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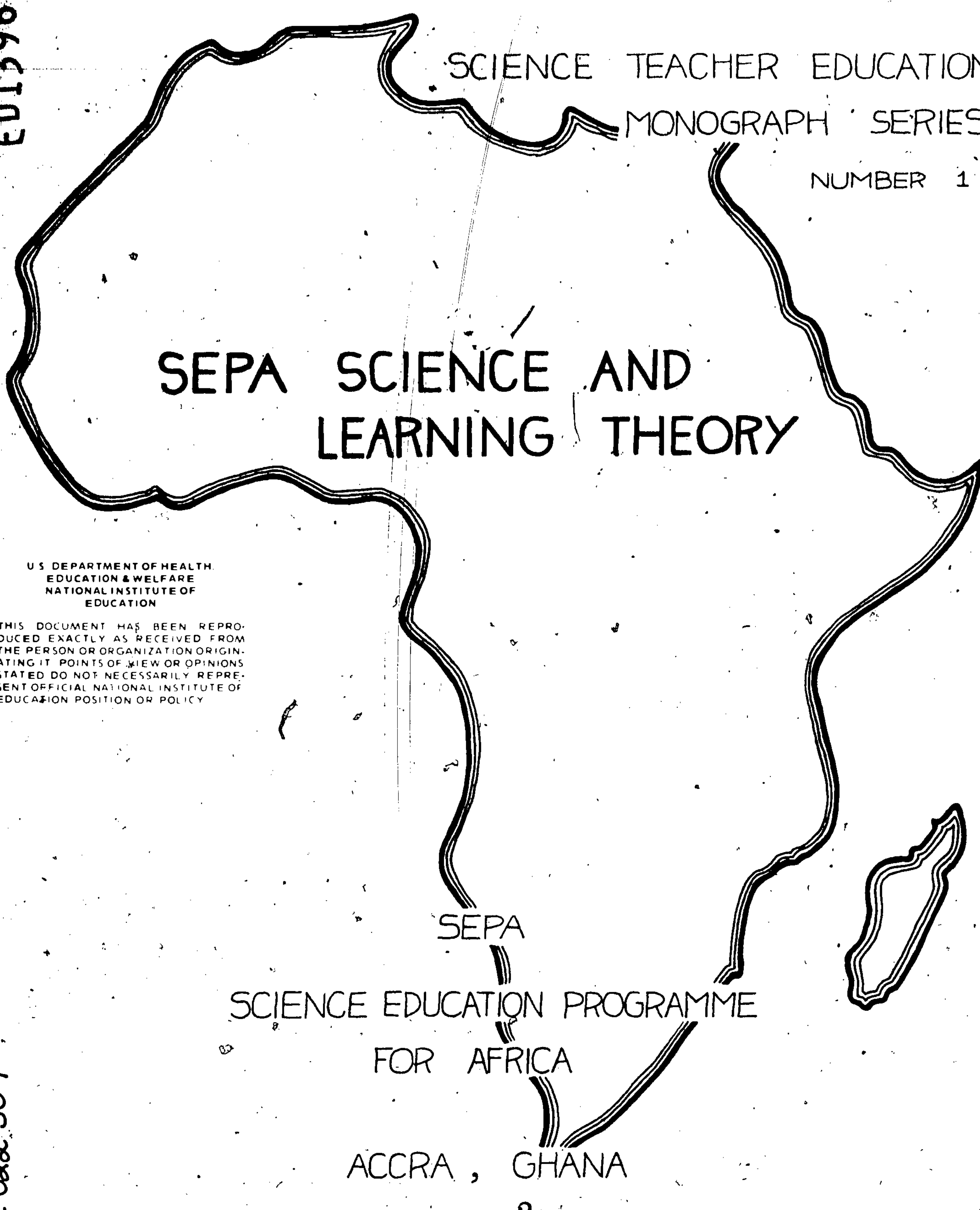
ABSTRACT

This monograph, published by the Science Education Programme for Africa (SEPA), is intended to help teachers and teacher educators with the skills and attitudes relating to learning science through activities designed to make the learner the center of attention. Presented is a review of Bruner's learning theory, Piaget's theory of intellectual development, and implications of these ideas for science teacher education. (SL)



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SEPA SCIENCE AND LEARNING THEORY

SEPA

SCIENCE EDUCATION PROGRAMME FOR AFRICA

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SEPA SCIENCE AND LEARNING THEORY

A Monograph for Teachers and Teacher Educators

by

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Preface

When science teaching was introduced in primary schools some fifty years ago, it was intended to increase the children's awareness of scientific principles which were affecting their everyday lives through technological products. Such products were the result of the increasing application of new scientific discoveries.

Initially, little more was required of children than to commit to memory facts and formulae that had been simplified to the extent of becoming, at times, half-truths. But as the mass of information grew, it became necessary for the body of knowledge to make sense to the children; to inspire them to become future science workers who would advance science still further. Thus, they were introduced to simple experiments which they could observe, or even perform themselves, to illustrate or prove some result or principle which they had learned.

This was a stage further in progressive science education. But little attention was paid either to the opportunities for both teacher and pupil to use their own imagination and ideas; or to the fundamental question of how children learn.

