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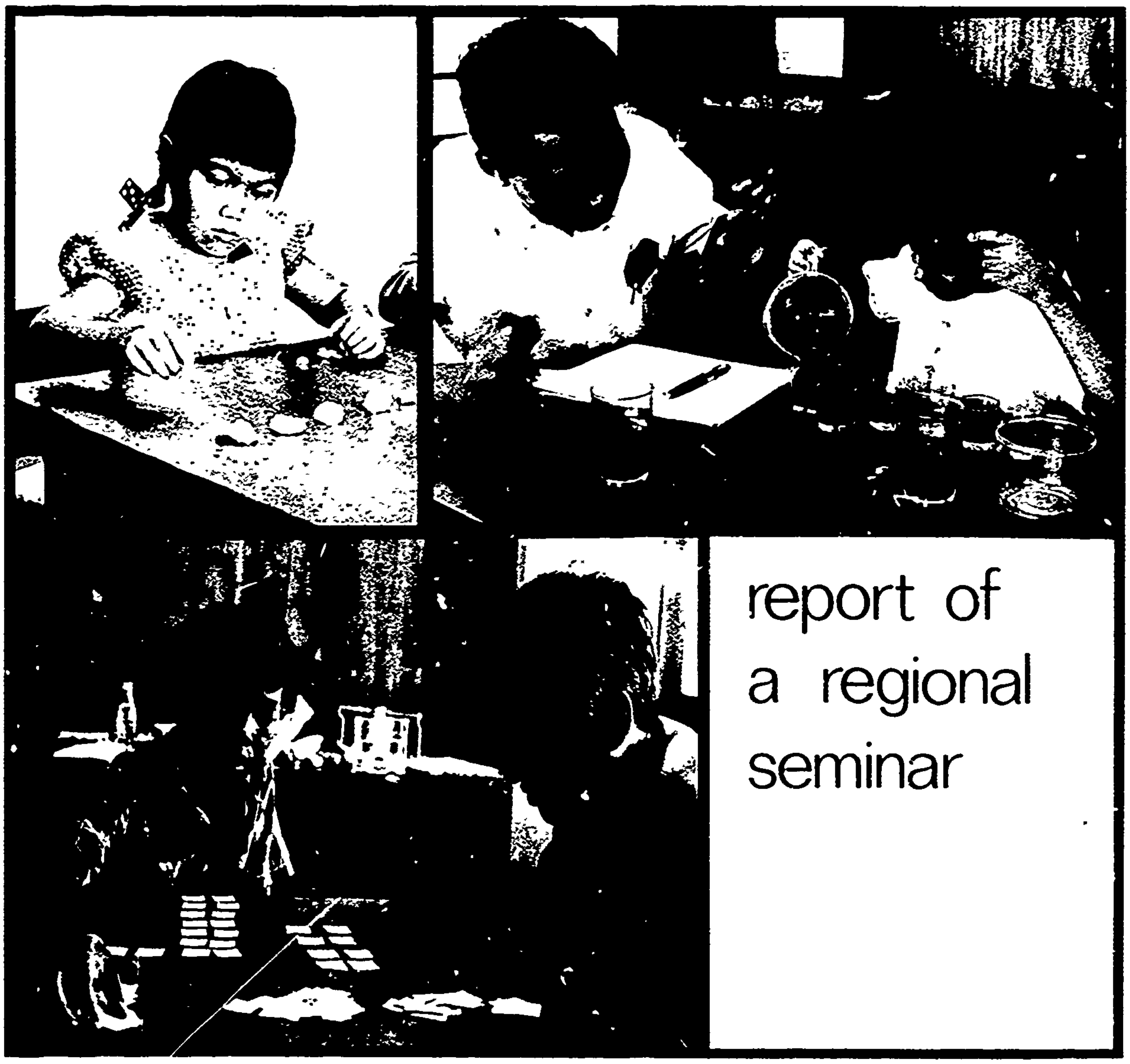
ABSTRACT

The objectives outlined for the seminar included the identification of learning problems encountered in curriculum projects in Asia and the development of solutions for these in the light of past or future research on concept development. The report is divided into six chapters. Chapter one presents a comprehensive review of literature on the present understanding about learning processes in children. The major portion of this chapter is devoted to the theories of learning as expounded by Piaget. A brief review of other viewpoints is also included. Chapter two deals with the question of diagrammatic representation as it related to the understanding of associated concepts. In chapter three, the implications of psychological theories, mainly Piaget's are considered for curriculum development and teacher education programs. Chapter four presents an overview of curriculum development projects in Asian countries and main problems encountered in these countries. The last two chapters present the conclusions and recommendations reached by the seminar participants regarding future programs for research and materials development. A selected bibliography on concept development is provided. (PS)

the development of science and mathematics concepts in children



report of a regional seminar

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Asian Expert Seminar on the Development of Science/Mathematics Concepts in Children, Bangkok, 29 May - 10 June 1972. *Final Report.* Bangkok, Unesco Regional Office for Education in Asia, 1972. p.

1. CONCEPTS AND CONCEPTUALIZATION
2. LEARNING, PSYCHOLOGY OF

ASIAN EXPERT SEMINAR
ON THE DEVELOPMENT OF SCIENCE/MATHEMATICS CONCEPTS
IN CHILDREN

Bangkok, 29 May - 10 June 1972

Convened by Unesco and UNICEF
in association with CEDO

FINAL REPORT

UNESCO REGIONAL OFFICE FOR EDUCATION IN ASIA
BANGKOK
1972

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The views expressed in this publication are those of the participants of the Asian Expert Seminar on the Development of Science/Mathematics Concepts in Children, and do not necessarily reflect the official position of Unesco. No expression of opinion is intended herein concerning the legal status or the delimination of the frontiers of any country or territory.

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TABLE OF CONTENTS

TABLE OF CONTENTS (cont'd)

FOREWORD

Do children always learn what we consider important? "One five is five, two fives are ten, three fives are fifteen, four fives are twenty, ..." chanted the class. Walking round the room, the teacher heard one boy repeating "Da da dee dah - Da da dee dah." "What are you saying?" the teacher asked. "Oh, I've learned the tune. It's only the words that I don't know yet," was the reply.

When we investigate the concept of time held by children at the primary level, it is found that their ideas are not what we would expect. Indeed they are startling. Two toy cars were started and stopped simultaneously. The simultaneous starting and stopping were emphasized by the loud clanging of a bell. The cars moved along straight paths, one moving faster than the other. The children were asked whether both cars were moving for the same amount of time. Typical answers were the following: "Of course not, that one went further, so it must have been moving for a longer time." Investigations of this type indicate very clearly that assumptions which many teachers have regarding the way that children think need to be recognized and re-examined very thoroughly.

Are students, and particularly young children in primary schools, always capable of understanding what the curriculum demands of them? How much is known about Asian children's cognitive development? Are there significant differences between children from one country and another; between children from urban and rural areas, from different cultural backgrounds? What is the effect of malnutrition? Research work in Europe and North America has established that there are important variations in the way children think from pre-school age to secondary age. Are there implications for education in Asia? How far is the school curriculum being designed to take account of these changes in children's thinking as they grow up?

Curriculum projects have so far, generally proceeded on an empirical view of how children in different environments learn science and mathematics concepts, and the teaching methods and instructional materials have grown up accordingly. Most effort has been put into the design and development of science and mathematics curricula which are up-to-date, coherent and 'logical' from the point of view of the disciplines themselves. Time and money have been spent in refining and adapting this work and devising means of implementing these new curricula, not only in the countries of the Asian Region, but throughout the world. But what is the impact of these programmes on the child? We really are not sure, and it is time to devote some money and intellectual effort in order to conduct research into the many questions that arise. The results of such research should be invaluable in designing curricula that are truly adapted to the needs of children.

Throughout the world vast increases in scientific knowledge are overloading the syllabuses. There is a keenly felt need to present the knowledge in a meaningful way so that an understanding of science becomes part of the heritage of every individual. Educators everywhere are reconsidering the content of curricula and teaching methods employed. In countries where universal education is still a goal to be achieved, far-reaching and urgent changes are needed. The focus on meaningful knowledge is one of the far-reaching changes urgently required here too.

Research work into various aspects of cognitive development in children, including such aspects as one-to-one correspondence, class inclusion, conservation of length, conservation of volume, etc., has been started in some Asian countries. The need has been expressed, however, by many Member States for more interchange of ideas and experiences between countries within the region, and for increased intellectual and material support to stimulate further developments and particularly to indicate how this research work can be usefully integrated with curriculum development in science and mathematics, and directed to the practical problems which confront the curriculum makers in Asia.

The importance of the need to understand more fully the learning process in connection with science and mathematics teaching was stressed at the Planning Meeting for Unesco's Programme in Integrated Science Teaching in Paris in 1969. Of particular importance is a paper entitled "The Learning Process and the Teaching of Science and Mathematics in Developing Countries" prepared for the United Nations Advisory Commission in the Application of Science and Technology to Development by Bruner, Lee, Levis, Rogers and Stone.[1] The Advisory Commission made use of this paper in emphasizing the importance of research on the learning of science and mathematics and indicated the need for a major programme in this field. The Asian Expert Seminar on the Development of Science/Mathematics Concepts in Children, of which this is the Report, represents a first important step in launching such a programme in the Asian Region.

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1. Ref. the Report on Science Education (The Learning Process and the Teaching of Science and Mathematics in Developing Countries) prepared for The Advisory Committee on the Application of Science and Technology to Development at its eighth session, November 1967 (UN/ECOSOC/ACAST. E/AC.52/3 June 1970).

INTRODUCTION

Unesco and UNICEF jointly convened, through their Regional Offices in Asia, an Expert Seminar on the Development of Science/Mathematics Concepts in Children. The Seminar was organized in accordance with the recommendation relating to regional seminars on science education which was made by the Third Regional Conference of Ministers of Education and Those Responsible for Economic Planning in Asia (Singapore, 31 May - 7 June 1971).[1] Assistance to the Seminar was provided by the Centre for Educational Development Overseas (CEDO) of the United Kingdom.

Objectives

The objectives of the Expert Seminar were:

i) To share knowledge of work that has been carried out in the field of concept development in science and mathematics in children (age range 3-11/12 years), and relate it to curriculum development in science and mathematics;

ii) To identify, through exchange of experience, the learning problems encountered in curriculum development projects in Asia and to examine them in the context of research in concept development;

iii) To develop plans and methodologies for new research in concept development in the specific context of the environment and conditions in the Asian countries;

iv) To consider ways and means by which the findings of research may be fed into practical curriculum development work in science and mathematics, including the design of science and mathematics teaching materials and equipment. (The Agenda of the Seminar is at Annex II).

Participation

The participants in the Seminar were specialists from the Member States which have Unesco-UNICEF assisted projects relevant to the theme of the Seminar or are doing research in the learning process in children. They attended

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1. Unesco. Third Regional Conference of Ministers of Education and Those Responsible for Economic Planning in Asia, Singapore, 31 May - 7 June 1971. Final Report. Paris, October 1971. 91 p. (ED/MD/20). Convened by Unesco in co-operation with ECAFE.

the Seminar in their individual capacity, and included (i) specialists in science education who were actively engaged in developing curriculum and instructional materials particularly for primary and lower secondary levels of education, and (ii) specialists doing research in the formation of science/mathematics concepts in children.

The assistance of two consultants provided through the courtesy of the Centre for Educational Development Overseas (U.K.) was available for the Seminar. (A list of participants, consultants and observers appears in Annex V).

Country Reports

The participants from the Member States were requested to send the following materials to the Unesco Regional Office. These were presented by the participants at the Seminar.

A. Those concerned with curriculum development and instructional materials

A report on past and current activities of their project, including identification of learning problems encountered, indication of methods by which research findings are used in curriculum work, and suggestions about the type of problems to which future research might be directed.

B. Those concerned with research

A report on past and current activities on investigations into learning processes in relation to science and mathematics concepts of children in the age range 3-11/12 years; and an indication of future plans for work in this field.

Documentation for the Seminar

Each participant received, in advance of the Seminar, a package of materials containing some selected books of reference, a comprehensive account of various approaches to studies in the learning processes, reprints/abstracts of some important articles on the subject and other relevant materials. A supplementary package was also presented to the participants on arrival. Additional resource materials were available for the Seminar Working Groups.

Copies of the Country Reports received from the participants were distributed at the Seminar. Bulletins containing further resource material for discussions were distributed to the members of the Seminar as needed.

Inauguration

The Seminar was inaugurated by H.E. Bhunthin Attagara, Under-Secretary of State for Education, Government of Thailand. This was followed by addresses delivered by Mr. Raja Roy Singh, Director of the Unesco Regional Office for Education in Asia, and Mr. Yehia H. Darwish, Regional Director of the UNICEF East Asia and Pakistan Regional Office. (These addresses appear in Annex V).

Officers of the Seminar

The Seminar unanimously elected Dr. Chancha Suvannathat (Thailand) as Chairman, and Mr. D.A. Perera (Ceylon) as Rapporteur. Mr. J. Ratnaike, Education Adviser of the Unesco Regional Office for Education in Asia was designated Secretary of the Seminar. The Seminar also elected six Vice-Chairmen, members of the Bureau of the Seminar, and the Report Drafting Committee. (List of Officers of the Seminar appears in Annex I).

Methods of work

The work of the Seminar was spread over four phases (The Schedule of Work adopted by the Seminar is at Annex III):

Past and Current Research (Phase 1): The Seminar started with presentations made by the participants regarding their curriculum and research projects with particular reference to the learning problems encountered. These formed basic background material on which the work of the Seminar was built.

During the first four days presentations were made and discussions held on past and current research in the field of concept development in mathematics and science, with particular reference to the age range 3-11/12 years. Work being undertaken in Asian countries was presented in the form of accounts of progress in individual countries by the participants. A discussion followed each presentation.

During the course of the Seminar, films and photographs were shown, including some prepared by the Development Support Communications Service in Bangkok, and by Malaysia, as well as sequences from films made in other countries.

Discussions during the Seminar pointed up other factors which affect the learning processes, such as the cultural environment, relations within the home and school and other influences. These factors were referred to in sufficient detail to create an awareness of their importance. The role of language in concept formation in science and mathematics was specially mentioned and relevant research projects were quoted.

Introduction to Methodology in Research (Phase 2): The Seminar was planned to encourage the establishment of problem-centered research and development programmes in the participating countries. Discussions on the approaches that could be used in investigating concept formation in children by research workers and curriculum developers were therefore an important feature. Demonstrations on how children are interviewed were given with groups of children by the consultants and by those participants who already had experience in this field. Opportunity was provided to other participants not only to observe these demonstrations but also to work with children.

Plans for National Research Programmes (Phase 3): At the end of the first week of the Seminar, participants were asked to consider areas in which further work by way of research or development might be initiated, and these plans formed the basis of the work during the last week. Particular problems and anticipated difficulties were discussed.

In the selection of research projects, the relevance of research programmes to curriculum development and to teaching materials including equipment was examined.

Preparation of Report (Phase 4): The Rapporteur and the Drafting Committee prepared and reviewed a draft report which was discussed by the participants and adopted as the Final Report of the Seminar.

The Report

The Report first outlines some of the knowledge about development of cognitive processes that is already available (Chapter 1). While there are a number of workers in the field of cognitive development, the studies of Piaget regarding the acquisition of certain concepts is of value in the context of school learning, particularly in the field of science and mathematics. Piaget has shown how understanding of such basic concepts of number, quantity and space develops in European children. The implications of these findings for curriculum development and teacher education are presented in this Report from two different perspectives. The researcher's point of view appears in the first part of Chapter III. The Seminar discussed the question "How can research findings be integrated into curriculum development and teacher education?". The latter part of Chapter III indicates their answers. Piaget's research method, based on a carefully worked out interviewing technique, in itself provides a valuable guide to improved methods of communication with children, and hence to improved methods of teaching.

The dangers inherent in making untested assumptions about the impact of visual symbols (such as the drawings and pictures used in charts and films) are pointed out in Chapter II. This Chapter suggests other areas for educational research which can be of direct benefit for the teaching methods and materials used in every classroom. The implications for teacher education are enumerated in Chapter III.

After more than a decade of activity in science and mathematics curriculum development, there has been, within the last few years, an upsurge of interest in developing learning psychologies to provide a theoretical framework for the curriculum developer's work. The work commonly cited is that of Bruner, and in the second section of Chapter I a brief outline of his school of thought is given.

Apart from a study of the psychological basis for learning, with which this Report is mainly concerned, it is vital in developing a curriculum to be aware of the aims and objectives one wishes to attain. People such as Bloom[1]

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1. Bloom, Benjamin S. Handbook on formative and summative evaluation of student learning, by B.S. Bloom, J.T. Hastings and G.F. Madaus. New York, McGraw-Hill (1971) 923 p.

and Gagné[2] have provided models for identifying and ordering these objectives. Yet another school of thought which appears to offer a useful framework for research in science and mathematics education has been developed by Ausubel.[3]

No attempt is made in this Report to deal with all these (and other) theoretical viewpoints, although a selected bibliography appears as Appendix III and is intended to be useful for those just starting or organizing research work in the field of science and mathematics education.

As a means of helping such research to get underway, the participants of the Seminar identified a number of research programmes which would meet the current needs of countries in the Asian Region. These are enumerated in Chapter IV of this Report.

The participants also tried out for themselves, with Asian children, the interviewing techniques developed by Piaget. They were assisted by the consultants and a number of observers actively concerned with the kind of work described in this Report. A brief report is in Appendix II.

