers to studies which attempt to simulate human cognition. In a sense, AI is something of a misnomer. A more appropriate term might be machine intelligence. The function of AI programs is primarily to provide machines with the capability of responding to directions or of responding correctly to sensory data. The appropriateness of the word "artificial" is dubious because it implies that it has been modelled after some other form of intelligence. The assumption is made that the model is the human being. This is not necessarily the case. Human intelligence, for example, is biological, and does not require the same environmental conditions as the computer. Furthermore, machine intelligence does not have the advanced capabilities, at present, of self-development, as does the human mind, as part of its intrinsic character. The closest approximation of an AI program to those qualities is one that has the capacity to learn from its own mistakes. Such programs interpret unfavourable world responses to their own conclusions as resulting from error in their own internal programming and subject the same data, including the mistake, to further scrutiny under different parameters.

While this process appears to be similar to the logical workings of the human mind, it depends again on parameters previously defined by a human being. Thus the intention of the device, as determined by world conditions and predetermined reactions to those conditions, is not a function of its own being, but of the human programmer who designed the AI program.

Behaviourism questions the ability of the individual to transcend the programming that results from the surrounding environment. For the behaviourist, the human mind is configured in a similar way to that of a computer– the output is directly dependent upon the input, and, the output can be predetermined, to a large extent, by the type and quality of the input. Behaviourist theory, however, is only one branch of psychology. It attempts to reduce the workings of the human mind to a simple, mechanistic formula. Such a formula is very convenient to implement when dealing with the extremely complex mechanisms of the mind, which at best are only remotely accessible. With behaviourist theory, it becomes possible to bypass the discussion on the exploration of the actual workings of the mind, and therefore miss the opportunity to discover the veracity of behaviourist learning theory. By transforming the brain into a mysterious black box, and by regarding only input and output, it becomes a relatively simple matter to deny the existence of free will and individual choice. In doing so, the capacity of the human being can be reduced to that of a programmable machine. When viewed in this light, the nature of intelligence has a very different meaning from a perspective that recognizes free will, and the power of rational thought in the decision-making process rather than external motivation as the fundamenal characteristic of the behaviour of human beings.

As well as philosophical considerations concerning the nature of intelligence, the actual machinery- the computer itself- has not yet reached a level of sophistication which even remotely parallels the mechanics of the human brain. It is, at present, technologically impossible for a computer to think like a human. Thus, limitations on artificial intelligence programs are imposed by the architecture of the computer itself. Since the machine is not constructed and does not function in the same way as the brain, the types of intelligences can only appear to be similar. It is possible, even likely, that for some types of problems, arithmetic processes for example, both man and machine use identical approaches, although in this case, the speed of the machine far exceeds that of the individual. For other types of thinking however, that require associative or speculative thought, the computer cannot operate with any measurable degree of success. The substance of even the most complex of AI programs is simply a series of preprogrammed yes/no, (or high/low, on/off) responses to events occuring in the world. When coupled with a device or machine of some type, the AI program is intended to function something like a brain. It has facilities for interpreting sensory data, (although this type of data may deal with information far different than data received by human senses), for interpreting the data and formulating conclusions, for storing, retrieving and transmitting information, and for implementing the conclusions generated by processing the information.

Essentially, investigation into AI or MI, is the study of methods of creating programs which can be used by machines in lieu of intelligence to enable practical environmental interaction. It is the nature of the investigation into the mechanisms of machine intelligence to compare facts that are discovered and conclusions that are developed to known dimensions and capacities of the human mind. To date, it has been ideas on the functioning of the human being which have set the standards for the construction of artificial intelligence programs which run machines. And this is likely the source of the confusion. Perhaps standards should be measured in terms of the known capacities of the machine itself, rather than from the unknown and elusive qualities of the human mind. In this way, the design of the machine's intelligence can be configured to fit the exact purpose of the machine. A more accurate picture of the function of this type of research can then be cultivated.

From the foregoing discussion, it seems that it is more reasonable to think of intelligence as operating along a spectrum. Rather than attempting to restrict the definition of intelligence or intelligent behaviour to processes typical of human beings, it seems more sensible to think of it in broader terms. It should perhaps be defined according to its degree rather than in categorical terms. Along the intelligence spectrum, then, intelligence can be viewed as increasing in association with the relative level of evolution. The evolutionary level itself can be measured according to the degree of complexity of the organism. At the lower end of the evolutionary band, intelligence can be described as the function that permits unicellular organisms, such as the amoeba, to operate their several internal components, such as the nucleus, the food vacuole, and the membranes and to respond to environmental changes, such as pressure, light, salinity and temperature. At the higher levels of the band, it is noted that greater degrees of intelligence are required to ensure the survival of the organism. Intelligence in these cases, must not only regulate the operation of cellular components but also must regulate and coordinate the workings of entire organs, which themselves are a composite of a multitude of different types of cells. When viewed in this way, intelligence can be seen as the function that coordinates internal functions and directs external behaviour. The degree of intelligence may be evaluated by the number and complexity of operations that come under its control.

Another important factor to consider is the degree of freedom from unconscious regulation the organism possesses. While intelligence need not necessarily be thought of as strictly a conscious activity, it appears to be that consciousness and self-consciousness are directly related to the higher levels of biological evolution. At these levels, the organisms concerned- the various types of porpoises, dolphins, whales, monkeys, apes, elephants and human beings- are considered to have an extremely high degree of intelligence and freedom from strictly unconscious patterns of behavior. In this sense, intelligence is equated with the amount of self-control over behaviour.