Recently, however, these two factors have become extremely important in the teaching of young children. Almost ten years ago, science educators and scientists from a number of African countries and from the United States, assembled at Entebbe, Uganda, for a workshop sponsored by the Education Development Center in Newton, Massachusetts. Out of this workshop the African Primary Science Program (APSP) was born to introduce a new approach to the teaching of science in primary schools.

From the outset, the emphasis was on fostering the development of certain skills and attitudes that would help children, as adults in the future, to solve their everyday problems through successful application of the scientific method of problem-solving.

The start was made with a thorough exploration of common and natural objects and phenomena, from which children could ask progressively more complex questions of their environment. From this point onwards, the process approach to science education could follow naturally.

Extensive development and trials of the educational software since 1965 have led to a large measure of verification of Piaget's ideas on learning theory. Since 1970 the program has expanded and control has been taken over by an enlarged group of African countries, leading to the formation of the Science Education Programme for Africa (SEPA).

As the work continues, emphasis is being placed also on teacher education, without which no new approach can succeed in the classroom. Programs organized to improve science education must always deal principally with the education of teachers and teachers of teachers if they are to be successful. Familiarity with the subject matter of science must be combined with an understanding of the processes of scientific inquiry. Students will come to an appreciation of the value of understanding and solving a broad range of problems only when teachers can recognize the validity of such an approach to learning.

This series of monographs is intended to help teachers and teacher educators keep uppermost in their minds not only the skills, but also the attitudes, both intellectual and emotional, that go with learning science through activities designed to make the learner the centre of attention or focus. The series will help to deepen the understanding of the nature of modern science education and its topics will be of particular interest to those who wish to place special emphasis on learning, rather than on teaching.

TABLE OF CONTENTS

SEPA SCIENCE AND LEARNING THEORY

Introduction

Education is the sum total of all the experiences assimilated by an individual as he develops and matures. It is a life experience which, when formal, normally takes place in a special environment called school. Ordinarily, school activities include planning, learning and assessment, and the product of planning is called curriculum which has been viewed as the set of skills and concepts which a learner is expected to acquire together with a blueprint for achieving the goals set.

It has become increasingly clear that a curriculum is effective to the extent that it involves those for whom it is intended in activities which help to modify their behaviour in desirable directions. For children, work with materials is important. Children also should be able to discuss with one another and with their teacher. They should acquire the habits of posing problems and raising questions. The challenge is enormous for those whose responsibility it is to train teachers who can relate with and aid children to develop these desirable attitudes and habits. Therefore, they need to be open, flexible, receptive and well-informed.

Foster (1971, p.31) has observed:

> "If the teacher is to cater adequately for the creative thinking abilities of children, his personal philosophy must be one which values the individuality of the child, recognises that the basis of education lies in the emotions and conceives that most children can be regarded as potentially gifted in some sphere if only it can be identified."

In science education, both the American Association for the Advancement of Science (AAAS) and the Nigeria Educational Research Council (NERC) have emphasized the importance of teaching elementary science as a process. The NERC has modified an original idea of the AAAS and come up with 15 sub-domains of this process of science. These are: observation, classification, communication, counting, measurement, raising questions, prediction, inference, formulating hypotheses, making operational definitions, controlling or manipulating variables, experimenting, formulating models, interpreting data, and manipulative skills. It is thought that if children become acquainted with these mental processes and skills, they will understand the fundamental structure of the subject.

The stress on the methods and skills of science is one which SEPA science has taken seriously. SEPA has elected a semi-structured approach to the teaching of science. This approach tries to build on the interest of the child and on his capacity for development. Emphasis has been placed on child psychology, and the teacher who will use SEPA's approach has to be psychologically committed to it and above all has to try to understand the child he is supposed to guide. While in training, the teacher should be given the types of insights into child behaviour which will help him acquire and maintain interest in child study all through his teaching career.

Some Insights Into Children's Learning

In recent times development as seen by Jean Piaget and Jerome S. Bruner has come to play a prominent role in our thoughts on learning but before we get into the contributions of these two prominent psychologists, it is worthwhile to refer briefly to some of the thinking of other learning theorists.

Learning has been viewed (Munn, p. 218, 1965) as:

> "A more or less permanent incremental modification of behaviour which results from activity, special training, or observation. A given learned performance whether motor or verbal, is often referred to as a habit."

The works of Gag'ne, Harlow, Hilgard, Hull, Jung, Lovell, Pavlov, Skinner, Thorndike, and Vernon have involved maturation, motivation and reinforcement among other factors. It has been demonstrated that what can be learned is dependent upon the level of maturation of the child. Maturation, which is growth resulting from a form of relationship between genes and the environment, is especially important in the early activities of the child. For example, a child should not be expected to run before he can walk.

Yet, there are other factors at play. It is known for instance that a child cannot learn what he does not wish to learn. The desire to learn or lack of it (as the case may be) of a particular concept is many times explained in terms of motivation, an idea which depends on both internal and external factors. Thus, we say that there are two forms of motivation; that which comes from within the child and is known as intrinsic motivation, and that which can be induced into him and is known as extrinsic motivation.

The former is usually operative when a learning situation has spontaneous attraction for the learner. Then he may compete with himself or others, sometimes without even consciously noting that he is doing so. The latter may be induced by external manipulation through the promise of reward or the threat of punishment. It is known that intrinsic motivation is more effective. This has led Yoloye (UIIE, p. 88) to observe:

> "A basic task of curriculum development therefore is the identification of learning activities that the child will have intrinsic motivation for. This task involves matching certain tendencies within the child with the properties of the learning materials and activities."