A review of some relevant research and curriculum development work already accomplished in Asia is given in Chapter IV. Finally, in Chapter V recommendations for future action, developed by participants at the Seminar, are enumerated.

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2. Gagné, Robert M. The conditions of learning, 2nd Ed. London, Holt, Rinehart and Winston (1970) 407 p.

   The work of Gagné has become embodied in the elementary science programme (Science - A Process Approach) which has been developed under the auspices of the American Association for the Advancement of Science. Some aspects of his work are incorporated in Appendix I.

3. Ausubel, David P. "A Cognitive Structure View of Word and Concept Meaning" in: Readings in the Psychology of Cognition, eds. R.C. Anderson and D.P. Ausubel, p. 58-75. New York, Holt, Rinehart and Winston, Inc. (1965 a).

CHAPTER ONE

INFORMATION ON THE THINKING PROCESSES OF CHILDREN *

The model expounded by Jean Piaget describes the way in which children gradually understand the world they live in. (The work of other people will be considered later in the chapter). Piaget's work has the advantage of not only providing an enormous amount of information from experimental work but also in presenting a theoretical interpretation of these findings.

Piaget's main concern has been the study of how intelligence develops and the laws which govern this development. In defining intelligence Piaget would say that it is the indispensable instrument which organizes the interaction between the individual and the environment thus creating adaptation - and that there is a tendency to always strive towards a better and more advanced form of adaptation. Thus intelligence may be thought of in terms of the 'known' processes of the individual becoming more and more flexible and always moving towards a state of equilibrium.**

In this analysis of intelligence Piaget constantly refers to its dual nature: the way it functions, and its developing form or structure. In every intelligent act these two aspects are inseparable, though for the sake of clarity they will be looked at separately.

By function, Piaget means the way in which intelligence actually works. The functional process can be seen as two complementary processes - assimilation and accommodation - but one can never exist without the other. The functional process is invariant, i.e., the process is the same at all ages.

When the child tackles any new situation he naturally goes about it in ways that are familiar to him. In other words, he tries to incorporate the novelty of the outside world to what he understands already. Assimilation can in this way be seen as the activity of the subject on the outside world with the gradual incorporation of the newness of this external reality into the child's actual thinking processes.

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* The material for this Chapter was provided by one of the two consultants to the Seminar: Miss Joan Bliss, who has worked closely with Prof. Jean Piaget in Geneva, and has had experience in conducting concept development research in the West and in Asia.

** Equilibration is the fundamental principle of mental development in as much as it can be seen as the mechanism of transition. There is a homogeneous process of equilibration which will gradually produce a series of states of equilibrium. The state of equilibrium always refers to a balanced state of relations between the subject and the environment.

The new objects and situations of the outside world cannot always be incorporated into the child's thinking process, thus imposing certain constraints on the child's activity. However the child does not submit passively to such constraints but adjusts his actions so that he can deal with them more appropriately. Thus, accommodation is the activity of modifying the assimilation schemes.

In any intelligent act the individual will assimilate or incorporate the external reality into his thinking structures and at the same time accommodate these structures to deal more appropriately with the reality. Adaptation, therefore, occurs when assimilation and accommodation are balanced.

In seeking to explore and understand the world around him, the perpetual functional process of the child will generate mental structures and these structures will develop and change with the child's growth. These successive mental structures, which will be helping the child to organize his experience, can be seen to develop in four stages - the type of mental structure thus characterizing the stage of development.

Although these mental structures will be very different according to the level of development of the child, there is an underlying principle that is common to all the structures. A simple way of looking at structure is to see it as a form of organization of experience. More fully, there is structure when the elements (or activities) are organized into a totality and when this totality has characteristics proper to itself as a totality, the properties of individual elements being less important than the properties of the totality.

A brief outline of the stages, based on research done in Europe and North America, is given here, but this will be elaborated later:

i) The sensori-motor stage is from birth until about one and a half/two years during which the child organizes his world through his senses and his actions. During this period language and thought processes are slowly developing and will only appear at the beginning of the next stage.

ii) The pre-operational stage is from about one and a half/two years until about six/seven years. During this period the child has acquired the power to think, and is putting into thought all that he learned in a practical manner in the sensori-motor stage. The child's thinking will be "pre-logical" as it is greatly influenced by perception and by the fact that the child would seem to take for granted, but unconsciously, that this point of view is the same as everyone else's.

iii) The concrete-operational stage is from about six/seven until about twelve/thirteen years - the child is beginning to think logically about the real world but is very much tied to concrete situations and finds difficulty in generalizing from one situation to another.

iv) The formal operational stage is twelve/thirteen years onwards - the child will gradually be able to extricate himself from the real world and, when thinking about a problem, be able to think in terms of all the possible hypothetical solutions relevant to this problem.

According to Piaget there are a number of important principles which regulate the development of stages.

The first of these principles is that the stages and the concepts within these stages occur in a certain order and this is invariant, though the age at which a stage is reached may vary from child to child. Therefore, the important fact is that the sequence of stages remains constant, that is, the pattern of development is the same for all children, whereas each individual child will vary in pace in attaining certain concepts or stages.

The second of these principles is that when a stage is reached the elements of behaviour will come together to form an integrated whole - a new mental structure having its own properties. This structure will now characterize the way of thinking of children during this stage.

A third principle regulating the development of stages is that everything the child has understood at any one moment of his evolution is always integrated into his later stages of understanding.

The fourth principle is that there is always a period of preparation during which the stage or the concept is in the process of formation and this is followed by a moment when everything falls into place and the stage is fully realized or the concept fully acquired.

Sensori-motor stage

The sensori-motor stage extends from birth until the acquisition of language. This is a remarkable period of development, as the child who enters the world with a few hereditary reflexes as his only equipment, manages to organize the whole of the world around him through his senses and his actions.

Piaget describes in detail the way in which the child's practical intelligence develops. However, during the sensori-motor stage he constantly refers to the notion of a scheme. A scheme is a series of co-ordinated actions that are capable of being applied not only to the situation in which they were organized, but also to other analogous situations.

During the first sub-stage (0 - 1 month) the child consolidates the reflexes which he is provided with at birth. The characteristic of the second sub-stage (1 - 4 months) is the primary circular reaction. There are three types of circular reaction during the sensori-motor period. What is common to all circular reactions is that the child does something quite fortuitously and this produces an interesting effect, the child repeats this action immediately so as to recreate the effect that fascinated him. During the second sub-stage the child's circular reactions are all applied to his body. For example, the child will find it interesting to suck his thumb once he has discovered this by chance and will repeat this, thus acquiring a habit. This habit formation is the first type of acquired adaptation.

The third sub-stage (4 - 8 months) can be characterized by the child's discovery of the secondary circular reaction and by the procedures he adopts for making interesting things last. In this instance the second circular reaction is applied to objects in the world. For example, the child finds a cord hanging from the hood of his pram, he pulls this and it makes a figure attached to the hood dance and move about in all sorts of interesting positions. The child keeps repeating this to make the figure dance. Later on the child will generalize this procedure to all things that are hanging in an attempt to see if the interesting spectacle will recur. The behaviour at this stage shows the first signs of intentionality.

Sub-stage four (8 - 12 months) is a very important one since for the first time in the child's practical world he can initially consider a goal he wishes to attain, and then find a practical means to achieve it, in other words a co-ordination between means and ends. This type of behaviour is due to the fact that the child is beginning to co-ordinate with each other the secondary circular reactions developed in sub-stage three.

The tertiary circular reaction appears during the fifth sub-stage (12 - 18 months). In this instance the child stumbles on something new that intrigues and excites him and instead of simply repeating the action to recreate the effect, the child now repeats the action with variation. It would seem as though the child is really exploring all the possibilities of the object, varying his action more and more to see how this affects the object.

In this fifth sub-stage (12 - 18 months) the child's practical world is really well organized. He can find all sorts of new means to attain pre-established goals by extremely active experimentation. However, there is one limitation. All of the child's activities are still limited to his perceptual field. Once things happen outside his perceptual field then he is at a loss.

In the sixth sub-stage (18 months on) a new important behaviour pattern appears. The child wishes to achieve some goal and, at that point, has no particular means available. He starts to experiment as in the fifth stage but then he suddenly stops, looks at the situation and after a while, without any further experimentation, finds a way of achieving his goal. In other words, the child now invents a solution in his mind rather than in action. Thus in this stage the child acquires the capacity to represent actions rather than to have to carry them out experimentally. The end of the sensori-motor period thus indicates the beginning of the pre-operational period.

Pre-operational stage

At about 18 months to 2 years, the child seems to have the capacity to represent activities in thought, that is, he can now think about his actions and does not always have to do them. Representation means the possibility to evoke by means of images or signs, something that is absent. In other words the image or the sign stands in the place of, and signifies the absent reality.

Piaget distinguishes between representation in the broad sense and representation in the strict sense: "In the broad sense, representation is identical with thought, that is, with all intelligence which is not simply based on perceptions or movements, but on a system of concepts or mental schemes. In the strict sense, representation can be limited to the mental image or to the memory-image, that is, to the symbolic evocation of absent realities. Moreover, it is clear that these two kinds of representation, broad and strict, are related to each other insofar as the concept is an abstract scheme and the image a concrete symbol ; even though one no longer reduces thought to a system of images, it is conceivable that all thought is accompanied by images, for if thinking consists in relating significations the image would be the 'signifier' and the concept a 'significate'.[1]

When considering representation in the narrow sense, the term 'semeotic function' should be used, as this is the function which allows absent people and things to be made present. Thus the semeotic function is made up of a number of signifiers namely signal, symbol and sign. These allow the individual to represent the outer reality and translate into meaningful terms the internal world of schemes, operations etc. Both the persons and objects of the outside world and the schemes of the internal organization are known as 'significates'.

Within the semeotic function the 'signal' is not differentiated from the significate it represents ; it appears already in the sensori-motor period, e.g. the sound of the telephone, the smell of food. These are all integral parts of the object. The symbol on the other hand is differentiated and yet bears some resemblance to the significate. For example, a child who ties a piece of string to a stick and pulls it along the street saying "Woof, woof", is symbolically representing a dog out for a walk. The sign is differentiated and only relates to the significate in an arbitrary, conventional manner, e.g. language.

At about two years the appearance of the power to represent, that is to use the semeotic function, becomes very clear in the behaviour of children. Not only do they represent acts mentally, their language is developing and considering near past and near future events. They are beginning to play symbolical games e.g. 'make believe', and they are imitating people and objects no longer present. By about three years old they will begin making drawings of people and things. All these activities require the semeotic function.

According to Piaget, the power of representation does not just suddenly appear at 18 months. It develops very slowly through imitation. During the sensori-motor period the child is slowly learning to imitate and he can do this successfully in the presence of the model he is imitating, at about 18 months. The first deferred imitation, that is without the model present, does not need a mental image as it has a motor image. For example, Kamala saw a friend of hers throwing a tantrum. She had never thrown a tantrum before, and was very impressed by this new form of behaviour. Several hours later, at home, Kamala throws a tantrum, but with smiles all over her face. It is as if Kamala has a motor image of the happening. This motor image, or first type of deferred imitation internalizes itself and becomes a type of mental image which will serve as the basis for much of semeotic functioning.

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1. Piaget J. La formation du symbole chez l'enfant. De la Chaux et Niestle S.A. Neuchâtel, Deuxième édition 1959. (English title: Play, dreams and imitation).

In the pre-operational stage there are two sub-stages, the first one from 2 years until about 4 years, which is the pre-logical stage, and the second one, from 4 until about 6/7 years, which is the intuitive reasoning stage. During the pre-logical stage the child learns about the world mainly through language play, deferred imitation and drawing. In all of these areas the child will be learning to look at the world, see how shapes fit together, explore the physical attributes of objects, discover how space is organized, etc.

During this stage pre-concepts dominate the child's thought. Pre-conceptual thought attains neither true generality nor true individuality, but tends to fluctuate between these two extremes. The objects classified by the pre-conceptual structure have less individuality, that is, they do not keep their identity through time, and the classes are less comprehensive a class, being (to the child at this stage) a typical individual reproduced several times.

In other words, due to the lack of a general class as a framework, the individual elements cannot be assembled into a whole and so tend to be confused with each other. Due to a lack of individuality of parts the whole cannot come into existence. This is due to the incomplete assimilation in as much as the child centres on one typical example which is the object that interests him in his lived experience and chooses this to represent and embrace the whole class. The chosen example does not include the characteristics of the class but is related to the child's interest. Also there is incomplete accommodation in as much as this stereotyped image is simply repeated to represent the extension of the class.

The reasoning process of the pre-logical child seems to be one of 'transduction' (as described by Stern[2]). In transduction inferences would seem to go from particular to particular, whereas in induction they proceed from particular to general and in deduction from general to particular. Thus the transduction process would seem to precede both induction and deduction. An example of transduction is the following: a father takes his young daughter for a walk every day and they always meet an old man who had been a soldier in the First World War. During the war gangrene had started in the soldier's leg and to save him the leg was amputated. The child had been very curious about this and her father had explained that the soldier's leg had something very wrong with it and this had made the soldier very ill and so it had to be amputated. Some time later the old soldier caught a cold and was not there to meet the child for several days. The father announced one day that the old man was better and they would see him again and the child asked in a delighted way: "If he's better then will he have his leg back?".

The pre-logical schemes used by the child at this stage are the product of assimilation which is distorted as it is centred on individual elements which interest the subject.

From about 4 years old the intuitive reasoning sub-stage starts.

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2. Stern W. Psychol. d. fruh. Kindheit, 4th edition.

There are two main obstacles the child's thought must overcome in order to reach the stage of logical concrete thinking, namely perception and egocentrism. The child has a tendency to believe his immediate perception. It is the measure of all things. He tends to see a great many things but does not organize his perceptions. His attention is limited and he does not make comparisons nor try at this stage to look for relationships between things. The child tends to believe what he sees rather than think about it.

With egocentrism, which for Piaget is an unconscious phenomenon, there is a confusion between the self and the outside world, an indifferentiation between the self and the world. The child tends to centre on his own point of view and there seems to be, at first, an impossibility for him to differentiate between his point of view and that of others. The child would seem to take it for granted, but not consciously, that everything he thinks everybody else thinks also.

The following brief examples illustrate the child's difficulties in very concrete situations and show at the same time the way in which the child gradually passes to a more logical point of view.

Example 1

A row of 10 or 11 coloured counters can be put out in a line in front of the child and he can be asked to put as many green buttons (from a large pile) as there are coloured counters. The young child will content himself with a row of buttons that is as long as the row of counters, without bothering about matching the counters and buttons. In this instance the child is evaluating the quantity merely by the space it occupies. A child who is a little older may match both sets, but when asked if he needs the remaining buttons will then proceed to fill in the empty spaces in the line. Here is a type of primary intuition. The child is beginning to understand the idea of matching but it is still very fragile. With children who can understand the idea of matching, when one of the matched sets of counters or buttons is either spread out or put in a pile, and the child is asked if there are still as many buttons as counters, some children will say that the number of objects in one of the sets has changed because they look different. In this instance there is an articulated intuition as the child knows there is equivalence as long as there is a visual correspondence. But as soon as one of the sets undergoes a transformation this equivalence disappears. Children who are reaching the stage of concrete operations might say: "Of course there's the same number of counters as buttons because you haven't added any or taken any away" ... or ... "This line is much longer but much more spread out and this line is shorter but the buttons are close together."

Example 2

The child is given a fairly large collection of geometrical shapes - say, circles and squares - which are red and blue, and large and small. He is asked to sort into piles 'things that go well together'. Four year-old children may simply make figural arrangements with them, or later put them in a line, one of the attributes of a figure, say the colour, the shape, or the size, determining the choice of the next figure.

Slightly older children will make as many piles as there are sub-sets in the whole collection, for example all the large red squares together, all the large blue squares together, all the large red circles together, etc.

Children at about 6 or 7 will tend to sort them into two piles according to one of the properties e.g. colour, shape, size.

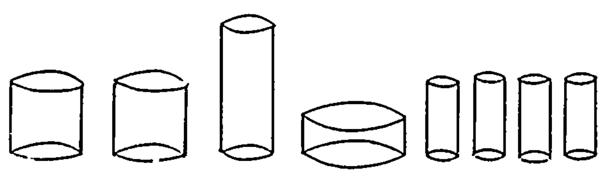
Children can be asked to sort the figures into two piles only. In general, children tend to sort according to colour. The object is then to see whether or not the child can re-sort in terms of either one of the two remaining properties. In this situation the child's flexibility of thought can be seen through his ability to shift from one criterion to another. The articulations of his thought processes will be observable in his very actions of sorting.

Example 3

The child is presented with three coloured beads (A, B, C) on a fairly rigid wire. The wire is moved into a paper tube from left to right. The child is provided with a drawing of the three beads on the wire, and this is placed constantly in front of him. The child is asked to anticipate which bead will appear first on the right hand side and he will have no difficulty in anticipating that C will appear first. Next the beads are again inserted from left to right, but the tube is rotated through 180° around the centre bead before the children are asked to anticipate. Four year olds will have difficulty here in anticipating the order, A first, then B, then C on the right hand side. With primary intuitive thinking the child is able to anticipate one rotation and then, as his thinking becomes more articulated, he will be able to anticipate the order of the beads through yet another rotation of 180° thus coming back to the original position.

Example 4

In the last example to be mentioned, there is a jug of coloured water, two glass beakers the same size and shape, one jar narrower and taller than the beakers and another shorter and wider, and a series of three or four glasses as nearly the same as each as possible but much narrower than the beakers. (see diagram).