The three factors considered when measuring intelligence- the number of operations it controls, the complexity of these operations, and the degree of freedom to over-rule or counteract implanted response- are all, to some extent, characteristics of the more advanced computer programs designed to operate machines. For this reason, it does not seem appropriate, when using these kinds of measurement criteria, to restrict discussions of intelligence to biological organisms. Computer controlled devices may also be said to exhibit some degree of intelligent behaviour. It can also be argued that instinct is itself a form of intelligence although it is certainly not a conscious intelligence controlled by the individual. The programming of a computer might be comparable to the instinctual process of an organism.

Knowledge and Reasoning in Machines

Investigators into the nature of intelligence have highlighted certain categories of knowledge, each of which describes abilities that permit intelligent behavior and which are considered essential to the generation of MI programs. Many of these categories are not unlike those developed by philosophers to describe the workings of the human mind. These categories include such abilities as problem solving and logical reasoning, language usage and learning. Other categories strictly limited to MI involve automatic programming, robotics and perception and the development of new operating systems and languages for computers and machines.(49) With such a broad range of applications there are necessarily different bodies of knowledge associated with each type. One general system of expressing these differences in requirements for intelligent behaviour follows.

Knowledge may be essentially factual in character. It may describe properties of objects or be simply a taxonomic representation of those objects.

Knowledge may be concerned with events and interactions. In this mode, it may deal with such factors as time sequence and cause and effect relationships, as well as descriptions of these events.

Knowledge may be concerned with skills, the ability to perform, and the ability to relate to society. The information necessary for performance may be: 1) cognitive, as in intellectual, technical or scientific endeavour 2) physical, as when using a particular machine or participating in a sport, 3) affective, as when responding to certain situations requiring interpersonal relationships.

A final category of knowledge may be described as meta-knowledge. This refers to personal understanding about a particular subject or body of knowledge. This type of information can be used in an evaluative capacity, to make predictions and recommendations.(50)

Knowledge representation schemes are not intended to demark absolute boundaries between the various forms of knowledge. They are useful, however, to help formulate broad categories, which, to some extent, define the limits of a program. A data base program, for example, may simply be designed to store and add new names and addresses and be able to retrieve these and print them on a screen or printer. Thus, the program designed to accomplish this task will primarily house object knowledge. Such a program will not require a great measure of "intelligence" to enable the various machines it controls to perform. If a spectrum of intelligence for computer-controlled machines were postulated, this type of intelligence would be of a lower order. The number and complexity of the tasks involved is not large and there is little, if any freedom in the decision-making process. Another program, however, designed to enable a machine to inspect electronic components and select and discard those of poorer quality, may be extremely sophisticated and therefore be associated with a higher order of intelligence. The program may coordinate sensory data retrieved from real world interaction with information stored in an internal memory, and must not only permit the device to use its sensors, to store, to compare and to evaluate the newly acquired data but also formulate a plan of action and allow the device to carry out this conclusion. At this level of sophistication, the MI program may need to use knowledge from all of the above categories. If it encounters circumstances it specifically has not been programmed to respond to, it may need to "reason" to find an appropriate solution. It must discover the unknown from what it already knows.(51)

MI programs implement one of several types of reasoning models.(52) They may use formal reasoning techniques in which data is manipulated according to prespecified rules of inference in order to synthesize new information. Mathematical logic is the main form of formal reasoning. This type of deductive logic, in its primitive form, may be seen in the famous syllogism of Aristotle in which a valid conclusion is derived from two true statements; 1)All men are mortal, 2)Socrates is a man, 3)Therefore Socrates is a mortal.

Another system is procedural reasoning. In this scheme, routine procedures are used by MI programs to solve problems which involve the utilization of knowledge. These problems include activities such as the selection of appropriate facts, the rejection of irrelevant facts and the ability to make inferences. An example of this type of reasoning can be seen in the program that encodes special procedures for drawing inferences about information. Certain characteristics are known about a class of animals, mammals for example, and these are stored in the programs' memory. The program, in an attempt to prove that a specific animal could give birth to live offspring, would try to demonstrate that it was a mammal.

These two types of reasoning are most frequently used in MI programming although some research is being undertaken in the areas of reasoning by generalization and abstraction and also in meta-level reasoning. This last technique involves the implementation of existing knowledge to make assertions and draw conclusions. I know, for example, that I have little aptitude in formal mathematical reasoning, and although I am inclined to study chartered accounting because of its lucrative financial rewards and intellectual challenge, I know also that such study involves the rigorous study of mathematics. I therefore advise myself not to take the program. The important factors in this type of reasoning are the extent of knowledge, the extent of ability, and the relative importance of certain facts.

Aside from the capacity of reasoning, an MI program must possess the ability to understand human intention. There must be a means to communicate. Machine code, which is the natural language of the central processing unit, is based on binary logic. Information is represented by the computer in a binary system as a series of zeros or ones, which can be translated as affirmatives or negatives, ons or offs, or any other system of opposing conditions. Combinations of these binary representations of information can be linked to produce what can be considered intelligent behaviour.