Another concept is reinforcement which arises naturally from the needs of organisms. Some of these needs are hereditary and physiological, others are acquired. Reinforcement may be primary as in the case when hunger is alleviated through feeding or it may be secondary as in the case when a child's need for affection is cured through words instead of cuddling.

It should be pointed out that the experts referred to and others do not necessarily agree on the relative roles of the various factors and therefore construct different learning theories depending on what they choose to stress. Some, like Tolman, would try to deny the effect of motivation and argue for what they call latent learning, a type of learning which is not demonstrably apparent. Some stress maturation while others stress insight or stimulus and response, and so on.

Bruner's Learning Theory

Jerome S. Bruner published The Process of Education in 1960 and therein gave the first systematic discourse of his position on cognitive development. More precise works such as Studies in Cognitive Growth have since followed. Bruner postulates that every subject has its structure or unifying ideas which anyone who intends to comprehend that subject must grasp. For example, the three unifying ideas necessary to master the process of solving all types of algebraic equations are the associative, commutative and distributive properties.

Bruner sees the child as moving through three levels of representation. Before getting to the first level, the child has already developed regularities in his intuition. When he encounters new situations, then he has to reorganise ideas already known to him in order to adjust to or accommodate them. That is, he discovers new concepts by internal reorganisation. It is precisely for this position that Bruner holds that the early teaching of science should stress intuition and the use of intuitive ideas.

Bruner's first or enactive level involves the direct manipulation of objects. The child is able to reach this level by associating intuitive regularities already developed with the regularities achieved through his manipulation. He then moves to the ikonic level at which stage he learns by seeing objects or by picturing them in his mind. Direct manipulation is unnecessary at this level. Finally, he progresses to the symbolic or third lével. Now he manipulates symbols and uses language and logic to present what he has learned.

Bruner advocates that the act of learning involves three processes which take place simultaneously. These are:

1. Acquisition - the ability to gain new knowledge, sometimes as a replacement for old ones.

2. Transformation - the ability to deal with available information and comprehend it to such an extent that one can go beyond it and derive new ideas, proper implications, appropriate inferences and the like.

3. Evaluation - the ability to check and make sure that one's observations, implications, inferences, consequences and so on, have justification.

Bruner holds further that transfer of learning is much easier if the student understands the structure of his subject. Then, some basic principles which have been learned well may be transferred either from one portion of a subject to another or indeed from one subject to another. That is, principles are transfering to new situations.

To determine if a child is ready to learn a new principle or concept, the teacher analyses the structure of the principle or concept. Should the analysis reveal that the structure is agreeable with the cognitive structure of the child at that stage of development, then that child may learn the said principle. Otherwise, teaching it should be delayed.

Bruner's theory has been associated with the discovery approach to learning. In this connection, Shulman (1967, p. 6) has observed:

> "The synthesis of these concepts of manipulation of actual materials as part of a developmental model and the Socratic notion of learning as internal reorganization into a learning-by-discovery approach is the unique contribution of Jerome Bruner."

The emphasis here is of course on manipulation which runs through all of Bruner's three levels of representation.

Piaget's Theory of Intellectual Development

For over 50 years Piaget and his collaborators at the Geneva School in Switzerland have carried out fundamental research on the development of thought processes in children. Out of this work has arisen the Piagetian theory of intellectual development which recognizes four major stages between birth and adolescence. Piaget relates these stages with different age levels but indicates that the time of appearance of stages depends on both the individual and his society.

The first period stretches from birth to about the age of 2 years. During this stage the reflexes present at birth have opportunities to develop. The child starts to use his senses. At about the age of 2 the second stage, known as the pre-operational period, sets in. During this period, which runs to approximately the age of 7 years, the child learns ways to explain the external world to himself through the use of objects and symbols. Also, he begins to develop intuitive ideas of casual relations, quantity, time and space and to assemble objects on the basis of a variable which may change with time. However, he may see only one relationship at a time.

He cannot yet coordinate variables. Dominated by his perception, he is usually carried away by physical appearance. He does not comprehend that an object may have more than one property and so lacks the ability to reverse his thought processes and to conserve discrete and continuous quantities. Given these failings, he can see a number smaller than itself, equal to itself and greater than itself all at the same time. For example, if four bottle tops are spread farther apart than they were, he thinks that the number (four) is now greater than four.

Then, from about the age of seven the child begins to appreciate that certain properties of objects (examples are area, volume and weight) remain unchanged in spite of external transformations. He attains what Piaget calls the conservation of quantity. He can now function through an internalized structure. For instance, he can add and subtract numbers. For him the volume of a given amount of water does not change if it is poured from one cup to another of a different diameter, or the number 7 does not change if bottle tops representing it are pushed closer to one another.

Also, the Geneva School has studied and continues to study the ability of children to relate sets of objects in one to one correspondence, that is, to match objects. Those children are able to relate who understand the true equivalence of sets, that is, the fact that two sets are equivalent if and only if they contain the same number of elements. Again, on the average, only children seven years of age or older can apply this matching or cardination principle. Moreover, such children, unlike younger ones, are able to seriate or arrange objects in increasing or decreasing sequences.