A certain amount of liquid is poured into one of the beakers until it is about half full and the child is asked to pour about the same amount in the other beaker. Once the child has agreed that 'there is about the same amount to drink in both glasses' the water is poured from one of the beakers into the tall thin glass and the child is asked: "Is there the same amount to drink in this beaker as there is in the other glass, or is there more or less?" Once the child has given his reply the water is poured back into the original beaker and the same procedure is adopted for a second step with the short, wide glass, and a third step for the four identical glasses.

Young children who are very tied by their perception will tend to reply that there is, for example, "Much more to drink in that glass" (tall one) "because it's so tall". As the child's thought starts to become a little articulated he might think of the other dimension of the glass when trying to justify his reply but he will not as yet be able to co-ordinate these two dimensions so as to arrive at the idea of invariance of the quantity of liquid.

Older children may well understand that the quantity of liquid to drink does not change when poured either into the tall thin glass or the short wide one, but their idea of invariance may still be very fragile and when the transformation is too great they may tend to fall back into a judgement that there is more water in one of the glasses.

In these instances when the child considers any static situation, he tends to explain it in terms of what he noticed at that given moment rather than seeing the changes that link up one static situation to another. This is essentially because his perception dominates. On the other hand, when the child considers the transformations linking states, he tends to see these as independent of the states and assimilate them to his own egocentric actions.

As soon as the intuitive reasoning stage starts the child begins to decentre and he does this in two ways. The first is through learning experience. There are two types of learning experience: the first is called physical experience and through this the child learns to abstract the physical attributes of objects, for example, their colour, texture, weight, smell, etc.

The second type of learning experience is logical-mathematical which consists of the child's activity on objects. In this situation the child will discover the properties of his actions and is not concerned with the properties of the objects themselves. Piaget calls this type of experience a 'reflective abstraction' as what is learned is abstracted from the co-ordination of actions.

The example Piaget often gives is that of the small child playing in a garden with ten pebbles. The child rearranges the pebbles in many different ways, counting each time the number of pebbles after every new arrangement. The idea that the child finally comes to is that no matter how he arranges the pebbles the number always stays the same. In this particular instance the pebbles could have been replaced by any other set of objects, as the child was learning about his own actions and not about the properties of objects.

A second way in which the child decentres is when he begins to co-operate with his peers. The child can remain egocentric until he becomes aware that someone else has another opinion, or idea about a certain question. The child is then forced to consider his own ideas and verify them in this new light and at this point the decentering process will gradually begin.

At the concrete operational stage the child will be using operations to think with and to organize his world.

For Piaget an operation is an action that is internalized, reversible and co-ordinated in a total structure. An internalized action becomes reversible by its co-ordination with other internalized actions. The reversibility and internalization of actions could be seen to be achieved through the process of decentering which itself is composed of this dual process of co-ordination of actions in logical mathematical experience and co-operation with peers.

Concrete operational stage

At about the age of 6 or 7 years the child will have at his command an integrated and coherent system of mental operations with which he will now be able to organize the world around him. The child applies logical, flexible thinking processes to a multitude of different situations in reality.

One of the concepts the child will acquire during this period is that of number. The concept of number, however, is very abstract and it takes the child some time to acquire it. If, for example, somebody in a conversation says: "No I didn't see those seven things", it is not possible to know what the person is referring to. It might have been seven pictures, seven trees, seven cars, seven 'anything'. The use of numbers implies that the properties of the objects are no longer being considered, all the objects are being referred to as though they are the same or, to use another term, equivalent. This is quite a big step from reality.

Suppose a young child is playing with three sets of objects: a set of bananas, a set of toys and a set of coins, and there are the same number of objects in each of the sets. The child will match the set of bananas with the set of toys and the set of toys with the set of coins, in a one-to-one correspondence relation. By doing this he will discover that there are as many objects in the first set as the second, and as many objects in the second set as the third set. Through the process of matching he will have found out that there is a 'sameness' about the sets which is the 'quantity of objects' in each set. However he can only establish this idea of 'sameness' if he ignores the properties of each of the objects. Otherwise it is impossible to say that a set of bananas is the 'same' as a set of toys. In this situation the child has been able to make a number of equivalent sets.

Later on this idea of 'sameness' will not be sufficient because the child will want to know how many objects there are altogether on the table. If the child ignores the properties of the objects in order to say they are all the same, how can he be certain that, when counting them, the same object is not counted twice? Thus, though the first step towards the idea of number is to consider the objects equivalent, once he has done this he has no way of distinguishing between them.

The child establishes differences between equivalent objects by ordering them. He will say in his mind "This one comes at the beginning, then this object comes next to the one at the beginning, and this object comes after those already lined up ...". The objects are, therefore, still the same as one another and yet at the same time different from one another, since each has a particular place in the series.

In this manner the child will gradually realize that there is a first object which is one element, that when he has counted to the second object there are two elements and so on. In grasping the concept of number the child will be understanding both the ideas of cardinality and ordinality.

Once the child has understood the idea of number he can then start doing operations on numbers, the most fundamental one being addition. Before the child starts adding numbers using an abstract sign for addition, he can, at the concrete operational stage, develop an understanding of this operation by uniting sets of objects. The sets of objects the child unites, however, must be disjoint, that is have no objects in common.

The child will discover by uniting two disjoint sets, say a set of daisies and a set of roses, that there must be as many objects in the new set of flowers as there were in the original sub-sets and no more. Every object in the new set of flowers belongs to one or other of the original two sub-sets.

One important aspect of union is that of inclusion. The child knows for example that the set of daisies is included in the new set of flowers and that the set of roses is included in the new set of flowers. The logical inference is that there must be more elements in the new set of flowers than in either of the sub-sets (provided that in all examples used for union, one of the sets is not empty).

In a practical situation, children are shown a bunch of flowers with say 7 daisies and 2 roses, having agreed that both the daisies and the roses are flowers, they are then asked: "In this bunch are there more flowers or more daisies?" Young children will tend to reply, for example, "There are more daisies than flowers because there are only two roses". In this instance the children are finding it difficult to compare the sub-set to the whole set. Children who have acquired the concept will say: "Of course there are more flowers, because daisies are flowers and so are the roses".

Multiplication is another important operation on numbers. In 'Beginnings 1'[3] a story of multiplication is told. There are three little girls and a set of two ring boards. The three children are going to play a game and will be allowed one turn at each ring board. The question is how many turns will there be altogether. This story can be imagined in the form of a table.

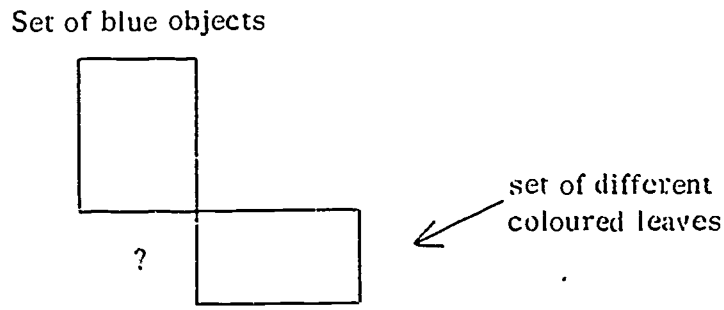
	Red ring board	Blue ring board
Anna	Anna's turn at red board	Anna's turn at blue board
Beryl	Beryl's turn at red board	Beryl's turn at blue board
Cleo	Cleo's turn at red board	Cleo's turn at blue board

Thus each girl from the set of children is matched in turn with the elements in the ring board set. Multiplication can be seen as the process of listing ordered pairs and counting them.

3. "Beginnings" 1, Nuffield Mathematics Project, U.K., Chambers and Murray, 1967.

During the concrete operational stage there are two examples which show how the child can slowly understand this idea.

In the first situation there are two strips of cardboard. A set of miscellaneous objects, is drawn on one of the strips - all the objects being of the same colour,e.g. blue. On the other strip a set of similar objects, e.g. leaves, is drawn and each element is a different colour from the other elements. The two strips are placed in the following position:



The child is asked to choose from among a series of cards spread out on the table, the one that will fit in the space (marked with a ?) so that 'it will fit in well with all the objects this way' (vertically) and 'and the objects this way' (horizontally).

This type of situation is repeated several times with different strips of cardboard.

Young children will have difficulty with this idea of intersection and will choose a picture of the object that is nearest the space. Children who are gradually coming to terms with the concept will choose a picture that contains the property of one of the sets only. Children at round about 8 or 9 will realize that the picture that fits the space must have two properties so that it is common to both sets, e.g. a blue leaf.

In a second situation the child is shown the following table :

	Red	Yellow	Blue
Daisy			
Orchid			
Rose			

In the top row there are a series of colours, each colour is descriptive of the objects in its column. In the column on the left there are black and white cut-outs of the flowers, and the flower determines the type of object to be found in that row. Thus each object placed in a square is determined at the same time by the row and the column.

Any one of the squares is indicated and children are asked to choose a card 'that will go well in this square both this way' (horizontally) ' and that way' (vertically). Children give very similar replies to those given in the first situation mentioned.

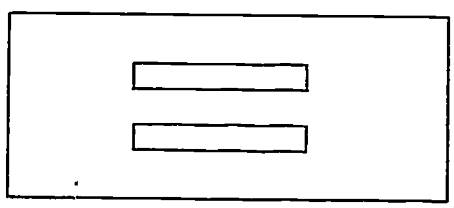
The first situation shows how children are gradually acquiring the concept of intersection. In the later situation each space could be seen as an intersection in as much as the first column of our table represents the set of all the pink objects on the desk and the first row represents the set of all the daisies on the desk. Each new object in a square will have two properties, that is colour and type of flower.

If this same table is looked at carefully, in another way it can be seen that every object in the set of flowers, e.g. daisy, orchid and rose can be matched in turn with every object in the set of colours and thus in the new set each object has a pair of properties.

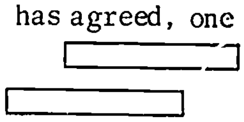
The activity involved in the acquiring of the concept of intersection can be seen as a springboard to multiplication.

Measurement is a necessary and vital activity of both children and adults in everyday living. The following situation shows how children discover the idea of measurement and the use of measuring instruments. A fairly tall wooden block may be placed on a table and a whole series of building blocks on the floor. The child may be asked to build on the floor a tower that is 'as tall as' ... or ... 'the same height as' the one on the table. Near the building blocks should be a series of possible measuring instruments such as strings, long sticks, pencils, small units, etc. Most children will tend to build the tower first and only afterwards think of measuring it. Some children at about 6, attempt to measure the tower by putting one hand at the top of the tower and the other at the bottom and trying to carry the length between their hands. Others may use their arms or hands as a measuring stick. Older children will discover that these measures are not efficient and will try to find a stick that is the same size as the model of the tower and refuse to use any of the others. Other children will take a longer stick, or a piece of cotton and mark the distance off but will refuse a stick that is smaller. It is only at about the age of 8 or thereabouts that the child will think of choosing a unit that is quite arbitrary in its size and stepping it along the total length of the tower to see how many times it fits.

Another concept that is interesting to investigate is the child's understanding of the invariance of length. Two sticks, each of about 10 centimetres long, can be placed on a table parallel to its edges as shown in the diagram.



The child is asked if both the sticks are 'the same length'. Once the child has agreed, one of the sticks is moved about 5 centimetres to the right, e.g.



and the child is asked again: "Are both the sticks the same length, or is there one that's shorter or longer?"

Children at the onset of concrete operations tend to think that when the ends of the sticks no longer coincide, one of them is longer than the other. A later step in development will show that some children will at first think that one stick is longer than the other, but when the distance between the two sticks is decreased, then they may think that they are of the same length. Round about the age of 8, children will begin to understand that the length does not change because the stick is moved.

During the pre-operational stage and leading into the concrete operational stage the concepts of the invariance of a quantity of objects and the invariance of a quantity of liquid are developing. The various concepts of invariance are important ones in the child's intellectual development.

The invariance of a quantity of substance (or amount of stuff), of weight and of volume, are all vital to children and the concepts develop slowly during the concrete operational period, the concept of volume bordering on the formal operational period.

In the situation where the invariance of a quantity of substance is involved, the child is presented with two balls of plasticine that are about the same size. He is asked: "Do you think there is about the same amount to eat in each of these balls?" In all experiments concerning invariance the initial equality of the two objects, sets, etc. being compared must be established. In a first step, once the child has agreed to the equality, one of the balls of plasticine is rolled into a sausage and the child is asked: "Is there the same amount to eat in the sausage as there is in the ball, or is there more somewhere?". After the child has given his reply and, if possible, justified it, the sausage is rolled back into a ball and the initial equality is established.

In a second step the ball is flattened into a pancake and the same procedure as in the first step adopted. This same thing happens in a third step but this time the plasticine is made into a series of tiny balls.

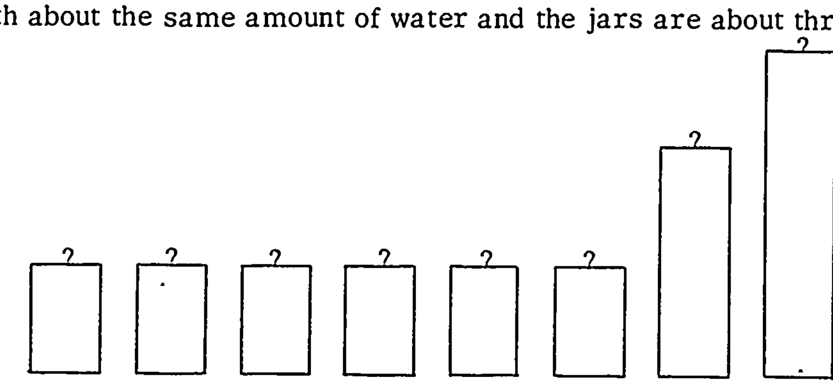
Children will tend to say that there is more to eat in the sausage because it is longer, or others might think there is less to eat because it is thinner. Children who are beginning to come to terms with the concept may realize that the quantity of substance remains the same for small transformations, but once the plasticine is made into a very long, narrow sausage, or a very large but flat pancake they may tend to change their judgement.

Once children have acquired the concept at about $7\frac{1}{2}$ they will justify their answer using the following arguments:

- "There must be the same amount to eat because it's still the same plasticine and you haven't taken any away or added any."
- "There's still the same amount to eat because all you have to do is to roll the sausage back into a ball, as it was before, and you'll see it's the same."
- "There's still the same to eat because even if the sausage is longer it's much narrower."

The concept of the invariance of the weight of an object appears a little later, round about 8-8½ years. In this situation two balls of plasticine are placed on a balance to make sure they weigh about the same amount. After this, the procedure is the same as in the illustration of the invariance of quantity. The balls of plasticine can be reweighed again after each step in the procedure, if the child so wishes. The replies the children give are similar to those given in the invariance of quantity.

Before discussing the invariance of volume, it is relevant to illustrate at this point that children have a difficulty in dissociating the ideas of weight and volume. The child is presented with a series of small cylinders all of the same volume. Four are made from aluminium. The others in the series are made from varying materials so that they are of noticeably different weights. Apart from these there is one aluminium cylinder that is twice the volume of the small ones and another which is three times the volume of the small ones. All the cylinders have a small hook to which is tied a thin piece of cotton so that they may be suspended in the water. There are also two tall thin jars both filled with about the same amount of water and the jars are about three quarters full.



In the first step the child is shown two cylinders of the same weight and the same volume, and asked to predict what will happen when they are put in the water. He is also asked to predict whether or not 'the water will go up the same amount in both jars', and to justify his statement. The cylinders are then suspended in the water, and the child is asked to observe and try and explain what has happened.

In the second step the child is handed two cylinders of same volume but different weights, and the procedure is then the same as in step one.

In the third step the child is shown the aluminium cylinder that is three times the volume of the small cylinders, and is told that it is going to be placed in one of the jars of water. The child is asked to choose, from the cylinders on the table, the ones he would need so that when placed in the second jar 'they will make the water go up the same amount as the water in the jar where the big cylinder is'.

Once the child has made his choice the cylinders are suspended in the water, and the child is asked to observe and try and explain what has happened.

In the fourth step the child is shown three small cylinders, all the same volume but each one having a different weight, and is told that they are going to be placed in one of the jars of water. After this, the procedure is the same as in step three.

Children at the onset of concrete operations are not able to dissociate weight from volume, and will constantly be referring to both when trying to carry out the various steps. Towards about 9, children will explain the rising water level by the weight of the objects, and though they will be very surprised by the second step they will revert to their idea of weight for steps three and four, always trying to choose objects that have the same weight as the one being shown to him. Children who are a little older will start off by thinking that weight is the determining factor, but they will learn as they pass through the various steps of the experiment that it must be 'the room' ... or ... 'the space' they take up. Children round about 11/12 will anticipate from the beginning that 'it is the space the object takes up in the water and not the weight' that counts.

The concept of the invariance of volume appears at the very end of concrete operational thinking and, in fact, borders on formal thinking. In this situation the child is shown two balls of plasticine and asked: "Are they both about the same size?" Once the child has agreed, he is shown two jars with the same amount of water in each and he is asked to anticipate what will happen when the balls of plasticine are placed in the water and to justify his reply. The balls of plasticine can have cotton tied around them and are placed in the water so that the child can observe the result of his prediction. One of the balls is taken out of the water and changed successively into various shapes as in the invariance of a quantity of substance and of weight. (Instead of the pancake transformation another one can be chosen, as the child often cannot imagine the pancake fitting in the jar).

Again the replies are very similar to those given in the invariance of substance and of weight. For example, the child who has grasped the concept might say: "Of course, the sausage takes up the same amount of space as the ball, it was a ball before and then it took up the same amount of space as the other ball and you haven't taken any plasticine away nor added any."