LOGO as a Language

Other languages, referred to as higher level languages, are used as mediators to facilitate man/machine communications. These languages act as interpreters and translate human intention into machine code. Each of these languages have specific purposes. Some of the better known languages are BASIC, COBOL, FORTRAN and LISP. FORTRAN refers to Formula Translation and is used primarily by the pure sciences. LISP is the language central to the man/machine dialogue. Some languages, BASIC for example, have attempted, with varying degrees of success, to accommodate all general needs.

LOGO, the language developed by Papert, is a subset of LISP, and is primarily designed to make programming simple, natural and accessible to all age groups, particularly children. As well, the language is intended to have the sophistication of the more established languages, so that novice programmers will not be restricted as they develop their abilities.

The degree to which the computer controlled device can participate in the environment depends upon two factors: the electronic capability of the computer itself and the capacity of the program that drives it. It is the program, or language, that can exploit the capacities of a computer.

An inefficient program will not use the computer to the fullest extent. From this realization, Papert draws an analogy to the development of human cognition. In an attempt to redirect the educational focus of attention, he has decided to use computers to provide pupils with an opportunity to express their ideas in a concrete manner. He suggests that having the opportunity to reflect on these conceptualizations will enable the individual to develop them more completely. Through corrections of procedure in the computer's program, the programmer will be able to systematically develop and enhance those conceptualizations, thereby affording the opportunity to correct and improve the thinking patterns that gave rise to the idea.

As well as the purposes stated above, LOGO was designed with this purpose in mind: the language is intended to correspond with and facilitate the development of the principles that govern human reasoning, thus making its acquisition a natural, evolutionary process. The purpose, then, is two-fold. It not only enables the programming of a computer but also, and most importantly, encourages the development of the programmer's personal cognitive abilities.(53)

It is this quality that is presumed to give LOGO its greatest advantage over other programming languages. The cognitive ability of the programmer need not be fully formed to use the language effectively. By using the language, the programmer may be encouraged to discover new ways of perceiving situations and viewing relationships. The key to understanding the special qualities of LOGO as an instructional and developmental tool for children is in the recognition of its visual representation of conceptions.

Other areas of LOGO which appeal to both educator and pupils are the simplicity and power of LOGO commands. With a relatively few, easily understood, commands graphic patterns of great complexity can be generated. This feature is presumed to be able to promote further exploration using different combinations of commands already understood and to encourage the acquisition of new and unfamilar commands to extend the range of control. It is believed that the pattern created by the child is representative of the unification of a number of previously unrelated ideas and bits of information. LOGO, the theory holds, provides a medium for the analysis and synthesis of information. Theoretically, LOGO allows children to follow their natural inclinations to learn and to investigate. Motivation is regarded in this view as an internal characteristic that is related directly to the learning process of the individual, quite unlike the behaviourist view.

Another premise concerning motivation finds its origins in the notion that the intrinsic beauty of the graphic patterns, and the corresponding recognition of the strengths or weaknesses of the program will motivate further action on the part of the child programmer. This system of learning is intended to be entirely under the control of the child who discovers autonomously and without direct instruction. LOGO attempts to encourage and reward this spirit of independence and investigations are continued in relation to the child's personal world experience.

In another arena, LOGO is intended to offer children entry into a previously inaccessible mental world. The computer is, under this language, configured to act as a powerful tool to permit children to express, with relative ease, certain ideas hitherto locked in the mind. For educators, it offers an unparalleled opportunity to investigate the actual degree of sophistication of the child's ability to conceptualize. While this method of investigation is not flawless, it will open new routes into the study of learning and thinking. Prior to the advent of the computer, children had to rely on strictly manual skills to express their ideas in other than oral form.

Children are often physically handicapped in so far as they may be unable to manipulate certain tools, such as drafting equipment, to transmit their conceptualization of a problem. While their mental image may be quite exact, their inabilities to transform that image to concrete reality inhibits subsequent development of that particular idea. LOGO specializes in the ability to graphically represent ideas. These representations are mathematical in nature and often require systematic procedure to fulfill the intent of the programmer. Papert suggests that while our culture has an abundance of opportunities to encounter number, and opportunity to practice systematic procedure, it does not provide the chance to discuss or investigate the nature of the procedures themselves. Thinking about thinking processes is not presently a culturally identified topic discussed in general social situations. Papert explains:

> When children come to LOGO they often have trouble recognizing a procedure as an entity. Coming to do so, is, in my view, analogous to the process of formation of permanent objects in infancy and of all the Piagetianly-conserved entities such as number, weight, and length. In LOGO, procedures are manipulable entities. They can be named, stored away, retrieved, changed, used as building blocks for superprocedures and analyzed into subprocedures. In this process they are assimilated to schematic or frames of more familiar entities. Thus they acquire the quality of "being entities". They inherit "concreteness". They also inherit specific knowledge. (54)

In the mind of the child who has learned the LOGO perspective, according to Papert, the internal structure is comprised not primarily of simple data, but of structures to use that data. While this may invariably be the case in all people, regardless of epistemological orientation, the advantage of the procedural approach, is that the procedures themselves are consciously recognized, categorized, stored, and implemented as procedures. This ability presents to the individual a visible structure, which is presumed to represent the workings of the mind. Without such a report, this level of mental organization might be obscured and possibly unrecognized.