From the viewpoint of elementary school science this third stage is very important because it corresponds mostly to the period spent in the elementary school. A child performing at this level, known as the stage of concrete operations, has learned certain concepts through experience. He can perform some additions and subtractions and recognize some congruences. He can classify objects into different groups on the basis of some given properties. He is able to retrace some of his steps in any thinking process. But all his thought is in concrete terms and he is unable to structure anything which he has not experienced before or which is not directly before him.

Anywhere between 11 and 14 years the final period called the stage of formal operations sets in. Now the child is no longer dominated by his immediate experience. He starts to operate on hypothesis. He begins to appreciate the interaction of several variables which he can handle and control in systematic ways. He can now evaluate ideas and reason purely in the abstract. He has arrived as an adult thinker.

Piaget explains the transition from one stage to another in terms of four factors. Two of these are maturation or 'the increasing differentiation of the nervous system' and social transmission or the transfer of information from person to person. The remaining two are experience with one's environment and what Piaget calls equilibration: auto-regulation or self-regulation.

An appreciation for what Piaget means by equilibration may be gained from the following example. One of us was considering the properties of integers with a class of undergraduate students and a member of the class was asked to prove that, given any three integers a, b and c, it is always true that if $a<b$ and $b<c$, then $a<c$. Following several probing questions and hints, he was able to derive a proof in about 20 minutes. But the lecturer was not satisfied that the concepts had been clearly understood in spite of the student's claim that he was now sure of the concepts involved.

The student proceeded to justify this claim by reproducing the proof in about five minutes. At this point the lecturer posed a similar problem. Show that, given any three integers a, b and c, it is always true that $a<b$ implies $(a + c)<(b + c)$. After 20 minutes the student was still battling with this problem.

Most learning theorists would say that essentially no transfer of training had taken place. The student had indeed not assimilated the experience he went through. Piaget would say that a state of equilibration had not been reached. In some ways then, self-regulation is like trying to attain the kind of balance which allows a person to generalize an experience he has gone through. When it is achieved a lasting effect is established. It is precisely for this reason that Piaget considers equilibration the most important of the four factors.

Replications of Piaget's Experiments

Many studies in Canada, the United Kingdom and the United States of America have used Piaget's theories on intellectual development as a springboard. These include investigations by Almy, Beilin, Chittenden, Churchill, Dodwell, Elkind, Estes~~, Harker,~~ Hood, Lovell, Mannix, Navarra, Woodward, and Wohlwill. Such studies have been reviewed in Almy's _Young Children's Thinking_ or Flavell's _The Developmental Psychology of Jean Piaget_.

Review of Piaget - Related Studies in Africa

In Africa, replications of various phases of Piaget's experiments have tended to confirm the major theoretical tenets of the Geneva School. Price-Williams, who studied some Tiv children in Northern Nigeria, reported in 1961 that by the age of eight all of them had attained conservation of both continuous and discrete quantities.

Etuk studied Yoruba-speaking children in Western Nigeria. She reported that her findings partially confirmed Piaget's ideas on conservation, seriation and classification developing concurrently in the child and that all were necessary for a true understanding of number. Moreover, she compared the performances of children from modern and traditional homes in an attempt to examine the effect of environmental experience on the development of quantity concepts.

She discovered that children from traditional homes were consistently worse in their performance than those from modern ones. One gets the impression from reading Etuk's work, as well as comparable work done by Almy in Uganda, that there may be permanent blockage of the development of number concepts caused by traditional homes. This is an issue that requires research in different settings. Is there a blockage? If so, is it permanent or is there a way to teach children in various age-groups to overcome probable blocks?

In 1966, Patricia Greenfield reported a study on conservation and culture done in Senegal. She used a selection of Piaget's tests with three groups of children from the Wolof tribe and found that school experience was significant in the attainment of the ability to conserve and that there were qualitative differences in the approaches of schooled and unschooled children to problems involving conservation.

Moreover, the Wolof children showed a time lag when their performance was compared with that of an appropriate group of American children, Greenfield (Bruner et. al., 1966, p.225) concluded: "It is obvious that in order to survive all peoples must somehow come to terms with a few basic laws of the physical world ... the conservation of a continuous quantity across transformations of appearance is one of these basic facts."

Ruth Beard investigated the development of mathematical concepts in Ghanaian children. She also compared aspects of number concept development in English and Ghanaian children. She concluded that children only slowly acquire an understanding of the concepts important to intelligent performance in arithmetic and that there was an increase of score corresponding with an increase in age. This increase was significantly higher for the English children studied. Moreover, these English children did much better on tests on spatial concepts than did their Ghanaian counterparts.

Olu Willson studied 50 children classified into three age groups in two schools in Freetown, Sierra Leone. He used five experiments involving equivalence of sets, equality of sets, splitting of a set into two equal subsets, cardinal correspondence and ordinal correspondence. The children were also classified into three groups according to the occupation of their parents. In group one were children of unskilled parents. Group two children were born of semi-skilled parents, while group three children belonged to skilled or professional parents.

He claimed that his findings "support Piaget's contention that there is a steady progression from the young child's prenumerical level to the numerical plateau of the adult ... a child's conception of number differs from that of an adult and that it is a mistake to assume that because he counts 1 - 10, he therefore has the concept of 6, say." In addition, Willson seemed to have discovered that the children of unskilled parents did just as well in the tasks he set as did those of skilled or professional parents, but that either of these groups did significantly better than the group containing children of semi-skilled parents.