It can be seen through these various examples that concrete operational thought has the limiting characteristic that it cannot be immediately generalized to all situations. Thus it would seem that the child's thought essentially remains attached to a type of empirical reality and can only handle a limited set of potential transformations.

Formal operational thinking stage

Piaget sees formal operational thinking as the state to which intellectual adaptation has been moving since the very first sensori-motor schemes. Although the child has reached this final stage, the type of structure characterising his thought will constantly be used in situations of increasing complexity and this continual functioning of the structure will make it more and more adaptable to new situations.

The most important property of formal operational thought is the reversal of direction in the adolescent's thinking and his method of approach to a problem in as much as 'reality' becomes secondary to 'possibility'. When the concrete operational child is solving a problem, he is very tied to the real world in which the problem is embedded. He will not see all the possible solutions to the problem, and those that he sees are only an extension of the empirical reality. When the formal thinking adolescent tries to understand and solve a problem, the reality of the situation is seen as a special sub-set within the totality of things which the data concerning the situation would admit as possible. As Flavell says: "It is the 'is' portion of a 'might be' totality."

Formal operational thought can be characterized by several other important properties. The first of these is hypothetical deductive reasoning. When an adolescent tries to understand a situation or solve a problem he may well start by manipulating the objects in the situation. However, very shortly afterwards, he will take a step back from the reality of the situation and start to think of all the possible solutions. In this instance he is making all the hypotheses relevant to the situation regardless, for the moment, of whether or not they are true. Once this has been done he will then go back to the real situation and see which of these hypotheses do, in fact, hold true. The child at the concrete operational level may well seem to make hypotheses, but these are limited to a sort of outline of possible action. He does not consider, as does the adolescent, what the real situation would be like if this or that theoretical condition were to be fulfilled.

Deducation no longer refers to things directly known or seen but is the hypothetical statements or the propositions which are formulations of these hypotheses. These hypotheses postulate facts and events independently of whether or not they actually occur. The deductive process consists of linking assumptions and drawing out the necessary consequences even when their validity is only provisional and not yet experimental.

A second characteristic of formal operational thinking is that it no longer deals with objects directly. Verbal statements are substituted for objects. The assertions and propositions the adolescent is dealing with are verbal abstractions from the raw data of the real world.

Formal operations, however, do not constitute a verbal logic. It is not so much the verbal propositions that are important but the various kinds of logical connections made between them. Verbal propositions may be linked together in many ways, for example, conjunction, disjunction, implication, exclusion. Thus, it is a logic of all the possible combinations of the propositions - a propositional logic.

Yet another characteristic of formal thought is that it is a system of second degree operations. Concrete operations could be referred to as first degree operations in that they deal directly with objects, whereas formal operations deal with statements about these objects. The concept of proportion, which the child only acquires during the formal stage, illustrates this characteristic. Logically a proportion is the equivalence of a relation connecting two terms 'a' and 'b' to the same relation connecting two terms 'c' and 'd'.

It would seem that the way in which formal thought can be characterized most clearly is by the fact that it constitutes a combinatorial system. This property would seem to imply all the other properties mentioned until now.

But to summarize, Piaget says: "However general it may be, the combinatorial nature of formal thought is secondary to a still more general property, the subordination of reality to possibility."

Throughout this chapter the gradual development of intelligence has been described. Intelligence can be seen as a mode of description of the different levels of organization or equilibrium of cognitive structures. The notion of equilibrium which is central to the notion of intelligence therefore, needs defining.

Equilibrium is the fundamental principle of all development as there is a certain coherence in activity which means a movement towards stability, and more and more complex levels of equilibration. Equilibrium can be seen as a series of compensations which are due to the activity of subject in response to external perturbations. Piaget says that equilibrium cannot be defined as 'a balance of forces in a resting state'. A maximum state of equilibrium corresponds to a maximum of activities of the subject which will compensate for both the actual and virtual perturbations.

Other viewpoints

Jerome Bruner also provides us with a developmental approach to the child's cognitive growth with special emphasis on language. Bruner suggests several themes that recur when considering the child's development. Two of these are important within the present context. The first relates to how the developing child represents all his experience of the world. The second is that cognitive growth, though certainly dependent on the activity of the subject, is also influenced by the fact it takes place in a cultural setting, "it occurs as much from the outside in as from the inside out."[4] Intellectual growth is, in Bruner's opinion, inconceivable without consideration of the cultural and linguistic community in which it develops.

The child's world is known to him at first by the habitual actions he uses for dealing with it. In this instance he 'knows' through doing things. This mode of knowing is called enactive representation.

After a while the child acquires a second technique of representation which is action-free. This is through imagery. Thus the child has another way of knowing about the world, that is through pictures and images. This mode of knowing is called ikonic representation.

The third mode of representation is symbolic. This is a very powerful method of knowing the world, and the child can translate actions and images into language.

Bruner is, therefore, concerned with intellectual growth, as it is affected by the way in which children learn to represent the world through actions, images and symbols.

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4. Bruner, J.S., Oliver, R. and Greenfield, P.M. Studies in cognitive growth, New York. John Wiley & Sons Inc. 1957.

Enactive representation

The origin of enactive representation is to be found in the way in which the requirements of the child's action are related to the visual world. The child's actions help him to 'objectify' the external reality. These actions and information received from 'distance receptors' will be sufficient conditions for the child to make progress.

The passage from enactive representation to ikonic representation is important. The child's actions form serial behaviour patterns, each new step being regulated by environmental stimuli. At some point, his motor activity will become 'regularized' and then the form of this behaviour will no longer be serial but simultaneous, and consequently free from an action - dominated world. The child achieves this freedom, according to Bruner, by a shift from response learning which is regulated by the stimuli from the external world, to place learning. In serial learning, the child or adult learns responses in a sequence. For example, the way out of a maze may be considered in terms of 'turn right, turn left, turn left again'. Such learning becomes much easier when it can be fitted into a special background or layout, so that all the actions can be seen in a type of pattern linked together. In this way, actions are no longer learned in relation - one action following another, but rather in connection with particular places they occupy in a given spatial context. Spatialization provides an a-temporal framework into which behaviour can be fitted, and therefore organized simultaneously in many more flexible ways.

Thus it would seem that enactive representation does not have an overall autonomous system of reference. Consequently, the child must first establish a correspondence between his spatial world of vision and his serial world of action in order to free himself from his dependence on action.

Ikonic representation

The ikonic mode of representation allows the child to represent in his mind the outside world either by means of an image or a spatial schema, both of which are relatively independent of action.

By about the end of the first year the child will be using these images and spatial schema to organize his experiences of the world around him. It is, says Bruner, difficult to infer directly the nature of the image, and it seems to him that the characteristics of perception at this age might give some clue as to the properties of images.

Bruner refers to the way in which Gibson and Olum (1960) characterized perception. Thus the features that are important are the following: perception is 'stuck' i.e. it is not transformable; it is 'autistic'; diffuse in its form of organization; 'dynamic' in as much as it is closely influenced by action; concrete rather than a schematic or a type of abstraction; 'egocentric'; unsteady in attention and added to this original list is the fact that a minimal number of cues serve in the organization of the child's perception and these are ones he can most easily indicate himself.

Various pieces of research will help to analyse or look at these characteristics.

Briefly, it can be observed that imagery must be concrete in as much as children can pick out hidden figures if they are familiar and meaningful.[5] Small children need a fair amount of redundancy in pictures to identify them and thus find it difficult to reconstruct a whole from only a very few details in a picture.[6] Children, on the one hand, tend to look at things in a very global manner not noticing significant details, and yet on the other hand they sometimes respond to very small irrelevant details.[7] Children do not give a very long span of attention to anything and also almost involuntarily follow changes that occur in the visual field such as movement, a particular brightness etc. A distinction was drawn by Titchener (1908) between this type of primary attention and secondary attention where there is "an effort to focus on some segment of experience that would not, under the laws of primary attention, be particularly compelling."

For Bruner by looking at the child's perception of the world a clear idea of his image can be inferred. It would seem that it has the following characteristics: it is very rigid, lacking in flexibility; although global and diffuse in the way in which it is organized it is also dependent on minor details, it is self-centred and tends to be distorted according to affect. It is 'action-dependent' and at the same time extremely distractable. For Bruner the ikonic mode of representation is a system that "is labile and highly lacking in economy."

The young child who uses the ikonic mode of representation could be said to be image-bound. It would seem that although he can think about his perceptual world without being linked to it through actions, he is nonetheless very influenced by its appearance and tends to deal with the surface of things. These surface attributes would seem to attract his attention rather than the deeper structures that are 'based on invariance'. It is as though the child must find a way of getting to the base structures from the world of appearance. With ikonic representation the child is searching to match something that is in his mind with something that he is encountering in the outside world. It is only when he goes beyond this direct matching, Bruner says, that he will begin to be able to cope with ideas such as 'relations between quantities, invariance across transformations, ...'.

Symbolic representation

Symbolic representation would seem to start from a form of primitive and innate symbolic ability which gradually becomes specialized into different

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5. Witkin, H.A., Dyk, R.B., Fattuson, H.F., Goodenough, D.R. and Karp, S.A. Psychological differentiation: studies of development. New York. John Wiley & Sons. 1962.

6. Mooney, C.M. Age in the development of closure ability in children. Canad J. Psychol. 11: 219-226. 1957.

7. Hemmendinger L. Perceptual organization and development as reflected in the structure of Rorschach test responses, J. Proj. Tech., 17: 162-170. 1953.

systems: these are language, tool-using types of behaviour, various 'a-temporally organized and skilled forms of behaviour', and lastly in the way in which experience itself is organized.

Bruner attempts to search for the nature of this proto-symbolic activity which supports language, and he does this by looking at early language. In the first instance a distinction must be made between the semantic function and the syntactic process. The semantic function (the learning of reference words and their meanings) can be seen to be a very slow process as it is a cumulative process. The syntactic learning process (the learning of sentence structures and patterns) is a much more rapid one than the sematic process.

In very early language, the word for an object is seen as integral part of the object. To quote Vygotsky [8] on this subject:

> "We all know the old story about the rustic who said he wasn't surprised that savants with all their instruments could figure out the size of stars and their course - what baffled him was how they found out their names."

It would seem, according to Roger Brown (1956), that the way in which a child uses his language, right from the very beginning, is categorical. Words cover classes of things and these classes themselves are rule-governed so that new members can be added. It would seem that even syntactical rules have a categorical use. All languages, once they pass the first stage of 'one-word utterance', would seem to have a basic grammar structure.* There are three properties to sentence structure: subject-predicate relation; verb-object relation; and modification. One of the universals of grammar is that there is a rule of transformation so that a phrase can be written in the passive, interrogative or negative. A grammar means a set of rules which will generate any or all the possible things that can be said in a language and not allow those which are impermissible.

In studying the child's very early language and his symbolic activity, it can be seen how the child moves toward the adult model of grammar. It is very difficult to explain the appearance of grammar in the child's early language, nonetheless it is there, and typifies the child's utterances from about 2 years onwards. Although the rules of grammar are clearly present in the child's language, what is less obvious is how he seems to master the use of categories and hierarchies of categories.

It could be said that the very use of language would in some way presuppose that certain cognitive processes would be necessary. For Bruner it would seem as if "these concepts are first used and perfected in the sphere of

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8. Vygotsky, L.S. Thought and language. New York. John Wiley Inc. 1962.

* Bruner states that he is very strongly influenced by the views of Noam Chomsky (1957, 1965) and George Miller (1965).

language and only gradually transferred to thinking in general, and often not well transferred." [9]

Bruner refers to the work of Brown and Bellugi (1966) in explaining how language is first perfected. For Brown and Bellugi there is a 'contingent cycle' that exists between the child and the tutor (parent or otherwise) in the original learning of language. The child says something and then the tutor takes the child's own utterance, and puts it into a more grammatical form. The child will then, in turn, match his following utterance to that of the adult model.

In this type of cycle not only is language being perfected through grammatical rules, but thoughts are also being organized. Bruner then looks at some aspects of early language which, although they are 'transmission specific,' do suggest certain characteristics of symbolic functioning. It is Hockett's list (1960) of features of communication that Bruner refers to. Some of these features are: semanticity; the arbitrariness or conventionality of human symbols (in Piaget's terminology a 'symbol' would be a 'sign'); the 'productivity', e.g. the number of utterances which is due to grammatical rules; traditional transmission - language is not environment-free.

'Discreteness' is an important feature in that there is discontinuity in language (the sounds that make up words are individual and the words in the sentence or phrase are themselves individual). This obliges the listener to analyse the sound and sense of what is being said and reconstruct this into a message. Thus, the mechanisms of analysis and synthesis would seem to be 'forced' upon anyone using language. 'Displacement' is another important feature in as much as it allows the speaker to refer to things and events that are remote in the temporal-spatial framework. At first, young children only refer to things that are present or that are in the very near past or future.

Briefly, the child is learning to use his words for picturable or ikonic aspects of the external reality. However, the words themselves are embedded in a hierarchical system of categories. Rules of predication, causation, modification are used to create sentences. All these elements are not used for structuring his experience, as he has not yet mastered 'the architecture of complexity' for things. When the child starts to use the symbolic mode of representation at about 6 or so, he will be learning to bring the world of experience under control. The principles of organization of experience are isomorphic with the structural principles of syntax.

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9. Bruner, J.S., Oliver, R. and Greenfield, P.M. Studies in cognitive growth. New York. John Wiley & Sons. 1957.

CHAPTER TWO

SOME ASPECTS OF UNDERSTANDING VISUAL SYMBOLS*

Communication is at the heart of the educational process. Communication may be inter-active, as in an enlightened teacher-pupil relationship, or it may be one-way, as in reading a book or watching an educational television programme.

The inter-active mode of communication has many advantages over the one-way mode. Chief among these is the feed-back effect, whereby the student can ask questions about anything that is not clear to him, and the teacher can ask questions to test whether what he thinks he has taught has in fact been correctly understood by the student. In this way, teaching is accompanied by a simultaneous evaluatory process, the results of which are used by the teacher to modify his teaching technique. Misunderstandings can be corrected, and uncertainties can be eliminated by spending more time on the point concerned.

Of course, not all classroom practice follows this pattern. Far too often, communication between teacher and student in the classroom is in effect a one-way process, and thus the teacher fails to capitalize on the greatest potential strength of his situation. The possibility, however, remains, and it is the task of teacher education to educate teachers to utilize it.

With a one-way mode, however, the situation is entirely different. By definition, there is now no possibility of feed-back, and the 'instruction' proceeds regardless of whether or not the student has correctly understood the preceding material. It is thus of crucial importance that the materials should be as clear and unambiguous to the students for whom they are intended as possible. Since books are, and are likely to continue to be, a major vehicle for teaching mathematics and science, it is pertinent to ask questions about their effectiveness as a vehicle of communication. To what extent do the ideas and information which the author intends to convey coincide with what the student understands from the material? Concept development is unlikely to be aided by any marked discrepancy between the two.

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* The material for this Chapter was provided by one of the two consultants to the Seminar: Mr. Bryan Wilson of the Centre for Educational Development Overseas, London, who is a mathematics educator with keen interest and experience in the field of cognitive development in children.

There is of course widespread awareness of the need for instructional material used in school to be meaningful to the students. The language level must not be in advance of the student's stage of linguistic development. The examples used must, whenever possible, relate to his own environment and experience (this is a major constraint on the suitability of transfer of teaching materials between different countries and cultures). The concepts required for a proper understanding must be appropriate to the age-group concerned and to previous educational experience. One aspect of this need to ensure that materials are meaningful and unambiguous has, however, been largely ignored by authors and others responsible for curriculum materials. This concerns the interpretation of visual symbols.

In most science books in use in schools, great reliance is placed on drawings and diagrams to give visual reinforcement to the written text. The same is true, though to a lesser extent, of many school mathematics books. For the most part, the subject-matter of such diagrams is likely to be within the experience of the pupils for whom it is intended. Neither an author nor a teacher is likely to base a lesson on relative motion, for a school in rural Thailand, on a series of diagrams of a moving escalator. In any sound course, the subject-matter of the diagrams will be meaningful to the pupils - if they can identify it.

This brings us to the neglected aspect of instructional diagrams, namely the relation between the technique of drawing and presenting such visual materials, and the cultural background within which the material is going to be used. Is the ability to recognize drawings and diagrams of familiar objects a function of cultural background, or are variations in the abilities of individuals purely random and independent of their social setting? How important are age, sex, educational level, rural or town environment?

There is a small but growing body of research which suggests that the problem of correct interpretation of drawings may be a far more acute one than is usually recognized. A number of studies have been carried out in various African countries. Others have been carried out in Central and South America. Conclusions drawn by Spaulding[1] from work done in Costa Rica and Mexico, to test the overall communication potential of a set of illustrated booklets prepared for new literates, included the following:

a) An illustration as such has no assured educative value and it may even be a distracting influence if its content has not been presented in terms of the past experience of the viewer.

b) Illustrations that are intended to communicate specific ideas will be most effective if:

   i) The number of objects that must be seen in order to produce correct interpretation of the picture is kept to the minimum.

   ii) The number of separate actions necessary to produce correct interpretation of the basic idea is kept to the minimum.

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1. Spaulding, S. Communication potential of pictorial illustrations. Audio Visual Communication Review, 4(1):31-46. Winter 1950.

iii) All objects and inferred actions are realistically portrayed and are not open to ambiguity of interpretation.

c) Colour used in picture symbols adds to the interest potential of the illustrations, but it must be used realistically and functionally or it may reduce the communicative value of the pictures.

d) Captions generally serve to add information which is difficult to express pictorially. They should not be used to explain the drawings but to extend, modify and relate the meaning of the pictorial symbols.