The ability to recognize that procedures exist to solve problems, even if they are currently unknown, and that their discovery is possible through systematic investigation provides children, and adults, with a powerful incentive to search for solutions. The procedures themselves are stored in the child's memory much as would be simple facts. A child who has been accustomed to solving problems in this way might remember that to answer the question, "In what year did Columbus sail the ocean?", he must consult the various encyclopedias under certain categories, such as Columbus, North America, or famous explorers, rather than simply recalling the date, 1492, as a fact.

This approach differs in a fundamental way from simple skill development. Skill development in the curriculum concentrates its attention on specific topics, printing, addition, and alphabetization. While these skills are of course necessary and vital to the pupil's academic success, they do not in themselves provide a meta-system through which the world and its phenomena can be approached in an independent and systematic manner. While it may be argued that the development of this inclination to search for problem solving procedures is itself a skill, it should be remembered that it is more importantly an orientation toward life and its everyday problems.

This search is, furthermore, if the genetic epistemology of Piaget is accepted, an unavoidable product of existence. From this point of view, whether we are aware of the process or not, our learning depends upon the evolution of our cognitive ability from a state of understanding dependent on direct, concrete experience, to a state where one can implement procedures and information which have been reduced to abstract categories to solve everyday problems. Presenting problem solving as a skill will bring the issue to the attention of the conscious mind, thus increasing the possiblity of enhancing its development.

Piaget has associated age limits with the various stages of this evolution. That there is a sequence of growth is not questioned. Some of this development is directly related to physiological conditions. Piaget's sensory-motor stage is an example. In this stage, which exists between birth and two years, the infant's intellectual ability is restricted, initially, to simple reflex actions. By the age of two, the child has learned to discriminate between shapes and forms, to imitate complex actions, to remember people, places and objects, has learned to associate words with their corresponding objects and to some extent to verbalize this learning.(55)

Biologically preceding this cognitive development is the maturation of the brain itself. Over the first two years, the network of neurons develops from a system that permits relatively gross physical movements in infancy to much finer motor control in the two year old.(56) Intellectual advances parallel these physical accomplishments and must be attributed, in the main, to biological growth. Piaget's observations induced him to associate biological development, and therefore physical age, with advances in cognitive ability. In fact, he outlines in great detail the ages which he observed to correspond with each type of cognitive skill. Following the sensory-motor stage, is his preoperational level which he claims exists from two until seven. This stage is refered to as preoperational because the child has not yet developed the ability to reason logically in either concrete or abstract terms.(57) Children's cognition deals with the world of immediate interaction. The child's mind has not constructed the mental schema necessary to transmute factual data into abstract categories. According to Piaget, this is a natural consequence of growing up. The mind, he suggests, cannot perform certain functions until it is biologically capable. This is not to say that the logical structures are innate in the mind and develop with time but that for logical thought to develop a biological structure is necessary. Piaget states,

> Thus, everything seems to happen as though the more complex-in their organization and autoregulation systems- cognitive systems are, the more their formation is dependent on a sequential process comparable to a biological epigenesis(58).(59)

From the quote, it seems that Piaget values the idea of preformation in the physical architecture of the brain as being prerequisite to intellectual advance. He does, however, qualify this belief, with further explanation. This comment relieves him of the burden of presenting his argument as a polarized position in the nature/nurture debate.(60) He continues,

> The sequential character of the stages of intelligence certainly seems to prove the necessity of an endogenetic(61) factor in nervous maturation, but by no means excludes either the intervention of the environment (experience) or, more particularly, the interaction of environment and maturation at the center of a process equilibration or progressive autoregulation.(62)

While Piaget's observations led him to construct a time frame for cognitive development in children, he did not deny the possibility of intervening environmental factors, which could alter this time-frame. It is concerning this possibility that Papert takes issue. The emphasis in the LOGO approach is not on what children cannot do at particular ages or stages, but rather on how enriched environments can assist children to facilitate their own learning.

> I take from Jean Piaget a model of children as builders of their own intellectual structures....Where I am at variance...is in the role I attribute to the surrounding culture as a source of these materials. In some cases the culture supplies them in abundance...but in many cases where Piaget would explain the slower development of a particular concept by its greater complexity or formality, I see the critical factor as the relative poverty of the culture in those materials that would make the concept simple and concrete. In yet other cases the culture may provide materials but block their use. (63)

Papert believes, then, that through cultural enrichment a concept, the acquisition of which is now generally associated with a particular age, may be learned much earlier than might be considered possible according to Piagetian stage theory.

"I see no reason", he states of environmental conditions, "to doubt that this difference could account for a gap of five years or more between the ages at which conservation of number and combinatorial abilities are acquired."(64)

By addressing this question, Papert has shifted the focus of attention away from the presumed inherent limitations on developing thought and the corresponding kinds of intellectual restrictions associated with approximate age groups. His questions deal not with restrictions but with possibilities. He has chosen to study the effects of what he believes to be an enriched environment on cognitive development in children. Rather than plan an environment to suit what has been accepted as the standard pattern of development, he has designed a tool through the use of which it becomes possible to explore and enhance one's own cognitive ability. LOGO is intended to be a tool to assist one in thinking about thinking and problem solving. If it does accomplish this purpose, it is a tool that serves a much neglected function.