He went on to state that semi-skilled parents were usually domineering, a situation which obstructed discovery. On the other hand, the unskilled parent was inclined to leave the child to his own devices as long as he did not get into dangerous things, while the professional parent recognized that a child should 'be trained in such a way that his individuality is fully realized.' In either of the latter two cases the atmosphere was conducive to independent inquiry.

This conclusion by Willson raises some interesting conjectures. It would seem at variance with Etuk's discovery of significant differences in performance between children from traditional and modern homes on tasks she set. It may well be that Etuk's tasks discriminated against children from traditional homes, or that Willson's were biased against children of semi-skilled parents. In fact, is Willson right in his assumption that each professional parent is aware that the individuality of his child needs to be maintained, or in the claim that just leaving a child on his own is conducive to enquiry? Again, the need for more study is underscored.

The author studied the relevance of Piaget's principle of conservation of discrete and continuous quantities among the Mende of Sierra Leone. 231 Mende pupils of three age groups in 16 schools located in villages or towns in four different districts were tested on three tasks in either Mende or English language. He obtained significant differences between the performance of children who were in the age group 7 to 8 and those who were less than 7. He concluded that his results confirmed the views of Almy and other investigators that conservation abilities vary with age, tasks and individuals.

Kamara investigated the reasons given for attributing life to objects by Temne children in Sierra Leone. A variety of reasons which were classified as animistic, biological or philosophical were discovered. He observed (1973, p.34):

> "Children may attribute life to non-living objects without meaning that they are animate. The additional reasons, which we have designed as philosophical, create the need for a distinction between usefulness when used in a non-animistic sense. The existence of that form of thinking among children which Piaget calls animistic was present amongst the subjects of this sample."

Ayisi investigated 74 Ghanaian pupils who ranged in age from 5 to 12 years. Their scores on 6 Piagetian conservation tasks were analysed. Among other things, he concluded that his results agreed with Piaget's views that conservation ability was age dependent.

Lovell, Millie Almy and Otaala have studied sets of school children in Uganda. Almy's study (1970) was exploratory. It involved 44 first and 20 third year elementary school children in two schools. The subjects were interviewed on conservation, classification and seriation. The researcher stressed the tentative nature of her findings and went on to conclude (Almy et. al., 1970, pp. 14-15):

> "The ways the P-1 (first year) children responded to the various tasks posed may be described in Piagetian terms as largely 'preoperational'. Their thinking appears to be impressionistic and unsystematic, untroubled by logical contradiction. To a considerable extent they are beguiled by the appearance of things, interested in small details, likely to pay attention to differences about as often as to similarities, more interested in colour than in form. The P-3 (third year) children are a little more systematic and somewhat less likely to focus on differences rather than similarities. As with the younger children, colour

appears to be a more salient property than form."

Otaala (1971) investigated 160 school children from two rural elementary schools in a district of Uganda. Of interest were the sequence of development as postulated by Piaget, and Piaget's claim that conservation, classification and seriation develop simultaneously. His sample included 102 boys and 58 girls ranging in age from approximately six years to about fourteen years. Altogether 13 conservation, classification and seriation tasks were involved.

The researcher emphasized that on the whole his findings supported the sequence of development postulated by Piaget, as well as recent results on other African samples. He (1971, p. 142) goes on to state that "the claim in the Piagetian theory regarding parallel development of conservation, seriation, and classification was supported only partially." Partial support for this parallel development concept is consistent with the findings of other researchers.

These replication studies have varied in methodology and detail. Some have used probing methods similar to Piaget's. Others have emphasized research design. Still others have been undertaken within a standardized framework. Yet, it may be stated that in general they have supported Piaget's position that cognitive development takes place in stages, with a transitional period falling between a pre-operational stage and a period of operational thinking.

Implications For Teacher Education And Curriculum Renewal

We now pass on to a discussion of some of the implications that Piaget's work has for teacher education and curriculum development. It has been observed that research done so far in Africa lends support to Piaget's claim that cognitive development is stage-dependent. It is, also, quite clear that while the sequence of appearance of the stages is the same for all children, the ages at which various stages appear, differ for individual children. Some of the factors that are responsible for this are hereditary, some are due to the environment and others are products of previous learning experiences. At least there are implications for a) learning, b) curriculum development and research, and c) teacher preparation, classroom organisation and evaluation of pupil progress. We now discuss these.

a) Intellectual development and learning

Piaget and Bruner provide us with developmental approaches to the growth of the child. For the latter researcher, the child progresses from manipulation of materials through dealing with pictures and mental images to dealing with symbols, logic and language. The importance of language is stressed. Moreover, Bruner holds that if a child is to comprehend a given subject-matter, he must grasp the structure of that subject, and effective learning will take place if and only if the structure of the subject is made to fit the developmental structure of that child. Clearly, the emphasis is upon the process of learning.

Piaget stresses the importance of development which he claims is stage-dependent. Learning, as it were, is subordinate to development. He (Almy, 1966, p. v) observes:

> "This is the essential conclusion, as far as education is concerned: learning cannot explain development but the stage of development can in part explain learning. Development follows its own laws, as all of contemporary biology leads us to believe, and although each stage in the development is accompanied by all sorts of new learning based on experience, this learning is always relative to the developmental period during which it takes place, and to the intellectual structures, whether completely or partially formed, which the subject has at his disposal during this period. In the last analysis development accounts for learning much more than the other way round."