A study was carried out in rural Brazil by Fonseca and Kearl[1] on comprehension of pictorial symbols. The following is a summary of the implications they drew from their study.

"The study confirms our assumption that the ability to interpret many kinds of pictorial symbols is a learned skill and has, in this sense, much in common with the ability to intepret verbal symbols. Young people, illiterate or with limited years of schooling, did a significantly poorer job in interpreting pictorial symbols than older respondents with more education. These two variables - age and education - are the key to one's opportunities for increased learning and are, at the same time, main forces influencing one's ability to comprehend and learn from pictorial symbols.

The analysis of the data allows us to draw some other generalizations from the study as follows:

i) Pictorial symbols to be most useful for young people of limited schooling must evidence intelligent selection of detail. Comprehension is reduced either by excessive unnecessary detail or excessive deletion of detail.

ii) Recognizable familiar objects presented in an illustration add to comprehensibility. Conversely the presence of locally unfamiliar objects tends to reduce correct interpretation of the symbol.

iii) The illustration of a process involving separate steps or actions should have at least as many individual pictures or frames as there are main steps or actions of the depicted process.

iv) To achieve the best comprehensions, pictorial symbols should be as realistic as possible. Any kind of imaginative treatment (such as 'humanization' of animals) reduces comprehension.

v) Special care should be taken with symbols which have both a literal and a figurative meaning, since people of limited education tend to give the most limited literal interpretation to such pictorial symbols.

vi) Except for symbols that are highly culture-bound, different levels of culture of geographical regions belonging to the same general pattern

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1. Fonseca, L., and Kearl, B. Comprehension of Pictorial Symbols: an Experiment in Rural Brazil. College of Agriculture, University of Wisconsin, 1960.

of culture are only a minor influence on the comprehension of pictorial symbols of a general nature.

vii) For symbols of a general nature, sex is not an important factor influencing differential comprehension of pictorial symbols among young rural people.

viii) Except for those symbols very closely related to their daily life experience, illiterate people do a significantly poorer job in interpreting pictorial symbols than do literate.

ix) Formal education sharply increases the ability to interpret pictorial symbols which:

a) have an 'extended' or figurative meaning;

b) demand more capacity of abstraction;

c) are to be interpreted as a series telling a story;

d) are not necessarily related to the daily life experience of the viewer.

x) Age also relates to the ability to comprehend pictorial symbols, but to a lesser degree than formal education. In most cases it was impossible to separate effectively age from education as factors influencing comprehension of pictorial symbols. Cross-tabulation for age and education showed a high correlation between the two variables, but indicated that general education has a larger role in increasing ability to interpret pictorial symbols."

Assessing the effectiveness of diagrammatic material is not only a problem facing those responsible for the production of curricular materials within the formal educational system. Equally it concerns those involved in a vast array of informal and adult education activities, who often rely to a very large extent on posters, models, films, and other forms of visual display to get their message across. It was in fact problems arising from rural health education in Kenya that gave rise to the piece of research from which the following results are quoted.

The research was a systematic attempt to analyse the factors tending to favour or impede the recognition of simple drawings of familiar objects. It was carried out in Kenya on a population representing a wide cross-section of age and level of formal education and sophistication.

In the first part of the work[1], diagrams of familiar objects were presented to the respondents, who were asked what they thought they were. In the second stage, those objects which had been misidentified most frequently were drawn in a natural setting with two or three other objects related in common experience, to test whether such a setting would increase recognition. Some interesting, and sometimes unanticipated, results emerged. The references are to diagrams on page 40.

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1. Shaw, B. Visual Symbols Survey: a report on the recognition of drawings in Kenya. Centre for Educational Development Overseas, London, 1969.

i) Many of the respondents did not look at even a simple diagram as a whole, but focused on a single feature and based the whole interpretation on that. The tortoise (a) was identified as a snake (by only looking at the head, this misidentification being made even by those who had correctly identified a drawing of a snake just beforehand), or as a crocodile, rhinoceros or pineapple (by focusing on the shell pattern), or as an elephant (by only looking at the feet).

ii) A single wrong detail can accordingly cause major misinterpretation. The goat (b), perhaps the commonest domestic animal in Kenya, was frequently identified as a cow; the baffled researcher eventually realized that the artist was at fault, in that goats have tails that turn upwards. The drawing was wrong in this one respect only.

iii) The idea of a drawing as representing a type, or class, was often absent. Great difficulty was experienced with the drawing of the old man (c), largely due to the respondent trying to identify the individual who he assumed was being portrayed. Similarly, the dancer (d) led to confusion, since no particular tribal costume is portrayed.

iv) On the other hand, cartoon stick characters, and isotype symbols caused surprisingly little difficulty. The mother and child were correctly identified in stick cartoon form (e) by 94%, and in isotype form (f) by 96%, of respondents.

v) Placing an object in a natural context does not necessarily increase recognition. A horse was identified by only 58% of respondents, but a horse with a man riding it brought identification up to 88%. On the other hand, placing a teacher in a classroom markedly reduced correct identification. It seems likely prima facie that the total context of a textbook or other teaching material would increase correct interpretation of a diagram. However, little specific research appears to have been done on this question in the Asian region.

vi) Pictorial symbols which can be interpreted literally or can be given an extended meaning will tend to be interpreted literally by people of limited education. For example, the skull and crossbones motif, very widely used in Kenya both on poison bottles and on electricity poles, was given a literal interpretation by 48%, but only 18% could give a symbolic interpretation such as 'poison', 'danger' or 'death'.

vii) Interpretation is sometimes 'impressionistic', particularly among rural people. The drawing of the maize cob (g), staple food in Kenya, was misinterpreted as bird, or fish (by turning the drawing sideways), or as a man (by turning it upside down). This drawing also illustrated finding (i) above, where concentration on the pattern of seeds led to answers such as tortoise, crocodile and pineapple.

A third stage of the research[1] consisted of testing a series of hypotheses by a comparison of recognition-levels for pairs of related diagrams. Among hypotheses which the results supported were:

i) That excessive unnecessary detail, and excessive deletion of detail, both seriously reduce the comprehensibility of a drawing. 88% of respondents correctly identified the man milking a cow when the drawing had minimum realistic detail (j); only 71% were correct when the drawing was schematic (h). This latter drawing was sometimes interpreted as a man milking a rhinoceros, an operation rarely performed, but which again points to the disproportionate impact of single details.

ii) That where an understanding of the convention of perspective is important to comprehension of a picture, correct interpretation will be made difficult. Both of the drawings of a man spearing a buck (k,l) were misinterpreted (usually as a man spearing an elephant) by over 90% of respondents.

iii) That whereas a familiar object is correctly interpreted when depicted life-size or smaller than life, it becomes more difficult to interpret correctly when drawn larger than reality.

It should be recognized that this Kenya research took place in a cultural setting in which diagrammatic representation is a fairly new phenomenon. The same is true in some parts of the Asian region, but not in others. Most societies, however, have a predominant style of traditional drawing, with its corresponding conventions, and this may be a very different style from that used by an artist for textbook diagrams.

Very little research has been done on this question in Asia. Such studies as there are indicate that the impact of visual symbols may be far different from what the artist intends. For example, a pilot study carried out in Northeast Thailand[2] lends support to the conclusion quoted at the end of the above summary of the Kenya study, that drawing a familiar object larger than life-size significantly reduces recognition. Advertisers as well as educationalists should be interested in such a finding.

On the other hand, the Thai subjects found it harder to identify a drawing of an isolated part of the body, such as a man's head or a hand, than did the Kenyan respondents.

Further research studies in this field are urgently needed in Asian societies if instructional materials are to utilize maximum effectiveness.

(A comprehensive review of relevant literature is contained in: Visual Perception; Commonwealth Secretariat, London, 1970.)

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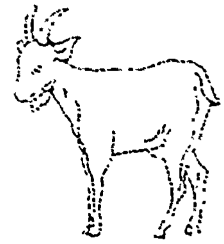
1. Holms, A.C. A Study of Understanding of Visual Symbols in Kenya; OVAC Publication No. 10. Centre for Educational Development Overseas, London, 1966.

2. Business Research Ltd. Aesthetic Perception of Villagers in North East Thailand. United States Operations Mission to Thailand, 1964.

(a)



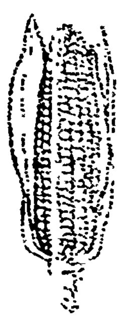
(b)

(c)

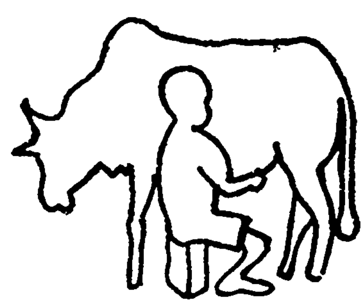
(d)

(e)

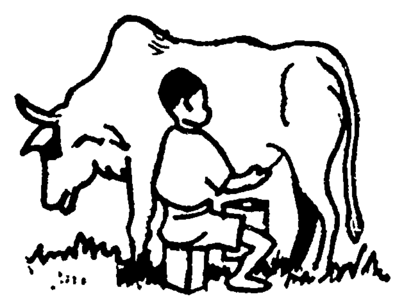
(f)



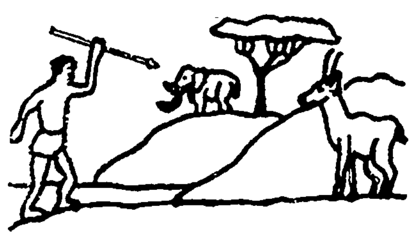
(g)



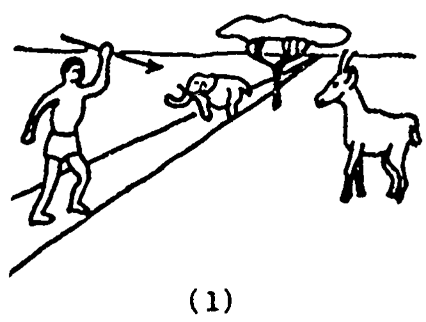
(h)



(j)



(k)



(l)

CHAPTER THREE

THE IMPLICATIONS FOR CURRICULUM DEVELOPMENT AND TEACHER EDUCATION

Basic Principles

In considering the relevance of Piaget's work to curriculum and teacher education, it is perhaps a good starting point to look at the principles regulating the stages of development.

Research within the European and North American cultural settings shows that the sequence of appearance of the cognitive stages in children's development is invariant, whereas the age at which a given stage appears may vary from child to child. There are many factors, such as the child's intelligence, his previous learning experience, and his social and cultural background which affect his 'pace'. This means that no two children will be acquiring a concept at exactly the same moment in time. Thus in a classroom it can be imagined that though the majority of children will be within a certain norm, there may be a great deal of variation from child to child. This does not mean that an individual programme is needed for each child. It would seem to imply more flexibility in the way in which the curriculum is taught, that is different teaching methods. These teaching methods should allow the child to develop at his own pace within the classroom situation. The idea of smaller groups within the class, the children in each group working together on a specific topic, and even sometimes individual work, might be a possible solution.

Another implication from this first principle is that there should be a modification in scheduling of the timetable of a school day. It follows that if children are working as a group or as individuals, at their own pace they should be given the amount of time they need in order to finish a task, rather than having to leave it uncompleted as the end-of-lesson-bell has gone. If this is the case then ultimately the idea of "the integrated day" should be considered. Evidently such ideas are more feasible at the primary level where the constraints are less. Their application to the secondary level might present certain problems in view of the present type of curricula.

Both pre-service and in-service teacher education are affected by these two implications as it involves providing teachers with experience of new methods of teaching and different ways of organizing their school day.

Another idea that this issue raises, and in the light of the two points previously raised, is the validity of tests and examination. On the assumption that children are allowed to develop, within measure, at their own pace, a collective test or examination systematically given to all children at various moments during the school year does not seem to meet the need of such a new approach. Although undoubtedly at some point a form of examination may be necessary, new techniques allowing an on-going evaluation of child's thought processes would seem more appropriate. The role of these techniques would not merely be to see what the child has 'learned' but to see where he is in understanding certain ideas, and to help partially re-structure his classroom experience towards acquiring the concepts in question. Thus, the on-going evaluation would become an integral part of the curriculum. The consideration of such an implication would affect all teachers and people who are involved in assessment procedures of any kind. This principle and the third and fourth principles, i.e. (i) that everything a child had understood is always integrated into his later stages of knowledge and (ii) that there is a process of formation and a moment of achievement within every concept and every stage, would seem to have direct relevance to the content of the curriculum. Thus the planning of a curriculum should be considered from the point of view of the logic of the child rather than the logic of the subject matter. Concepts are acquired in sequential hierarchies and therefore certain concepts are fundamental for the acquisition of others. They serve as a spring board for further development and become an integral part of the later knowledge.

Existing curricula could, therefore, be analysed with a view to seeing at which moment and in which order certain notions are introduced. Such an analysis may reveal that some topics are introduced too soon, and could be re-sequenced so as to be more profitable for the child's learning experience. Although this point of view is valid, it should not be taken too far. Some people tend to say that if it is known that children can only acquire certain concepts at a certain moment in the sequence and they are not yet at that stage then the teacher should wait. Appropriate activity and experience introduced early can provide the child with an intuitive understanding of certain ideas that will be grasped in greater depth at a later moment.

Generally speaking, it could be said that rather than some arbitrary sequence of concepts directing the planning of curriculum, the principles of hierarchy and integration provide the curriculum writer with a frame of reference within which to work.

Again the idea that the process of formation of a concept and its moment of acquisition can be characterized by specific types of behaviour patterns would seem to lend itself to the writing of specific activities within a teaching sequence for the introduction of the concept.

The second principle, i.e. that when a stage is reached the elements of behaviour will come together to form an integrated whole - a new mental structure having its own properties - would lend itself to the extrapolation of a type of learning model. The characteristics of thought at each stage could be used as a basis for the way in which children can learn at that particular period. For example some of the characteristics of the concrete operational child which would seem to dominate their learning processes are the following:

i) The children need to think about situations concerning the real world;

ii) The use of concrete material to illustrate situations helps the child;

iii) The terms in which a problem can be phrased should not be too abstract, for example the child can be asked to observe results and to try and draw a conclusion but he cannot be expected to predict hypothetical results;

iv) The degree of generalization possible is limited in as much as children are very much tied to the concrete context of the situation in which they are working. They will only very gradually generalize their conclusion from one situation to another similar situation.

These are examples of some of the characteristics of how the child learns about the world at the concrete operational level. A similar analysis could, of course, be done for the other stages of intellectual development. However, this implies that teachers should have an overall view of a theory such as Piaget's, rather than just examples of development of certain concepts, as it will give them indications about the child's thought. The teacher should be provided also with other learning models as all of these ideas will help him to understand through overt behaviour what is going on in the child's mind.

An important implication that follows from the idea of stages is that if the acquiring of "knowledge" is an evolutionary process then every step in this process is vital. Even though at times the responses the child may give do not correspond to the "objectively correct response", they are nonetheless the child's interpretation of the world at that particular moment and, therefore, an essential step in the whole process. The child must, of course, reach the "objectively correct response"; however, the teacher himself should see that every reply given is relevant in some way and will be revealing the child's underlying thought process. The teacher should, therefore, consider each response in its own right with a view to seeing which type of activity would be appropriate in taking the child one step further in his understanding of a problem. Thus, the teacher's attitude should be positive towards the diversity of the child's possible replies. Also the teacher's appraisal of the child's reply could be seen more in the light of a type of "diagnosis" rather than response to be matched to a checklist of "rights and wrongs".

Piaget's assimilation-accommodation model could be seen in the very broad sense, as a model of how children learn. However to be more specific, the "logical mathematical activity" described by Piaget (see Chapter 1 page 20) which stems from this process would seem to make the ideas of "doing" and "activity" a little more precise.

Activity is often seen as a series of situations in which children are active, doing things, etc. However there is not necessarily any relation between these activities. Logical mathematical activity is the co-ordination of the child's action on objects. The abstractions made from these co-ordinations of actions would be those that will internalize themselves into mental operations. Operations that are co-ordinated together provide a mental structure for the child's thought and with this he can organize his new experience of the world.

The continual activity of the child in trying to understand and incorporate the novelty of the outside world into his knowing structures, will create equilibrium and this in turn will create modification of the assimilation structure in his accommodation to the situation. Therefore if the activity of the child is to become a knowing activity it should involve not only discovering properties of objects, but also the properties of the actions themselves. Activities presented to the child should allow him the possibility of repeating and co-ordinating his actions in a series of similar situation, so that he may in the end abstract the general scheme which can be seen in the co-ordination of all these actions.

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 curricula and teaching methods in most countries. A great deal is already known as to what kinds of educational changes would represent an improvement. Technical know-how, and methods of implementing new ideas, are needed even more urgently than further research. As innovation proceeds, however, new research can be generated and its results fed back into the curriculum development process.

Within the realities of education systems as they are, it is often recognized that although innovations exist, they cannot be practised in their ideal form. Numerous compromises have to be made to accommodate the various constraints that exist in real education systems. Series of compromise deflections have to be made towards the ideal innovation over a period of time. There is little doubt that research, both pure and applied or operational, has a significant contribution to make to innovation. It needs to be stressed that with the deflection or approximation process action research becomes vital to evaluate the validity of the deflection and to provide evidence for further deflections towards the ideal innovation.