CONCLUSION

The idea of reducing, or in some cases perhaps eliminating the time interval between the acquisition of various concepts as the cognitive faculties of children develop, is one of the central notions that gave rise to the development of LOGO. Languages and programs prior to its appearance were designed primarily to be used in conjunction with reductionist and systematic thinking. Papert refers to this type of thought as obsessional. He describes this process in the following way:

> The obsessional is one who likes writing little details, is concerned with detail, who likes to see things in a fine sort of way, who likes to concentrate on detail.(65)

Programming a computer in LOGO can be accomplished in this way, but the language has the additional quality of being useful to those who think along other lines. This type of thought, rather than forming a larger picture from a series of interrelated component parts, takes a more holistic approach from the beginning. This kind of thinker may use not only intellectual techniques for programming but also emotional cues as well. This method of problem solving is characterized in the following way:

> The other kid puts a blob on the screen and sort of likes it. Then he modifies it a little and gradually builds it up into something much more

> complicated. He's not doing a simpler job; he's not learning less...But he's interacting with reality in a profoundly different way, in a way that corresponds with his personality.(66)

It is this additional dimension that enables the bridging of the hiatus between strictly scientific/reductionist and other, equally valid approaches to thinking and solving problems. Further, it manipulates the strengths of the computer to be used to the advantage of the child without the constraints associated with rigidly scientific, patterns of thought. Papert's classifications of thinking types, obsessional and hysterical, appear to correspond closely to existing classifications, analytic and holistic, respectively. One method of describing the meaning of these terms is to view the analytic mind as one that builds structures from component parts with the completed work assuming its final shape en route, while the holistic thinker works to perfect an already existing larger vision.

The nature of computers and most of the programs written for them appears to reflect the intellectual bias of the engineers and programmers themselves. Papert suggests this cognitive paradigm is not conducive to the development of the "hysterical" approach to learning and he extends this train of thought to note that the scientific and technological world in general is notable for the distinct absence of this type of thought. According to Papert, contemporary computer design exhibits the intellectual characteristics of the social group- the engineers and mathematicians- that created them. His theory is that the equipment is simply not designed for purposes outside that particular sphere of concern and it is not flexible enough to be used, without modifications, in areas that relate to areas outside logical, mathematical or scientific thought. Thus, regardless of the final use of the computer, its design, and hence its power, is contained within a specific paradigm which does not serve all conceptual schemes adequately. This paradigm sets limits and predetermined rules on the operation of the machine itself. In order to use it, one must conform to its limitations. Computers, for example, are notable for their abilities to operate in a linear, systematic manner. There is a danger, however, that because the computer excells in this area, the operator may tend to attempt to use it not only for jobs that require this type of analysis, but also for tasks for which it is not suited. We may also attempt to tailor the task to fit the machine, and thereby avoid finding a solution for the real issue. In this type of case, the device has begun to dictate to the operator, determining boundaries and limiting the options of the computer user.

In the same way that the cognitive growth patterns of children are determined, in part, by the choice of curriculum content, those same growth patterns can be directed by the intrinsic requirements of computer operation, regardless of the degree of sophistication of the computer program or language. In both cases, it is the educator's concern to be aware of the inherent limitations and to make accomodations, supplements or concessions in relevant areas to those who are affected. Without this kind of attention, there is a risk of educating students in a system that cannot properly evaluate either its own strengths and shortcomings or those of its wards. In this situation, which has been described as a "closed system", new ideas and information are not permitted to flow freely into the existing structure, thereby creating conditions for the assimilation of knowledge that potentially could be vital for its continued evolution or survival.(67)

It is for this reason that experimental programs, such as Papert's, are to be welcomed as an opportunity to investigate new possibilities and to re-examine existing structures. Papert is not alone in his assessment of a need to expand our awareness of possible methods of learning and thinking. While Papert suggests two modes of thinking, the obsessional and the hysterical, it is possible that there are many more. Developing these alternatives may be necessary for the advanced development of the mind and its thinking ability. As Edward de Bono says:

example, deals not with number, but with form, colour, size, background and the like. For a dancer, reality is comprised of timing, steps, movements, music and so on. These are all "realities" in the minds of those concerned and each is expressed in a different manner. It makes little sense to restrict our attempt to express the conception of what is real to a single methodology, which is, in Papert's case, mathematical. By doing so, a dichotomy between the mathematical and the non-mathematical is generated. He then suggests that this polarization is transmitted socially, and implies that it is the obligation of educators to overcome this problem, using LOGO.

Further, he claims to have designed LOGO to parallel the workings of the mind. This, in itself, the claim continues, will allow the acquisition and application of concepts learned under LOGO to be a natural process.

These assumptions, however, may not be warranted. Simply understanding LOGO relationships and concepts is not a guarantee that understandings in other areas of personal experience will follow. As well, it may not be reasonable to assume that ideas learned through interaction with a computer language on a two dimensional screen will be applicable in everyday situations. There is a distinct difference between manipulating images on a screen and interacting with people in social situations. Some of the concepts and ideas learned under LOGO might only find expression when the child is operating the computer. The mental skills required to master LOGO simply might not be useful in everyday activity, and the ideas learned in its study might not be generalizable to other applications. If this is the case, the educational usefulness of LOGO can be called into question.

A.R. Orage, a philosopher and writer, suggests that the ability to think is not in itself a quality that can stand by itself.(69) He indicates that thinking ability may depend upon the degree of fluency with which an individual operates in any given field of study. As the degree of familiarity with a topic increases, the ideas contained therein become progressively more comprehensible. In this view, practice in manipulating the symbols and concepts of the topic precedes the ability to think effectively in that field. Orage concludes, however, that there are certain mental exercises that will enhance an individual's understanding of a topic once the language unique to that field is mastered. Orage's stance on the process of enhancing cognitive development consists of three separate factors: biological potential of the individual, his mastery of the information contained in a particular discipline or perhaps general knowledge, and special development through training.