Piaget views intelligence as having two inseparable dimensions; a structural dimension which, as we pointed out earlier, is stage-dependent and deals with the manner in which intelligence organises experience, and a functional dimension which relates to the manner in which intelligence works. Intelligence develops as a result of physical or mental actions of a person and it is this intelligence which guides the interactions between that person and his environment. In so doing, the individual is made to adapt.

This adaptation is achieved through two compensatory processes; assimilation and accommodation, which may be explained as follows. A child faced with a novel problem tries to comprehend it through things already known to him. That is, he tries to absorb external elements into his thinking processes. This activity is assimilation. However, sometimes he fails and this limits his activity. He then adjusts his actions in order to succeed. That is, his assimilation schemes become modified through a process called accommodation.

It is when there is a balance of relations or a state of equilibrium between accommodation and assimilation that adaptation occurs. Adaptation in turn controls mental structures. Thus, the individual passes through states of equilibrium and disequilibrium, moving on to higher states of equilibrium gradually. It is clear that learning is viewed as an activity-oriented process.

b) <u>Curriculum development and research</u>

The report (UNESCO, 1972, p. 44) of an expert seminar for Asia jointly sponsored by UNESCO and UNICEF with the cooperation of CEDO made the following significant points:

> "Looking at the issue from the point of view of the curriculum developer, a distinction needs to be made between curriculum innovation (the development of new ideas, perhaps based on research, and their implementation) and educational research (the investigation of problems and the development of theories). Innovation cannot wait for further research. Enough is already known to realize that there are serious deficiencies in curricular and teaching methods in most countries."

Continuing, the report states:

> "Curriculum development should be seen as a totality, in which research, teacher education and other aspects of implementation are as much a part as the drafting of new syllabuses and the production of new materials. Within this total process there should be simple research projects or investigations into specific aspects of the learning processes of Asian children, the results of which can be directly applied to classroom situations."

One can only add that the situation in Africa is not different.

The problem of developing models that will integrate curriculum development and research deserves serious attention, including the consideration of all relevant local factors. Some of the many areas for investigation are:

1. The development and transfer of science concepts.
2. The development of logical structures in children.
3. Interactions between the environment and science learning and teaching.
4. The relationships between science and the needs, aspirations and interests of pupils.
5. Effects of such variables as mode of instruction, income of guardians, etc., on the acquisition of science concepts.
6. The interplay of language and science concepts.

c) <u>Teacher preparation, classroom organization and pupil evaluation</u>

Piaget has emphasized that children should be free to investigate with materials that are intrinsically useful. He has also been quoted (Duckworth, 1964, p. 173) as saying:

> "The principal goal of education is to create men who are capable of doing new things, not simply repeating what other generations have done ... The second goal of education is to form minds which are critical, can verify, and do not accept everything they are offered."

This statement is similar to those found in pronouncements by the Science Education Programme for Africa and various African Ministries of Education. The implications for teacher education are several. First, teachers in training have to be convinced that to acquire the kinds of attitudes that will enable them when they become teachers to develop this enquiring attitude in children is a primary goal. Often, teacher training institutions have tried to achieve this through preaching to student teachers. What happens then is that student teachers do not acquire enough practical experience and facility with working with enquiry techniques, and so not surprisingly, they fail to develop the confidence necessary for guiding children through meaningful investigations. It is proposed that teachers in training learn how to do by doing.

Second, part of this learning to do by doing involves giving student teachers first hand experiences in the study of children. Such experiences should include the observation of one child over a period of time, as well as situations in which student teachers have opportunities to exchange ideas with children, one at a time.

Piaget's probing techniques would appear to be very useful in this regard. Piaget and his collaborators have developed interesting and unique interviewing techniques which should help enrich the background of any persons who would care to perform some of their experiments.

Third, Inskeep (1972, p. 257) has stated:

> "A theory that focuses only on the child, or only on the content to be learned, is deficient. Piaget's theory takes into consideration and accounts for the interaction of the child with his environment."

It is of course essential that the would-be teacher learn how to help the child to cope with his environment. Pebbles, buttons, bottle stoppers, leaves, sticks, pieces of string or rope, and so on, can all become effective tools in this venture.

Piaget (1970) himself has discussed the training of elementary school teachers. He has pointed out the need for them to be well-trained in child psychology through active participation in research projects, although indicating the difficulty of achieving this objective in the present teacher education set up.

Directly associated with this is the method of evaluating progress. If children are to be given some degree of freedom to develop at their own pace and cope with their environment, doubts begin to arise as to whether mass or group examinations designed for the same 'class' will suffice. Surely, possibilities can be held out for observing each child's thought processes as he proceeds. What the child has been able to understand at certain points in his career may be discovered, and such discovery should be a great asset in the programming of his classroom experience, as well as in evaluating his progress. Such evaluation necessarily becomes an integral part of curriculum renovation.

In-service teachers need to participate actively in the development of curriculum. Some of this is being done through vacation and similar short-term workshops. Much more needs to be done.