By its very nature these action research programmes may well not bear the rigid design considerations of "pure" research. Nevertheless they are inevitable if a measure of rationality is to be built into the decision-making process for deflection. Research, whether pure, applied or action-orientated, serves both as a resource and a mediator.

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. Such projects may take the form of long-term investigations, or merely of pragmatic attempts to re-examine existing curriculum ideas to test them for their appropriateness for the children for whom they are designed.

The Seminar resisted the temptation to produce a standard model for the total curriculum development process which could be applied in any of the countries represented. Many existing models transferred from other parts of the world are limited to cognitive processes, and would inevitably ignore important cultural, social and linguistic factors. The problem of developing a suitable overall model for integrating research and curriculum development is one that requires a great deal of careful investigation, and must be done from a thorough knowledge of the relevant factors, which are likely to prove to be quite different in Asian countries from those pertaining in other parts of the world. A limited amount of work in this field has already been carried out in the Asian region.

A necessary condition for a global approach to educational innovation is that Curriculum Development Centres, currently being established in a number of countries of the region, should have expertise in various fields. Working groups should include educational psychologists, teacher educators and classroom teachers, as well as content-specialists. Such a group should also have access to other specialists, such as sociologists and linguists.

Curriculum development in its contribution to the overall education system provides a unifying principle in as much as it gives specifications, such as the following: (i) guidelines to the writing of curriculum and instructional materials; (ii) the logistics of the construction of structural apparatus, the use of which facilitates a real understanding of basic mathematical concepts in children; (iii) guidelines for teacher education, both pre-service and in-service; (iv) the control and management of curriculum implementation in the classroom; etc.

Research in the development of science/mathematics concepts in children has significant implications for building curricular structures. Curriculum development should be geared to the child, not just to the logic of the subject. Science educators have been primarily concerned with the logical structure of the material, and have tended to view curriculum organization from the viewpoint of the interrelationship and homogenuity of the topics. Research studies on children's learning help us to view the component elements of the curriculum from the point of view of psychological organization. Children do not necessarily see the logical structure of the subjects they learn in the way that an adult does. This points to the necessity for practising classroom teachers, teaching at the level concerned, to be involved in curriculum development projects from their inception.

A comparison of normative concept formation, as shown by research studies, with many curricula in science and mathematics is likely to indicate that topics and techniques are frequently introduced too soon. On the other hand, much preparatory experience can be given to a child to assist in the formation of the corresponding concept.

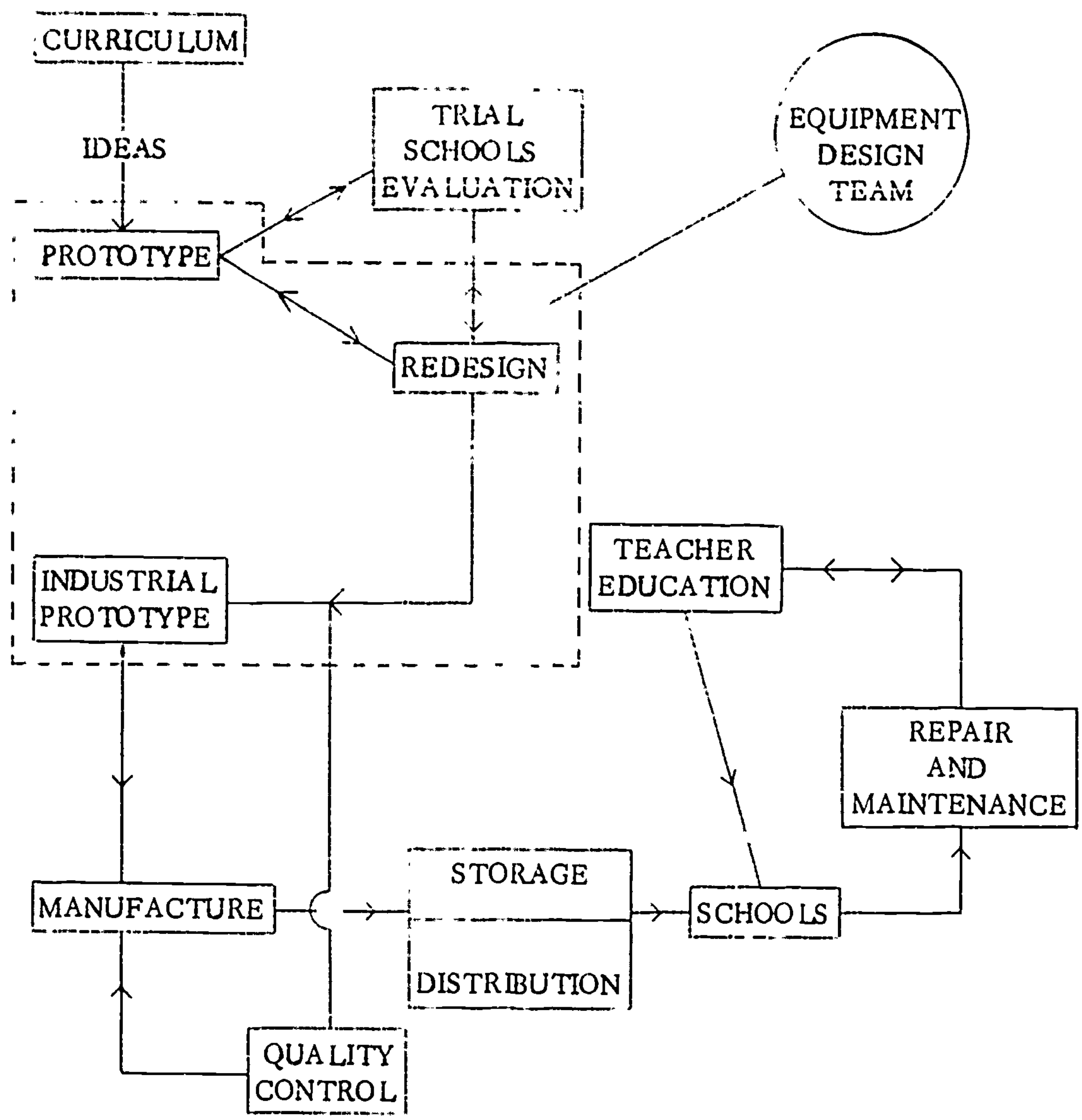
Turning to the methodologies of teaching, the major implications stem from the basic realization that children are different from each other. While the developmental stages may be universal, the speed through them certainly varies very considerably. Children also vary in the amount and variety of experience that they need before a concept is securely established. Thus there is need for much greater flexibility in school courses, particularly at primary level, than the customary linear, fixed-pace programmes permit. Many countries have stringent constraints on primary education, particularly when it is not the prerogative of all children. Much can be done, however, within existing constraints to cater for the differing needs of the children within a class. A variety of methods, the use of assignment cards, techniques of group-work and the increased use of simple low-cost apparatus can all be utilized by the resourceful teacher.

The need for children to acquire logical mathematical experiences implies that schools be provided with suitable concrete materials and equipment to enable the teachers to organize relevant activities for their pupils. The materials need to be carefully selected and equipment needs to be suitably designed and produced. The mere provision of material resources does not necessarily lead to an improvement of the quality of instruction. Curriculum designers should provide guidelines for the selection of materials and designing of equipment. Participating countries cited instances from their own experiences where this is already being done. It has to be recognized that if any significant impact is to be made material resources will have to be supplied on a large scale considering that materials are needed most urgently at the primary level. Hence a compromise may have to be effected in designing equipment. The most suitable design from a strictly educational point of view may not be the best design for production on a large scale. Hence there is the need for consultations with industrial designers. Equipment design teams working in very close co-operation with curriculum development teams are already at work in a few of the participating countries. Even if problems of design are satisfactorily solved there are a multitude of other problems that prevent materials and equipment being used by children. Regulations which inhibit teachers from using even the material that is supplied, lack of production, storage and distribution facilities, meagre financial resources were some of the major difficulties discussed. Among the solutions adopted by the participating countries were the establishment of equipment factories working directly under the Education Ministries, state controlled storage and distribution networks and aid agreements with various agencies. Another possible solution discussed was regional co-operation to keep down costs.

It was also suggested that Science Centres could undertake to design and test suitable prototype apparatus and request different manufacturers to construct the component parts (plastic, wooden, metallic parts etc.) in bulk. These would be assembled by staff at the Science Centres and distributed to schools. This procedure would considerably cut down costs.

A significant problem that emerges is the component to be incorporated into the teacher education programmes to ensure that teachers make the optimum use of the materials supplied. Not only should teachers be able to make use of the material that is supplied, but they should also be able to make maximum use of their environment to collect a variety of materials which may be easily available at no cost except in terms of teacher-time.

A systems map for the design, production, storage, distribution, repair and maintenance of school science and mathematics equipment



Teacher Education

Teacher education, both pre-service and in-service, comes into focus as the key issue in translating into classroom practice existing knowledge of how children learn. The involvement of practising teachers in the curriculum development process is itself a most effective means of in-service education. There is a need to provide situations in selected schools where curricular innovations can be tried out, improved and then made available for wider use (in some countries this may require legislative action). In this way, a widening circle of teachers will be actively involved in the innovatory process in the successive stages of expansion.

At the pre-service level, attempts should be made to introduce courses on simple research methodology to enable the teachers to take up action research programmes when they go to the schools. Child psychology courses at Colleges of Education will also need to be updated to include various learning theories, with more opportunities given to the students to take part in simple research activities themselves, rather than just listen to lectures. Such changes in turn imply the need for in-service education programmes for teacher educators and other key personnel to enable them to keep abreast of development in their fields of specialization.

Few countries of the Asian region can afford the luxury of research for which no practical outcome can be foreseen. Research projects should be relevant to the needs of the country and of its schools. Lines of communication between different departments, agencies and specialists must be kept open. The curriculum developer is in a good position to take the initiative by bringing problems as they arise to the attention of specialists in various disciplines, such as linguistics, psychology, anthropology and sociology. Research studies with a practical approach are thus generated among these specialists. A field where there is need for research, particularly in multilingual settings, concerns ways and means for closely relating language, mathematics and science at the early primary level.

While it is hoped that the findings of short-term research projects may have an immediate impact on the curriculum, it must always be borne in mind that the ultimate goal is the benefit of the children, the effect on whom may not become apparent for several years after the research is originally undertaken. Whatever research projects are launched to this end, and whatever findings emerge which can be embodied in curricular change, education must never be viewed merely in cognitive terms. A major aim of education should be to share with the child the enjoyment of learning.

CHAPTER FOUR

ANALYSIS OF COUNTRY REPORTS

This analysis is based on the Country Reports submitted by the delegates and the presentations made by them at different stages of the Seminar. The Country Reports were prepared specially for the specific purposes of the Seminar.

Curriculum development work in Science and Mathematics

Current activities

All the countries indicated that revision of curricula in science and mathematics was an on-going activity in their countries. Some countries have had a history of systematic curriculum development going back over a decade or more. Special institutions have been set up and have been functioning for some years. India, Philippines, Ceylon, Thailand, Pakistan and Malaysia would be examples of such countries. On the other hand, Nepal has only recently organized a Curriculum Development Centre. In some of the countries represented, the curriculum development activity is not the work of a particular centre or institutions set up by the government, but the work is done by different institutions such as universities or by special groups set up for the specific purpose. Burma is one such example. In all the countries teachers are represented in the curriculum development committees. Many countries have obtained the services of foreign consultants. While local university staff are represented on some of the curriculum committees, some countries have established only informal communications with the universities. A very encouraging feature is the extensive participation of local personnel in the curriculum development activity and the outright rejection of transplanting foreign curriculum materials.

The activities described ranged from the primary school to the senior secondary level. But most of the projects described are for the final years of the secondary school. Burma indicated plans for science and mathematics reforms in the higher grades. They plan to have the revised curricula taught in grade IX by 1975. The revised mathematics curricula are to be based on the new mathematics content that has been entering the school system during the last couple of decades. Based on this experience they propose to introduce revised curricula into the lower grades. Thailand has initiated projects for the revision of science and mathematics curricula at its Institute for the Promotion of Teaching of Science and Technology. The general science project is at the middle level i.e. the first three years after the primary school while science and mathematics are at the upper secondary level. Field-testing the science material is expected in 1973/74 and full scale implementation by 1976. The programme is meant for all pupils at this level. The Republic of Korea is developing a new science and mathematics curriculum for the elementary schools. The material for grades I to III is now on trial. The material for grades IV, V, VI is to be tried out during 1973 in selected schools. The revised grade I, II, III material is expected to be used throughout the country in 1973, and those for the other grades in 1974. Work on the grade VII material will start in 1974. Ceylon, which started its first curriculum revision cycle in 1959 at the middle school and in 1961 for the grades X and XI, has launched on a project to introduce mathematics to the primary grades (i.e. grades I to V). This project started in 1968. Implementation in the school system will start in 1973 on a phased basis. It is expected that by 1977 all the primary schools will be using the project material. At the junior secondary stage (grades VI-IX) Ceylon has launched projects to teach science and mathematics to all pupils. Singapore described a project at the primary level for the development of an integrated science, mathematics and English curriculum. The project material is now being tried out this year. Nepal is continuing with two projects, one for the enrichment of science teaching, and the other in mathematics. Both projects are for the higher grades. The project material is now being used in a number of schools. Malaysia reported their attempt to improve science and mathematics teaching in the primary schools. A significant feature of the Malaysian attempt is the immediate impact they hope to have on current teaching. A very keen effort is being made to work within the existing syllabuses to introduce more effective ways of teaching and more useful ideas. Malaysia has also initiated science and mathematics curriculum revision programme at the secondary level. Pakistan first revised the curricula at all levels more than a decade ago. A further revision of science and mathematics curricula was undertaken in 1966. Pakistan is again envisaging a concerted revision of the elementary and secondary curricula. A better balanced science course is being planned for the secondary level. In India each State and Union territory is responsible for revising its own curricula. Each State has an institute set up for this specific purpose. However, the National Council of Educational Research and Training advises the State and Union territories with respect to necessary educational reform and research. The Council's recommendations regarding curriculum reform are communicated in the form of a total package consisting of a syllabus, indicating a sequential development of concepts, pupil texts, teachers' guides, suggestions regarding equipment with recommended equipment kits and materials for pre-service and in-service education. Curriculum materials have been produced for science and mathematics for primary and middle school stages. These are now being tried out in selected schools. Materials for the higher levels are now being prepared. The Philippines initiated a curriculum development project in 1964 to prepare science and mathematics curriculum materials for the elementary and secondary school levels. Most of the materials are now in experimental editions. A few have been published in final editions e.g. textbooks in biology, physics and chemistry, and two resource books for biology teachers. All of the textbooks have undergone a two-year period of trial in selected schools, each undergoing several revisions before being released as final editions. In the current year (1972) at least one book in elementary school science and two in mathematics will become available in final editions.

Problems encountered

Lack of adequate knowledge regarding the local physical environment

The need for each country to develop its own curricula with its own personnel has led to curriculum workers, particularly in the science field, taking a closer look at their own environment. When judgements have to be made as to what science/mathematics content is appropriate in the local context, it is necessary that the local environment be known thoroughly. The writing of a biology curriculum, for example, would require access to knowledge of the local biological environment. It is not uncommon to find that not enough is known. It is easier for curriculum workers to get information about a foreign plant, animal or factory than it is to get information about similar things in their own country. As one participant expressed it: "there is sheer lack of information relating to many common things in the environment."

Lack of adequate knowledge regarding the local cultural environment

Many countries are faced with problems relating to the use of the local languages. Sometimes the language does not have the words required. At other times the words used by the teacher may have different meanings in the world outside the school. Sometimes a word available in the local language may not be precise enough for use in science or mathematics. Another problem is whether the local cultural environment is antagonistic to some of the values that the curricula are intended to develop.

Lack of adequate knowledge about school children

Many curriculum workers in the Asian region have to go about their work in almost total ignorance of very many relevant characteristics of the child population concerned. In particular, participants expressed the need to know whether the stages of cognitive growth postulated by Piaget are applicable to the children they are concerned with. In some countries there are the problems associated with having, in one and the same classroom, pupils from a wide variety of social and cultural backgrounds.

Other problems

Many countries emphasized problems relating to the teacher population. Shortage of teachers, the need to update subject-matter knowledge and methodology of the science/mathematics teachers were mentioned. A particular difficulty was to convince the majority of science teachers of the need for new approaches to teaching. Large class size was also a matter of great concern for some countries. Another problem area was the inadequacy of material resources for science, mathematics teaching.

Research into learning processes in relation to the development of science and mathematics concepts

Current activities

A number of countries in the region are carrying out research based on

Piagetian theory. Thailand reported a series of studies relating to such aspects as conservation of mass, weight and volume; the existence of the stage of formal operations; colour-form discrimination; etc. In general the results tended to confirm the existence of the developmental stages postulated by Piaget; larger samples need to be used and techniques need to be refined before more definite assertions can be made. The Child Development Centre of the University of the Philippines has been conducting research in cognitive development over the last few years. Five of these research projects were presented at the Seminar. Three of the projects investigated the effects of different treatments on the development of class inclusion concept, invariance of continuous and discontinuous substance, multiple classification, multiple asymmetrical relations and multiple spatial relations. The results indicated marked training effect of the Piagetian learning experiment known as intervention experiment. Of the other two studies, one investigated the growth of logical thinking as related to nutritional status. The development of the time concept in Filipino children is in the process of completion. Pakistan reported a number of studies on the cognitive aspects of learning done in her universities. The studies were directed at answering questions of a general nature relating to the teaching of science and mathematics. Ceylon reported a child study programme which stemmed from the curriculum development work she had undertaken in primary mathematics. One of the purposes was to investigate whether the developmental stages postulated by Piaget were applicable to a purposive sample of Ceylonese school children. Ten areas such as invariance of a set of discrete elements, invariance of a continuous quantity, shape, measurement, etc. were selected. A significant feature was that the areas selected for investigation were chosen from the areas in which curriculum materials were being prepared for grades I and II. Interviewing of children was done by curriculum workers trained for the purpose. Burma described a research project designed to investigate the influence of culture on the development of science concepts.