It is the composition of this special training that presents the difficulty. According to Papert, tools were not available to enable the development of certain kinds of cognitive training. Others, such as Orage, de Bono and Adler, disagree, and maintain that special teaching techniques rather than tools are needed. In the light of this dissention, Papert's claims concerning LOGO's unique possibilities must be closely examined. While it is certainly true that the computer is the most powerful of tools yet devised for some applications, it is also true that this machine is not yet flexible enough for universal application. In a like manner, the thinking ability to program a computer in LOGO may not be the same kind of thinking ability necessary to deal with other types of problems.

Although Papert has attempted to account for differences in types of thinking by his obsessional and hysterical classifications, he has provided little evidence to suggest that these types do in fact correspond to individuals or that classifications of thinking types should be restricted to these two. It is one thing to make observations about how children respond to a computer language and another to extend that observation to construct a cognitive theory. Papert also attempts to use this particular observation to describe what he believes to be a social condition of vital concern, the rift between the humanities and the sciences. The rift, Papert believes, is responsible for the development of the social dichotomy and the tendency to think only along either holisitic or scientific lines. This split however, C.P. Snow notwithstanding, may be contrived to suit his observations. By encouraging a belief that our culture is deficient in certain intellectually enriching media, in this case mathematical understanding and the means to promote that understanding through LOGO and the personal computer, Papert advances his own interests. It may be that our culture is not at all lacking in that particular area. For example, exposure to number, arithmetic, geometry, and algebra are required of every child in the western world, a situation unparalleled in history. As well, Papert's descriptions of the thinking processes may simply be part of larger, more comprehensive patterns of thinking which remain outside the sphere of Papert's investigation. From this point of view, LOGO, as a teaching tool, cannot be regarded as complete in itself as a means to deveop thinking processes.

Another belief central to Papert's theory concerns the motivation of LOGO users. He states that the child's natural learning ability, coupled with the power and simplicity of LOGO commands, and the intrinsic beauty and elegance of LOGO designs will be enough of an incentive to induce children to study and refine LOGO techniques for the purpose of completing their computer project. Further, he believes that the self-satisfaction the child derives from his project will encourage further study and effort.

It is well known that many of the greatest thinkers have been attracted to such factors when searching for solutions. Of this phenomenon, Horace Judson writes,

> The deeper we see into nature, the more beauty we find. Elegance in a theory becomes a criterion of truth...Scientists unabashedly try to capture the beauty of nature in their models and explanations. (70)

It may not be appropriate, however, to draw the comparison between a child learning to use a computer and a scientist committed to to extending the bounds of knowledge. Children do not possess the mental skills, the background and experience, the perseverance, or the attention span of the scientist. For these reasons, a child's understanding of beauty and truth will likely differ substantially from that of an adult researcher.

Doubtless Papert would reply that it is the same quality in children and adults that must be encouraged, and that the particular impetus to learn and know can be cultivated in all. He assumes, however, that all will find beauty, and hence reason to continue, in LOGO designs and programs. Again, this assumption may not be justifiable and many children may require different types of motivation in different areas of study. Some may simply not be interested in computers over the long term. In these cases, neither the natural simplicity of LOGO nor the intrinsic attraction of the design will be of use as a motivator.

Consider the difference between two types of children. One spends his time after school designing a computer program, while the other uses the computer to master the intricacies of a certain game. Each child carries with him a different set of values and priorities. They interact with this dimension of the environment in completely different ways. They respond differently to environmental cuing. It does not seem reasonable to think that a simple choice of programming methods will provide enough incentive to induce the game player to learn to program. It may also be the case that an initial interest displayed by the child toward programming in Logo is not indicative of a lasting cognitive perspective.

It is important to remember, though, that Papert attempts to offer one more alternative. He claims to present the child with an additional choice, the holistic approach to programming. This approach is intended to allow the individual greater freedom to explore in a heuristic environment than would be possible if thinking were restricted to the scientific/reductionist paradigm.

Papert's claim, however, is to offer more than a simple intellectual choice to children as learners. One of his major epistemological claims is that children's natural learning ability can be exploited more fully if the environmental conditions enable ego and body-syntonic understanding. Logos, as reasoning ability, can be developed through praxis. The actual practice of the computer language LOGO, rather than just the formal study of its procedures and methods, will enhance, according to the theory, intellectual evolution. Essentially, the virtue of this system is that it recognises the improvement of the intellect as its final goal, and approaches this directly. It does not assume that intellectual acuity results from a collection of abilities such as a sharp memory, the capacity to solve arithmetic equations, the ability to read and the like. The methods used in LOGO to promote intellectual advance are believed to complement the actual workings of the mind so that progress will be natural, uncontrived and self-motivated.

In the final analysis, it must be concluded that while LOGO offers a rather unique approach to learning and to learning to think, it cannot stand by itself as a solution to this problem. The premise that the art of thinking, as a topic, is neglected by the educational systems is interesting and, in a formal sense, quite true. Curricula do not seem to provide courses, except perhaps at advanced levels, in this area. Papert's contribution is invaluable because it investigates an area that appears to be generally avoided by educators. Most effort is directed toward the structure and content of curriculum. Papert outlines major areas of concern in the thinking process itself and offers a possible solution, thus approaching educational problems from an epistemological perspective. While some of his claims may be exaggerated, they are certainly worthy of further examination and research.