The Philosophy of SEPA Science

Piaget (1970, pp. 50-51) has said:

> "The traditional education of certain great countries has placed all the emphasis, in fact, upon the humanities and upon mathematics, as though the two prominent qualities of rational man were to be at ease with history and with formal education. As for practical experimentation, that was seen as a minor activity, useful for civilizations with an empirical philosophy ... Consequently, a sufficient experimental training was believed to have been provided as long as the student had been introduced to the results of past experiments or had been allowed to watch demonstration experiments conducted by his teacher."

Piaget goes on to note that this lecture-discussion approach was in many instances supplemented by laboratory work performed by students. But, he observes that repeating past experiments would at best help to produce fact machines rather than innovative explorers. In his opinion, as a child progresses between the age ranges 11 to 12 and 14 to 15 years, he should acquire "all the intellectual instruments" conducive to proper experimental work.

Anyone who reads Piaget is aware of his love for mathematics and logic. In fact, his theory applies many mathematical models. Therefore, the depth of his feeling for experimental science can be inferred. It is also quite clear that he wants people to be exposed to experimental work early in their lives. He (Almy, 1966, p. vi) has remarked "school children and students should be allowed a maximum of activity of their own, directed by means of material which permit their activities to be cognitively useful."

It is therefore understandable that Piaget's theory is associated with discovery learning. He calls for activity, which need not be physical. He wants children to be inspired to investigate problems and to invent. In this endeavour they will have to observe, classify, formulate hypotheses, manipulate variables, and so on. We are led naturally to a process approach to the study of science.

Hence, it can be said that one implication which Piaget's work has for science education derives from the method of teaching science. Rather than seeing science as isolated and unrelated bits and pieces of information which an individual has to collect from books, the Piagetian model views the subject as a process whose methods can be taught through activity. Associated with this is the emphasis which the model places on the study of science.

Another related implication has to do with the sequencing of science curriculum. Here thoughts fly to the spiral curriculum of Bruner, which is founded on the basic premise "that any subject can be taught effectively in some intellectually honest form to any child at any stage of development." If this is to make sense, Bruner has to be understood to mean that one can take most concepts, reconstruct them and make their structures fit the cognitive structure of the child. It should, therefore, not surprise you that Bruner's contribution to discovery learning has been seen as "an out-growth of the developmental work of Jean Piaget."

Various programmes have been pioneers in this attempt to bring about harmony between the methods and content of elementary science. Representing a completely open-ended approach is the Nuffield Junior Science Project and at the other end of the continuum are structured programmes for elementary science, such as Science Curriculum Improvement Study (SCIS) and Science - A Process Approach. SEPA science occupies a happy middle in the sense that SEPA's open-ended approach is buttressed by Teachers' Guides which are somewhat prescriptive.

The idea of a science education programme for Africa originated at the Rehovoth Conference in Israel in 1960, and a programme was officially initiated in Kano in 1965 as the African Primary Science Program (APSP). Three international workshops followed in 1965, 1966 and 1967 at Entebbe, Dar es Salaam and Akosombo respectively. Emphasis in these workshops was on the use of indigenous materials. Draft units were produced which were then tested over a period of years in classrooms in several African countries. Subsequently, the edited and modified versions of these were printed to meet local conditions.

The approach has been to look at science as an integrated subject. Units such as Mosquitoes, Inks and Papers, Bricks and Pots, Liquids, Tilapia, Making Paints, Wet Sand, Sound, Small Animals, Seeds, Construction with Grass, and so on, have been written. These deal with basic aspects of physical and biological science. In producing them, proper attention has been given to the manner in which pupils work with and explore and discover their environment.

Dyasi and Cole (p.3) have stated:

> "The APSP approach was new to primary science teaching in Africa and it created a new sense of direction for the pupils who began to find their schooling more meaningful as they were able to pursue their natural interest in nature out of school with a certain amount of confidence and understanding."

SEPA developed naturally from the APSP. While direction and leadership during the APSP era rested mainly on decision-makers at Education Development Center in Newton, Massachusetts, the formation of SEPA in 1970 transferred decision-making to Africans. One result is that SEPA policies now are formulated to meet the present needs of participating African nations. Excellence and relevance are being promoted in science education in the continent and forums are provided for cooperation of member countries.

There are other characteristic features of the SEPA approach to elementary school science. One such is that concrete objects are considered important instruments in the educational experience of the child. Materials are chosen which provide intrinsic motivation to the child while at the same time exposing him to alternative solutions to the same problem. Also, the semi-structured nature of SEPA science encourages initiative on the parts of both the teacher and the individual. Units are provided only as guides, as examples of the types of activities that are possible. There are no generally prescribed procedures. Those teachers who have contributed to the production of units have become conditioned to looking for each child's unique talents and attributes.

Training the Teacher for His Role in SEPA Science

Nevertheless, the big question is how to train teacher candidates (and also many serving teachers) to function effectively in a SEPA science framework.

At several SEPA workshops, considerable attention has been paid to necessary and sufficient conditions for producing teachers who can meet the challenge above. At a 1972 strategy workshop in Accra, some of the issues were raised in the following language (SEPA, 1972, p. 41):

> "What educational experiences would give the teacher candidates an opportunity to equip themselves with these capabilities? Should they be the kinds of experiences teacher candidates would be expected to afford pupils in their own classes? Should they be experiences that enable them to perceive the world as primary school pupils perceive it? How do we handle the fundamental differences in thought processes and in levels of maturity of teacher candidates on one hand and those of primary school children on the other hand? What will be the conceptual level of the transactions involving "science" phenomena? Should there, in fact, be any organizing theme or themes to these educational experiences? How should the experiences relate to the nature of science?"