Applications of research to curriculum development

Direct application of research in curriculum development work was not reported by many of the countries. While not being in the area of cognitive development, Philippines reported a piece of research designed to answer at least partially problems relating to language. The study was conducted by an anthropologist and was intended mainly to provide information about the terms actually used by people in a community to describe science concepts. The study is expected to help sensitize teachers to the notions children, and people in the community in general, have about the concepts that the teacher deals with in the classroom, and so to help them to communicate more effectively with their students. Ceylon indicated that the participation of curriculum workers in this kind of investigation was of great value in the preparation of curriculum materials and also in in-service education work, even though the direct research evidence is still being processed.

CHAPTER FIVE

GUIDELINES FOR RESEARCH

The implications of the theoretical structures which were the subject of major study during the Seminar (See Chapter 3) indicated that research evidence needs to be collected to take necessary actions. The Seminar devoted some time to identify studies that need to be undertaken. The following major studies were identified:

a) Comparative study of the development of science, mathematics concepts between groups stratified by relevant variables such as income, proximity to town, medium of instruction, etc.

b) Study of science, mathematics concept development in relation to needs, aspirations and interests of children.

c) Study of the growth, stability and transfer of science, mathematics concepts.

d) Study of the early development of logical structures.

e) Evaluation of existing curricula to identify their strengths and weaknesses.

f) The effect of the environment on the teaching of science and mathematics in the primary and secondary schools.

g) Effect of different instructional procedures on science, mathematics achievement at the secondary level.

h) Study of the languages used by different communities to identify words related to science teaching.

i) Effect of different instructional procedures on cognitive growth.

j) Study of problems encountered in translating curriculum material from one language to another.

k) Study of problems connected with introducing scientific terms in the elementary grades.

l) Validation of selected tests for use in the Asian region.

m) Cognitive growth of children in the Asian region.

n) Investigation of non-technical vocabulary difficulties in teaching science.

Within the above broad areas, certain specific studies were further discussed and elaborated. The research proposals generated at the Seminar fell broadly into the following categories:

i) Studies to establish whether the stages of growth as postulated by Piaget are applicable to children in the Asian region.

The Seminar agreed on the necessity to determine whether the stages of cognitive development that have been found to be applicable in other regions may be so for the Asian region also. The research work done in a few of the Asian countries indicated that such activities are likely to be useful. In many instances the research proposals discussed were feasibility studies, and small samples were envisaged. This was very largely due to the shortage of trained personnel, and a general scarcity of other resources. This preliminary work was intended to pave the way for more substantive studies at a later date.

ii) Studies to establish how different factors such as medium of instruction, the cultural environment, nutritional deficiencies affect the cognitive development of Asian children.

A significant problem facing many countries of the Asian region was the diversity of the cultural/physical environment from which the children are drawn. It was hypothesized that different environments affect the cognitive growth in different ways. With respect to cognitive development, how was the urban child different from the rural child? While it was felt that a difference existed, it had yet to be substantiated.

iii) Studies to establish whether the development of certain selected concepts are affected by cultural/social factors.

It was felt that there may be certain features of the socio-cultural environment which may inhibit the development of certain concepts, particularly those relating to science. For example authority structures and linguistic patterns in the home may be at variance with the approaches used in the teaching of science and mathematics.

iv) Studies to investigate possible sequences of concept development in mathematics/science.

The fact that many curricula are structured using a subject matter logic had been stated earlier in this Report. Countries indicated the necessity to examine the adequacy of the present structuring, particularly from the point of view of whether concepts are presented in an order which facilitates their being learnt. It was also possible that certain concepts may be taught to children at an earlier age than was the practice now. It was necessary to investigate such aspects also.

v) Studies to determine effective instructional procedures.

Many countries were still using very traditional instructional procedures. Inefficient instructional techniques need not be a necessary concomitant of large class size, shortage of equipment, inadequate specialized teaching spaces, etc. Research needs to be undertaken to establish whether the Asian teacher, subjected as he is to many deprivations, cannot do better.

vi) Studies to develop data-gathering instruments for research purposes.

Many countries of the Asian region lack basic instruments needed in research work, e.g. non-verbal intelligence tests. These need to be developed. During the initial phases, instruments developed in other area may need to be adapted.

Illustrative research proposal for the validation of Piagetian theory (A Replication Study for Asia)

Justification

1. During the last decade curriculum development has tended to consider more carefully the findings of developmental psychology and epistemology as these offer an insight into the function and structure of intellectual processes. This has been shown to be useful specifically in the areas of mathematics and science education.

2. Among the developmental schools the work of Piaget has received world-wide recognition as a useful framework for its relevance in the above-mentioned context.

3. It has been felt by the participants of the Seminar that it is necessary to base curriculum development in Asia on a valid psychological theory of cognitive development. Learning would seem to be more effective when the logic of the child is considered rather than the logic of the subject-matter alone.

4. In the light of this, it was thought vital and practicable to undertake a preliminary validation in Asia of some of the crucial insights of Piaget. This validation, if carried out in many of the participating countries, would add substantially to the value of the findings, and consequently make possible crucial innovations in the field of curriculum development, thus permitting science and mathematics educators to achieve their objectives more efficiently and meaningfully.

5. A next important phase would ultimately be the development of models for the establishment of the link between research and curriculum development in Asia.

6. On the basis of the foregoing, the following action is required:

   i) a replication study in Asia for the validation of Piagetian theories;

   ii) action research in Asia for the development of models which will enable curriculum developers to integrate research findings into their work.

Co-operative research projects could be carried out on a regional basis with suitable co-ordination to ensure a common research design.

Objectives

1) the validation of Piagetian theory in the selected areas of number concepts, spatial-geometrical concepts, and invariance of physical quantity concepts; and, subject to the results of this research showing a cognitive profile in Asian children comparable to the original findings of Piaget,

2) the development of models to permit the intergration of the research findings of the replication study into curriculum development in the fields of science and mathematics.

Outline of action for replication study

1. Experiments

The specific experiments to be carried out in the areas mentioned are:

1.1 Logical-mathematical concepts (Number):

a) Invariance of discontinuous quantities
b) Classification
c) Ordering
d) Hierarchical class inclusion

1.2 Spatial-geometrical concepts

a) Neighbourhoods
b) Construction of a straight line
c) Estimation and measurement of length
d) Co-ordination of perspectives

1.3 Invariance of physical quantity concepts

a) Invariance of quantity of liquid
b) Invariance of quantity of substance
c) Invariance of weight
d) Invariance of volume

2. Sampling

2.1 Each experiment would have to be replicated in a number of Asian countries. In each country, sampling of children would have to be carried out according to the following design:

	Schooled	Unschooled
Urban	30	30
Rural	30	30

Although stages of intellectual development can be explored within any category of subjects, certain pieces of research have shown that factors such as urbanization and schooling have a significant impact on the development of cognitive processes. In view of this observation the sampling design provides for a study of within-cultural variance of thinking processes in four categories of subjects: urban/schooled, urban/unschooled, rural/schooled and rural/unschooled, as shown on page 56.

2.2 In view of the following considerations, namely:

i) that the major concern of the Seminar was the teaching of science and mathematics at the primary level,

ii) that heavy constraints are imposed upon research due to the scarcity of resources (human, material, time, space and communications),

iii) that Piaget's theory offers the inherent possibility to validate selected sections of this theory separately,

it is proposed that the sample will consist of children between 6 years, 0 months (6;0) and 9 years, 11 months (9;11) of age, distributed within each of the above four categories, as follows:

Age / Number	6;0 - 7;4	7;5 - 8;8	8;9 - 9;11
	10	10	10

2.3 Before any of the Piaget experiments are carried out on Asian children in the above age-ranges it is essential that adequate communication between the child and the experimenter is established so that the child may understand the task. Therefore, the children will be further selected according to their score on a specially designed test which will assess their verbal comprehension.

3. Instruments

3.1 In the research design, the experiments and the methodology will be as identical as possible to those developed and used in original Piagetian studies. (The instruments would, of course, have to be adapted so as to be appropriate to the linguistic and cultural setting)

3.2 The instrument as mentioned under point 2.3 will have to be developed as an integral part of the project. It is suggested that a starting point for this instrument may be found in the research of H. Sinclair-De-Zwart. [1]

1. Sinclair-De-Zwart, H. Acquisition du Langage et Développement de la Pensée, 1967.

3.3 The actual development of the research instruments would have to be carried out at one central location. However, the adaptation of these instruments would be the responsibility of the participating countries.

4. Implementation

4.1 Participating countries will select and strengthen the research centres to which the replication study will be entrusted. The participating countries will, in consultation with, and assisted by, the co-ordinatting agency:

a) adapt the research instruments to local use and for this purpose, carry out feasibility study with these instruments;

b) train research field workers, if necessary;

c) finalize the research design in detail;

d) sample groups of children;

e) collect data;

f) analyse and report the findings.

4.2 With reference to the above-mentioned points d) and f), the collection of data will be organized as follows: Each child will be interviewed individually four times. The programme of these interview sessions would contain the following activities:

Session 1: "Invariance of discontinuous quantities"
"Neighbourhoods (verbal response)"
"Construction of a straight line"
"Invariance of continuous quantities"

Session 2: "Invariance of quantity of substance"
"Classification"
"Evaluation and measurement of length"

Session 3: "Invariance of weight"
"Perspectives"
"Ordering"

Session 4: "Hierarchical class inclusion"
"Invariance of weight"
"Neighbourhoods (graphical response)"

4.3 The interval between each of the sessions should ideally be four or five days.

5. Reporting

The Centres involved in the above research would be invited to commit themselves to report their findings to a co-ordinating agency. The co-ordinating agency would be requested to study the findings from the various participating countries and then disseminate this information to interested parties.

CHAPTER SIX

RECOMMENDATIONS

Introduction

Curriculum development should be viewed as a total process: It involves the co-ordinated development and testing of written and visual materials as well as equipment designed to be used by teachers and pupils to facilitate understanding of scientific and mathematical concepts. With a view to the improvement of learning science and mathematics, this report emphasizes the need to take into account the way in which children think, which is not always the same as adult thinking. Thus curriculum development teams should include not only subject specialists and those experienced in teaching methods, but also specialists in child development.

A number of specific recommendations follow which are intended to lead to the development of science and mathematics curricula geared not only to the needs of a scientific and technological age, but also to the needs of the child.

The Third Regional Conference of Ministers of Education and Those Responsible for Economic Planning in Asia, convened by Unesco in co-operation with ECAFE, in 1971, stressed the need for qualitative changes in education. The recommendations in the present report could lead to one such important change. They could be implemented through the Asian Centre of Educational Innovation for Development and the national centres forming the regional mechanism of co-operation proposed by the Ministers' Conference.

Recommendations at regional level

1. Identification of problems

In considering the education of the school child, the following educational problems in cognitive development should be investigated as research studies in common throughout the Asian region:

a) Longitudinal studies of particular concepts as they develop in Asian children;

b) studies on the effect of environmental background on concept development in Asian children, e.g. comparative studies with rural and urban children;

c) the effects of different learning experiences on concept development in Asian children;

d) studies of the relationship between the development of language, and of science/mathematics concepts, in Asian children.

2. Sharing information

In designing and implementing research programmes in each country, priority should be given to programmes directed towards meeting national needs, particularly in the field of science and mathematics curriculum development. Nevertheless, a sharing of information, even while programmes are in the design stage, will enable cross-national comparative studies to be made. The results of these studies, collated at regional level, could provide a valuable pool of information for Member States of the Asian region.

A first step could be the compiling of a directory of information on centres and individuals studying various aspects of cognitive development in children.

In order to keep information up-to-date, a regional newsletter could be published giving details of current programmes. As a complement to this, the regular publication on a regional basis of abstracts of research studies related to curriculum development would be very valuable.

To provide for the sharing of information in depth, research publications and sample sets of new curriculum materials should be shared through suitable regional and sub-regional organizations.

3. Sharing resources

Some countries have already developed particular strength in studies of children's patterns of thinking, in relation to curriculum development. Attention should be given to using national, bilateral and international funds for fellowships to provide on-the-job experience within the region to members of various curriculum development and research groups.

Advantage should also be taken of courses and workshops on studies in learning school science and mathematics offered by various regional, sub-regional organizations, (e.g. the SEAMEO Regional Centre for Education in Science and Mathematics), and national institutions. Funds should be made available for Member States to participate in such courses. Places on these courses may, with advantage, be taken up by teacher educators as well as workers in research and curriculum development.

Increased access to information on work in different Member States may be expected to lead to a greater demand for the interchange of actual curriculum materials, including equipment, among Member States. The organization of resource centres within the region to provide for this interchange should be given careful consideration.

4. Further regional meetings

To follow up the work of the first Asian Regional Seminar on the Development of Science/Mathematics Concepts in Children, further meetings within the region may be arranged:

- A meeting in about two years' time to review and share experiences of the work of Member States in the field of cognitive development as applied to curriculum development and research in science and mathematics;
- A meeting to consider the implementation in the classroom of the practical implications of this work. This should include a consideration of various teaching methodologies (including team teaching, group work, and methods of assessing children's progress). A possibility to be carefully considered would be the production of illustrative materials, including a film and an illustrated source book.

Recommendations at national level

1. Mathematics and science syllabuses

Research shows that young children think in different ways from adults. Children's thinking develops in quite well-defined stages.

In most curriculum development work in science and mathematics, concern has been directed to the logical structure of the subject. This report shows the need for relating the sequence of topics in the syllabuses to the developmental stages of children's thinking.

2. Teaching methods in primary schools

The emphasis in primary education should change from teaching to learning. Increased flexibility should be provided to take account of the varying speeds with which different children's thinking develops. Teacher education should equip teachers to use a variety of teaching methods, including group-work, and to provide a variety of learning experiences for the child, in place of existing linear fixed-pace class-teaching programmes. The Seminar is of the opinion that considerable improvement can be effected even within existing practical constraints.

3. Teaching materials

For most of their time at primary level, children are at the "concrete-operational" stage of development. This emphasizes the importance of activity methods in the classroom. Activity methods need materials. The training of primary teachers should place emphasis on the collection and improvisation of locally-available materials for the children to use. There is also a need for more simple structural apparatus specifically designed for teaching mathematics and science at primary level, and for in-service and pre-service teacher education in its use.

Textbooks and assignment cards should be written in such a way as to encourage practical activities in primary classes. The introduction of abstract symbols should not precede an understanding by the child of the relevant concept.

Studies in the perception of visual symbols indicate that great care must be taken in the preparation of pictorial materials. Such materials should be thoroughly tested with children to ensure that they convey the meanings intended.

4. Examinations in primary schools

Examinations powerfully influence curriculum development and teaching procedures. Where an examination exists at the end of the primary education stage, it should faithfully reflect the desirable objectives of the curriculum if it is to be of value both in encouraging better teaching and in being of maximum efficiency as a selection procedure. There is a trend in the region to abolish formal examinations within the primary stage. The removal of this constraint encourages the increased flexibility of approach which is so desirable. Young children should never be categorized as "failures."

Informal tests, however, have a valuable function. Their purpose is to provide information about a child's progress, and to indicate the subsequent learning experiences needed, rather than to grade children for promotion purposes.

5. Action research programmes

In order to provide the basic information necessary to implement these suggestions, it is recommended that countries initiate some of the research studies described in Chapter 5. External specialist resources should be provided when required, together with the necessary financial support.

The results of the research studies should not only be applied within the countries but also shared on a regional basis.

NOTES ON CONCEPTS AND CONCEPT LEARNING*

Many terms are multi-ordinal, i.e. they take on a wide variety of meanings in different contexts. The word theory, for example, embraces meanings ranging from "a strongly held set of abstract statements at a high level of generality" to "a vague, unsupported hunch".

The term concept is also multi-ordinal, and it is important to recognize that there are differences between the vague meanings given to the term by the layman and the more precise technical meanings needed by the educational researcher. For the layman, concept is synonymous with "idea, notion, thought, abstraction, generalization". For the researcher, this vague and general set of meanings is useful only as a starting point, and a much finer analysis is required if discussion on concept learning is to be fruitful.

An analogy drawn from the history of science may help to indicate the importance of a precise definition for research purposes. Three centuries ago, scientists had a vague idea about the "quantity of motion" of a body, related in some way to the amount of matter (mass) and the speed of the body. It was thought that "quantity of motion" was important in helping to explain the behaviour of objects involved in collisions. The discussion became clarified when momentum (mv) and vis viva (mv^2), which two centuries later gave way to kinetic energy ($\frac{1}{2} mv^2$), became clearly defined. Such clear, operational definitions are obviously vital in the development of a system of meaningful generalizations such as the various conservation laws.

The educational psychologist is also interested in constructing generalizations. His generalizations may not be the precise, highly general, laws of the physicist. But if his generalizations about concept learning are to be meaningful, they must be founded upon precise definitions. If they are not, assertions about the best way to learn concepts will be as confused as the seventeenth century assertions about the best way to analyse collisions. Three centuries ago, insults were traded by the supporters of momentum and the supporters of vis viva as each group argued that its measure of "quantity of motion" was the best way to analyse collisions. There might be a moral in this for educational researchers!