For Papert, the world appears to be primarily a mathematical world. It is one in which the ability to think and understand in mathematical terms is of paramount importance to a successful life. In order to further his ideas, and those of his colleague Piaget, he has taken the most powerful of modern tools, the computer, and adapted it to assist the student in the effort to enhance individual thinking ability. LOGO is a dynamic system that purports to require the participation of the student on more than a simply intellectual level. Physical interaction with the computer and emotional commitment to the intrinsic beauty of the product are also vital components. Papert's contribution must be recognised not only for its novel approach to children's learning but also for its endorsement of the belief that learning is enhanced if the tripartite nature of individual being- physical, emotional and intellectual- is acknowledged and incorporated into learning and thinking activities.

Footnotes

The title of this thesis, "LOGOS VIA PRAXIS", was taken from an essay written by Marx W. Wartofsky entitled "From Praxis to LOGOS: Genetic Epistemology and Physics". This paper can be found in: Mischel, Theodore. ed., Cognitive Development and Epistemology. New York: Academic Press, 1971. In his work, Wartofsky argues that the nature of genetic epistemology is such that it must deal with the biological and human conditions for the development of physics.

1) Mortimer J. Adler, The Paideia Proposal: An Educational Manifesto (New York: MacMillan Publishing Co. Inc., 1982), pp.15-36, 69-72.

2) E.W. Romaniuk, Chairman, Computers in Schools: The Minister's Task Force on Computers in Schools (Alberta Education, June 1983.), pp.41-97.

3) Seymour Papert, Mindstorms (New York:Basic Books, Inc. Publishers, 1980), p.7.

4) Ibid,. p.7.

5) Ibid., p.22.

6) Ibid., p.32.

7) Syntonic is a term which generally refers to a pair of instruments, one of which transmits and the other which receives. These instruments are tuned so that the latter responds to the specific frequency emitted by the former. Ego-syntonicity is a term used by Papert to explain the type of understanding about the world possessed by a child. The term finds its origins in Piaget's work on ego-centricity in children, wherein he attempted to demonstrate that children of a certain age "understand" things only in relation to themselves as the focal center of activity. The child must be able to relate to that which he perceives in terms of his understanding of himself before he attains an ego-syntonic

understanding. Essentially, then, the child is attempting to relate his empirical perceptions to his self-perception.

8) Body-syntonicity is a term used by Papert which indicates his conviction that knowledge, for children, is not acquired solely through the action of the intellect, but in conjunction with physical activity and manipulation of the environment. It is through the actions of the body that the child comes to realize his relationship with the objects of his attention and develops a strategy for future interactions.

9) Seymour Papert, Mindstorms, (New York: Basic Books Inc., Publishers, 1980), p.205.

10) Ibid., p.192

11) Henri Poincare was a French mathematician who discovered a class of mathematical functions. As a contemporary of Einstein, he independently made inroads into the theory of relativity.

12) Bloom constructed his taxonomy for the purpose of enabling educators to clarify their educational objectives. The taxonomy refered to in the thesis is intended to deal specifically with the cognitive domain. Each component of the taxonomy is arranged sequentially with the highest level of cognitive activity placed at the end. These levels are; knowledge, comprehension, application, analysis, synthesis and evaluation. Bloom also helped devise a taxononmy for the affective domain. Other researchers have constructed a schema for psychomotor objectives.

13) The turtle is a term which describes a device used to trace patterns directed by a computer program. The device may be either a two-dimensional image on a video display or a three dimensional mechanical "creature" that can be commanded to move, to draw and so on. The mechanical device can remember a series of commands so that it may perform complex tasks. It is, essentially, a computer controlled robot.

14) Jean Piaget, Beatrix Walsh, Trans. Biology and Knowledge, (Chicago: University of Chicago Press, 1971), p.119.

15) Ibid., p.53.

16) Ibid., p.119.

17) Eric Fromm, The Anatomy of Human Destructiveness (New York: Holt, Rinehart and Winston, 1973), p.69.

18) Fredrich Copleston, S.J., A History of Philosophy: Kant, Vol.6, Part 2 (New York: Image Books, 1964), pp.116-121.

19) Konrad Lorenz, On Aggression (New York: Harcourt, Brace & World, Inc. 1963), p.247.

20) Sigmund Freud, A General Introduction to Psychoanalysis (New York: Permabooks, 1956), p.27.

21) B.F. Skinner, Beyond Freedom and Dignity (New York: Alfred A. Knopf, 1972), p.205.

22) Fromm, op. cit., p.40.

23) Piaget, Beatrix Walsh, Trans., op. cit., p.339.

24) Robert I. Watson, The Great Psychologists (New York: J.B. Lippencott Company, 1963), p.24.

25) Fredrick Copleston, S.J., A History of Philosophy: Greece and Rome Vol.1, Part 1, (New York: Image Books, 1962), pp.49-50.

26) Francis M. Cornford, Trans., Plato's Theory of Knowledge

(New York: Bob-Merrill Company, Inc., 1957), p.10.