Many more questions may be asked. Furthermore, experts are not necessarily agreed on the answers to these questions. Yet, it is reasonable to presume that teachers tend to emulate those of their own teachers whom they considered good and effective. Also, it is sensible to claim that people become effective teachers through different routes and effective teachers are known to differ in their methods of teaching. Therefore, it would appear unwise to advocate any one strategy for teacher education.

Yet, only those methods would have a chance that emphasize thought, student interest and active participation on the part of the student. Stress has to be put on the acquisition of skills and techniques of investigation with the subject area used "as a medium for portraying the nature of the teaching act and of the logic of learning and of teaching in practical situations." Piaget has emphasized that children need to use materials that are cognitively useful as aids to learning. He has also made the point that effective learning is activity oriented. Sometimes the activity is principally physical; at other times it is principally mental. The important point, though, is that the learner needs to be actively involved in what is taking place.

Obviously, the adult who is training to be a teacher is not capable of seeing the world in exactly the same light as the young child, for as SEPA has pointed out in the Handbook for Teachers, adult thinking is more conceptual than young children's thinking. Therefore, many adults tend not to have some of the spontaneous intuition that characterizes young children's thought processes. Yet, the case for exposing would-be teachers to experiences similar to some of those to which they will expose pupils is strong indeed.

Piaget's approach to development and learning has provided some evidence to support Bruner's claim that any given subject can be taught in an appropriate manner to students of different ages. This is precisely the form which the 50 odd units produced so far by SEPA/APSP have taken. Given any one of these units; it can be treated at different levels with varying degrees of emphasis.

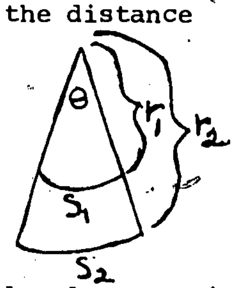
Consider the unit, Pendulums, as an example. On page 4, pendulum experiments with big rope swings are discussed. It is suggested that children can observe the many paths that a pendulum traces as it swings. For young children it was not considered important to discuss in a detailed way the nature of these paths but they can observe that the paths are curved. Older children and adults who have developed the necessary vocabulary can take this further. The path is a simple closed curve known as an ellipse. How does the ellipse differ from the circle? This is but one of many questions that deserve answers. At advanced teacher training college or university level, the equation of the path could be developed.

On the same page it is stated:

"A thin rope tied near the top of the thick rope can be pulled by another pupil so that with little effort, the

> child on the swing can be made to move. This will help the children to see how a string or stick between two pendulums can cause one to start the other swinging."

We may be interested to find out if the pendulum is moved a greater distance by moving the rope toward the top rather than toward the bottom. Figure 5 indicates the solution to this problem and (in this mathematical form) it is certainly beyond the reach of most young children. On the other hand most adults can appreciate that the distance swept out depends both on the angle of swing and on the radius of the circle. In fact, the distance is an arc length given by $s = r\theta$ where s is the distance, r is the radius of a circle and θ is the angle of sweep. Since $r_2 > r_1$ and θ is the same, s_2 is greater than s_1.



On page 6 of the unit the game of skittles is introduced. Certain mathematical and scientific concepts can be discussed around this game depending on the level of the students. For instance, if we number the blocks and put each one back in the same position every time, which blocks seem to be knocked down most frequently? Possible abstractions are ideas of rows and columns, including entry into matrices and ordered pairs of numbers. Also, there is room for probability theory in the record of the number of times each block is knocked down.

We can continue in this vein not only with this particular unit but with all of the SEPA-related units. But the important point has been made that these units may be used with different levels of students.

Finally, the opportunity does exist for training teachers to be innovative and creative. If teachers are to help children to be aware of, and explore their environments, then they too must know how to cope with their environment. Moreover, teachers in training should be provided with opportunities to study children at work.

In the case of serving teachers, SEPA has indeed taken a big step in the direction of helping many of them. In-service institutes were co-sponsored with the respective Ministries or Institutes of Education at Ife, Nigeria in September, 1971, at Monrovia, Liberia in January/

February, 1972 and 1973, and in Cape Coast, Ghana in August, 1972. Similar institutes were held in Nairobi, Kenya in December, 1972 and at Njala in August, 1972 and 1973. A major step in innovation in evaluation has been taken in the establishment of a centre for evaluation at Ibadan University. Already 15 teachers or educators have benefitted directly from the establishment of this centre.

Summary

At this stage in the development of teacher education in Africa, the continent is blessed to have such a dynamic organisation as SEPA working actively to make science education relevant to the needs of the African society. This monograph has tried to provide a basis for the type of learning which SEPA science is encouraging. The basic foundation used has been the developmental psychology of Jean Piaget and the related work of Jerome Bruner. Emphasis has been placed on the increasing opportunities being provided to in-service teachers to upgrade their understanding of both science and children. Also, the hope has been expressed that teachers' colleges will provide more and more opportunities to teacher candidates to observe and study children.

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