27) Natural Realism is a term used by T. Reid (1710-1796) to refer to the belief that the senses provide accurate perceptions of reality and the external world. This position is in diametric opposition to the Platonic notion of forms and the illusions of the senses.

28) Jean Piaget, Wolfe Mays, Trans., The Principles of Genetic Epistemology (London: Routledge & Kegan Paul, 1972), p.20.

29) Psychogenesis is a term used by Piaget to refer to the formation of knowledge in the human mind. He sees this process as being inextricably linked to biological development, although he does not discount the role of the environment.

30) Interiorize is a term used by Piaget to refer to the child's ability to transform actual behaviour to a conceptual scheme in the mind. In the stages of growth prior to this abilty, the child is unable to understand behaviour as a scheme because all actions are spontaneous and not premeditated and are therefore not classifiable.

31) Piaget, Wolfe Mays, Trans., op. cit., p.51.

32) Piaget, Beautrix Walsh, Trans., op. cit., p.5.

33) Reuven Kohen-Raz, Psychobiological Aspects of Cognitive Growth (New York: Academic Press, 1977), pp.16-17.

34) Papert, op. cit., .42.

35) Assimilation is a term used to refer to the ability to integrate new information into previous structures. Genetic assimilation has been used by the biologist C. H. Waddington to refer to the process of transforming and making permanent certain traits or behaviours initially dependent for their existence on environmental conditions by their addition to

the genetic pool. Cognitive assimilation refers to the process whereby we incorporate new knowledge into cognitive structures that are already (at least partly) established.

36) Exteriorize is a term used by Piaget to refer to the process by which concepts and ideas are subjected to experimentation and testing in the environment. The information received by this exercise is used to confirm or reject previously existing beliefs.

37) Piaget, Beautrix Walsh, Trans., op. cit., p.350.

38) Ibid p.349.

39) Ibid p.350.

40) The sea otter, for example, will collect a large flat rock at the same time it takes an oyster. It will use the rock as a tool to crack the oyster's shell. Certain monkeys and apes will use sticks as tools. There is evidence to suggest that these skills are not necessarily transmitted genetically but are transmitted socially.

41) Piaget, Beatrix Walsh, Trans., op. cit. p.368.

42) Ibid p.368.

43) Piaget refers to this phenomenon as the "bursting of instinct". This phrase is not intended simply to describe the process by which instinct is replaced by intelligence as a method of interaction with the environment. It has the more important connotation of indicating that the primitive functions of the instinctual mechanisms are taken, extended upon, manipulated and altered. As this happens, hereditary programming, to ever greater degrees, begins to disappear.

44) Piaget, Beatrix Walsh, Trans., op. cit., p.368.

45) According to Piaget, the three main stages of operative

intelligence are; 1) the sensorimotor period, lasting from birth to one and a half or two in which the child's understanding is guided primarily by instinctual responses, 2) the period from two until eight or nine in which the semiotic function develops, and which is followed until the age of twelve by the development of concrete operations in which the world is understood primarily through physical contact with material objects, and 3) a stage beginning about twelve in which formal intellectual operations, such as the construction and combination of propositions about the material world, are possible.

46) C.P. Snow, Two Cultures: And a Second Look. (Cambridge: The University Press, 1964), pp.1-21.

47) Papert, op. cit., p.7.

48) James Martin, Design of Man-Computer Dialogues (Englewood Cliffs: Prentice-Hall Inc. 1973), p.7.

49) Avron Barr; Edward A. Feigenbaum, eds. The Handbook of Artificial Intelligence, Book 1 (Stanford: Heuristech Press, 1981), pp.7-10.

50) Paul R. Cohen; Edward A. Feigenbaum, eds., The Handbook of Artificial Intelligence, Book 3 (Stanford: Heuristech Press, 1981), p.144.

51) Ibid p.146.

52) Ibid p.146.

53) Papert, op. cit., p.175.

54) Ibid p.223.

55) Dorothy G. Singer; Tracey A. Revenson, A Piaget Primer: How a Child Thinks (New York: International Universities Press, Inc., 1979), pp.26-40.

56) Morton Hunt, <u>The Universe Within</u> (New York: Simon and Schuster, 1982), p.40.

57) Singer; Revenson, op. cit., p.32.

58) Epigenesis refers to the theory that the "germ" is brought into existence by successive accretions and not merely developed in the act of reproduction.

59) Jean Piaget, Beatrix Walsh, Trans. op. cit., p.19.

60) The nature/nurture debate is an ongoing discussion in which the relative value of the roles of the environment and genetic factors in the development of intelligence and aptitude are considered.

61) Endogenetic is a term used to refer to a genetic component in biological structures that regulates the developement of various systems, in this case, cognitive awareness and intellectual structure.

62) Piaget, Beatrix Walsh, Trans., op. cit., p.18.

63) Papert, op. cit., p.7.

64) Ibid p.175.

65) A. Richard Immel, "The Father of Logo" <u>A+</u>, Volume 1, Issue 1, November 1983, p.136.

66) Ibid p.136.

67) Ibid p.134.

68) Edward de Bono, <u>Lateral Thinking</u> (New York: Penguin

Books, Ltd., 1970), p.13.

69) A. R. Orage, Psychological Exercises and Essays (New York: Samuel Weiser, 1974), p.8.

70) Horace F. Judson, The Search for Solutions (New York: Holt, Rinehart & Winston, 1980), p.8.

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