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* In Chapter 1 concepts and concept learning were interpreted from specific psychological points of view. Here another view-point has been briefly reviewed.

Appendix I

Taxonomic (Classificatory) concepts

One common meaning of the term concept in the psychological research literature refers to taxonomic, (or classificatory) concepts. Examples are concepts such as 'triangle', 'five', 'blue', 'mammal', 'transition element', and 'elastic collision'. These examples are very diverse, yet they all involve learning to discriminate classes of objects, events or situations, which have some common set of properties. This does not mean that all taxonomic concepts are learned in the same way. 'Triangle' and 'five' involve recognizing sharply discriminable classes of situations. 'Blue' involves categorizing a continuous range of stimuli, somewhere between bluish violet and bluish green. 'Mammal' is a higher order concept which requires preliminary learning of sub-ordinate concepts such as 'animal' and 'suckle'. 'Transition element' is a highly abstract notion, involving concepts which cannot be learned by direct observation.

Non-taxonomic (Quantitative) concepts

The other common meaning of the term concept refers to quantified variables such as the concepts of 'length', 'mass', 'volume', 'momentum', and so on. In the earlier case of taxonomic concepts it is meaningful to speak of positive and negative instances. ('Whale' is a positive instance of 'mammal'; 'calcium' is a negative instance of 'transition element'). Such a distinction is meaningless in the case of quantitative concepts. An object can have zero momentum, or some momentum, or more momentum, but we cannot speak of positive or negative instances of momentum. The distinction between taxonomic and non-taxonomic concepts is educationally fruitful because different sequences of teaching operations are clearly involved.

Concepts by observation and concepts by definition

Another distinction, made by Gagné[1] (1966), overlaps with but is not identical to, the taxonomic/non-taxonomic distinction.

Concepts by observation refer to abstractions which may be learned from perceptions of positive and negative instances, reinforced by knowledge of the correctness or otherwise of the learner's classificatory attempts. The child is told, "Yes, that is a cat," or "No, that is not a dog" and gradually a clear concept of cattiness or dogginess emerges. It should be noted that the learning of concepts by observation does not require the ability to verbalize the basis for the discrimination. The reader is invited to provide a verbal definition which clearly differentiates between cats and dogs! This does not mean that such concepts must be learned by observation and reinforcement of responses. The concept of 'poison' could, presumably, be learned by observation. For obvious reasons, however, it usually is treated verbally!

Concepts by observations ('blue', 'five', 'triangle') are commonly taught by presenting positive and negative instances of the concept, and tested by asking the child to display classificatory behaviour. After

1. Gagné, R.M. The learning of principles. In Klausmeier, H.J., and Harris, C.W. (eds.), *Analysis of concept learning*, New York: Academic Press, 1966.

the child begins to display consistently correct classifications, instances can be made more complex by introducing more irrelevant information. This can lead to the child generalizing the concept to a wide variety of situations.

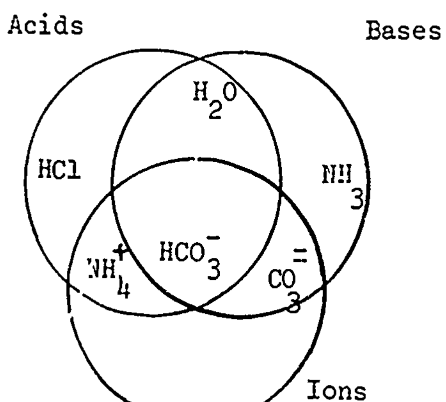
Concepts by definition are another class of concepts in Gagné's classification. These are verbalized statements ("An uncle is the brother of a parent") and may be learned if the component concepts and the grammatical, mathematical and logical operators which connect them are known. Concepts by definition are formally similar to statements of principles and laws (e.g. Boyle's Law: "The product of the pressure and volume of a specified mass of gas at constant temperature is constant") and are analytic statements. They involve assertions about the meanings of words and they make no assertions about nature. In contrast law statements are contingent: they make testable assertions about nature.

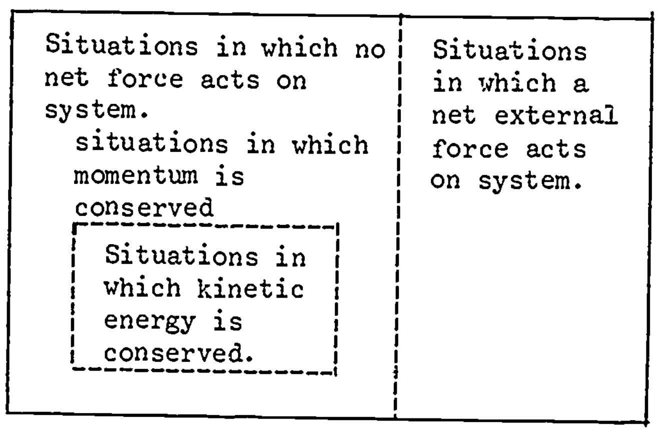
Although concepts by definition and principles may be learned by verbal means, it needs to be stressed that the ability of the child to state or recognize the verbalization, is certainly not a sufficient condition and perhaps not even a necessary condition, for establishing that learning has occurred.

Venn Diagrams

Venn diagrams represent a potentially useful technique for teaching and testing for concept learning in science. They are frequently used in mathematics teaching, but seldom in science teaching. Since learning taxonomic concepts requires classificatory behaviour, and since Venn diagrams are visual ways of representing relationships amongst sets, it would seem that some work in this field by science curriculum developers might prove fruitful.

Examples of Venn diagrams in science





Appendix I

Attributes, attribute values and rules

The discussion on taxonomic concepts may be elaborated by introducing a number of technical terms in common use.

An attribute is a dimension of variation of a set of objects. Minerals, for example, vary along dimensions such as colour, hardness, density, crystal structure. Animals' attributes include number of legs, body temperature, number of chambers in the heart, mode of reproduction, body covering, etc. Some attributes are relevant in defining the concept; others are irrelevant. 'Number of legs' is irrelevant to a definition of the concept of 'mammal'; 'mode of feeding young' is relevant. For the relevant attributes, certain attribute values define whether an instance is positive or negative. 'Milk-feeding' is the required attribute value if an animal is to be classified as a mammal. 'Colour' is an attribute of leaves; 'green' is the most common attribute value.

Most concepts are defined in terms of the joint presence of a number of attribute values. For example, monotremes are animals which have fur, constant body temperature, suckle their young, and lay eggs. (The Australian platypus is one positive instance). Such concepts are termed conjunctive; the vast majority of taxonomic concepts are of this type. The research literature suggests that the larger the number of relevant attributes, the larger the number of irrelevant attributes, and the greater the degree of abstraction of the attributes of the concept, the more difficult it is to attain the concept.

Most concepts in science and mathematics are defined according to a conjunctive rule, but other concept rules are possible, and are occasionally encountered. Some concepts are inclusive disjunctive: one attribute or another (or both) must be present for the instance to be classified as positive. For example, a spotted leaf may indicate the presence of a plant virus, or damage by insects, or a trace element deficiency. Other concepts involve negation, the absence of a particular attribute value rather than its presence. Implication, biconditional and exclusive disjunction are other conceptual rules. Extensive research has shown that non-conjunctive concepts are more difficult to learn than conjunctive ones. This is hardly surprising. Concept rules involving conjunction can be learned by abstracting the attribute values which are present in all positive instances, and this is relatively easy. In contrast, disjunctive concept attainment heavily depends upon processing information derived from negative instances. Deriving what the concept is from examples of what it is not is a cognitively difficult task.

However, this finding does not appear to be generalizable in all cultures. Research by Gay and Cole[2] (1967) has shown that Kpelle children in Liberia find disjunction easier than conjunction; the Kpelle language is weak in equivalents for 'and', but much clearer than English in the various connotations of 'or'. Clearly, difficulty with conceptual rules is related to the language system of the child.

This suggests that teachers should attempt to i) gather information about the first-language of the child, when this differs from the

2. Gay, J. and Cole, M. *The new mathematics and an old culture: a study of learning among the Kpelle of Liberia*, New York, Holt Rinehart and Winston, 1967.

teacher's own first-language and ii) give extensive practice at correctly using logical operators ('and', 'not', 'or', 'if .... then', 'all', 'some') with emphasis upon the ambiguous use of 'or' in English. This implies that there ought to be close liaison between teachers of English and teachers of science and mathematics. The work done in Singapore, which seeks to integrate English, science and mathematics, looks most promising.

Hierarchies of concepts

A set of concepts may be hierarchically related so that lower level concepts may in turn serve as attributes for higher level concepts. The concept 'enzyme' is a two-attribute conjunctive concept: enzymes are biochemical catalysts. Thus urease is an enzyme; vanadium pentoxide, a catalyst, is not; likewise progesterone, a biochemical substance, is not. 'Biochemical' and 'catalyst' are themselves definable in terms of other lower level concepts: 'catalyst' requires mastery of concetps such as 'substance', 'change', 'rate' etc.

The concept of energy is a high level concept, embracing a variety of meanings (kinetic energy, gravitational potential energy, electrical potential energy, heat energy, mass energy) which are related together through a highly abstract conservation law. The concept of energy only takes on its ultimate meaning within a rich network of sub-ordinate concepts, super-ordinate concepts, and law statements which relate various concepts.

This discussion may help to suggest why 'energy' is such a difficult concept to teach to young children. Without its accompanying conservation law, the concept of energy is unnecessary. Yet to try to teach the conservation law to young children is to lapse into dogmatism, verbalization and quasi-proof. The common school demonstrations showing energy transformations do not provide supportive evidence that energy is conserved. Conservation of energy is a precise, mathematically expressed idea, and in order to accept the evidence in support of it, the child must first master algebraic transformations and rudimentary integral calculus. The implications for curriculum developers are clear: when a concept is part of complex cluster, careful logical analysis, and considerations based on the knowledge of the development of cognition are needed in order to generate valid learning sequences.

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APPENDIX II

RESEARCH METHODOLOGY AND INTERVIEWS WITH CHILDREN AT THE SEMINAR

Research methodology

The method used by Piaget in his research reflects very clearly the objectives he set himself in starting his work. Piaget says: "The object of these studies, initially, was not to establish a scale of development and to obtain precise determinations of age as regards stages. It was a question of trying to understand the intellectual mechanism used in the solution of problems and of determining the mechanism of reasoning".[1] Piaget's principle concern is with the process by which understanding develops.

Piaget felt that he needed an interviewing technique that would allow the child's thought to flow freely rather than a more standardized test type of situation,and for this he adopted what is commonly known as the Clinical Method (sometimes referred to as the Critical or Operational Method). This basically entails a dialogue between the experimenter and the child, in which the child is free to follow his own cognitive orientation and thus reveals through his overt behaviour, his underlying intellectual structures.

Basically the clinical/critical method is a mixture of verbal and non-verbal methods, the non-verbal method involving the use of objects. Having identified the specific field of knowledge to be investigated, the experimenter must do two things (i) he must have a directing hypothesis, but as Piaget points out: "It is hard to find the middle course between systematization due to preconceived ideas and incoherence due to the absence of any directing hypothesis".[2] and (ii) the idea to be explored must be translated into a concrete situation involving real objects that are meaningful to the child.

This method, therefore, will always involve the subject acting on the outside world in some way. The situation, however, is not a test nor an examination. It is a conversation between the child and the experimenter who should do his utmost to help the child feel at his ease.

The experimenter starts with a problem, a concrete situation and a directing hypothesis. Although the experimenter may have a general idea about what he would like to observe relevant to the problem, it is each successive response of the child that should give the direction to

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1. Tanner, J.M., and Inhelder, B. (eds.). *Discussions on child development.* Vol. 1, London, Tavistock Publications Ltd., 1956.

2. Piaget, J. *The child's conception of the world.* New York, Harcout Brace, 1929.

the interview. In this manner the experimenter will be taking into account the total mental context of the child. Therefore, at each response of the child the experimenter makes a hypothesis about the "meaning" of the response and this will allow him to formulate his next question to the child.

A good experimenter must know how to "observe", that is let the child talk freely, listen closely to the child without sidetracking him, and yet, at the same time, he must think about how the information from the child can guide his next question. The new question is, therefore, in accord with the child's intellectual functioning.

The clinical method became known as the critical method when the notion of a counter-argument was introduced. The idea of a counter-argument is to propose to the child, once he has justified his argument, another point of view. For example, the child who says in the experiment with the two balls of plasticine that "there is more in the sausage because it's longer" can be asked: "A while ago a little boy, who was younger than you said to me that he thought there was less in the sausage because it was thinner, what do you think about this?".

A counter-argument is not used to confuse the child, nor to try and shake the justification he has already offered. It is used to see how he incorporates the new view-point into his actual reasoning processes. He may reject the argument altogether; he may use it as a piece of information that brings him along a stage; or he may oscillate between what he has said and the counter-argument, the counter-argument revealing a new side to the problem that he cannot quite yet accommodate to.

When the experimenter uses a counter-argument he must always refer to the fact that it was made by a child younger than the one being interviewed. If children feel that it is the experimenter's personal point of view they may tend to agree with him as he represents an authoritative figure.

There is never a question of the experimenter inventing a counter-argument; they are drawn from the various children's justifications at different stages in their understanding of the concept in question. These counter-arguments are then formulations of the child's spontaneous way of gradually grasping the concept.

It is perhaps wise, at this point, to distinguish the difference between replication studies and research into new areas of cognition. In replication studies the procedures used are ones which have been tried out and proved successful in revealing the child's thought processes about certain concepts. It has been shown that a great many of the procedures worked out by Piaget in Switzerland can almost, as such, be adopted by countries in Europe and North America. It is not known, however, whether these procedures can be used in countries where the linguistic structure and cultural background are radically different from those in which they were originally carried out. Well-thought-out adaptation is probably necessary.

Standardization is necessary in research in order to have comparability. The establishment of a procedure for interviewing, which can be used in replication studies, allows for a certain degree of standardization in as much as it provides the outline of a known sequence of questions that can be asked. Also in view of the fact that the stages in the development of concept are known, it allows the formulation of counter-arguments. In a new cultural background, however, qualitatively different replies may appear and influence the sequence of questions. The experimenter should then explore the significance of these new replies rather than adhere to a rigid sequence of questions.

The use of the clinical method in replication studies although admitting a similarity in procedure, allows for a flexibility in the way in which the questions are asked. Should the child not understand a question, it can be rephrased so as to contain the same information as before but to be more appropriate for the child. It can also contain flexibility in as much as the counter-arguments used will depend upon the response of the child. However, it could be said that a response A will always be followed by counter-argument X whereas a response B will always be followed by a counter-argument Y. Thus although the procedure is known, the underlying principle of a dialogue with the child is retained as the experimenter will adapt himself to the child's mental framework always.

The characteristics of the clinical or critical method, particularly when used in new areas of cognition, are then the following: the child is always given a concrete task translating the more abstract notion to be studied. As soon as the child makes a response to a question based on a directing hypothesis, the experimenter will then formulate a new question, which incorporates in some way part of the child's response. Thus, each response of the child is a partial determinant of the next move to be made by the experimenter.

Each question and/or counter-argument should set out to let emerge or make clear the child's thinking process. And the interview process continues in this way. In view of the dependence relationship between the behaviour of the child and that of the experimenter, it can be seen that no two children will ever have exactly the same type of interview - as the response of the child varies, so too should the questions of the experimenter.

During the interview there are several important things the experimenter must constantly be on the look-out for: he must let the child talk freely and not make suggestions to help the child to the "right" response; he must listen carefully to all that the child says and, if necessary, formulate questions using the child's language, though this does not mean "baby-talk"; and he must avoid trying to teach the child in the research interview situation, as what is vital is the spontaneous response.

The experimenter must also be aware that the question the child is answering is not necessarily the question the experimenter is asking. The child will always be answering the question he is asking himself, which sometimes can be a misinterpretation of the experimenter's original question. The experimenter must be constantly aware of this and can often ask: "What did I ask you to do?" or "What did I say?".

The analysis of the information obtained from the research is primarily a qualitative one. Piaget looks for categories or types of replies that seem to be common to a number of children, and then tries to see if a hierarchy emerges from these categories. The particular points of interest for Piaget, in such an analysis, are often the replies that seem to go partially into one category and partially into another as they would seem to show in a behavioral way the passage from one to the other. In this way Piaget tries to analyse the intellectual mechanism of reasoning involved in reaching the understanding of a certain idea.

Interviews with children at the Seminar

The participants at the Seminar were exposed to a three-phase introduction to the research techniques outlined above.

In the first phase the clinical method of interviewing children was briefly presented to the participants in demonstration form, by one of the consultants. Children who had a reasonable grasp of the English language, and who were of Asian parents, participated individually with the consultant in a series of experiments. The ages of the children ranged from 4 to 12 years. The experiments covered the development of concepts such as invariance of continuous and discontinuous quantities, ordering, sorting, invariance of weight and volume, spatial relationships and permutations and combinations.

In the second phase the participants were divided into two groups and two of the Asian participants, who were already involved in child development research programmes, were invited to lead the groups and demonstrate some of these techniques with children.

In the third phase the participants were divided into small groups of three or four so that each participant would have an opportunity of interviewing children with the particular techniques already demonstrated. Many of the participants became so involved in the interviewing of the children that they attempted to adapt the techniques to meet some of the linguistic and cultural problems being encountered. Great enthusiasm was shown for this part of the Seminar both by the participants and the children.

The following categories of difficulties were encountered at the Seminar when trying to adapt for the first time interviewing situations validated in another cultural setting.

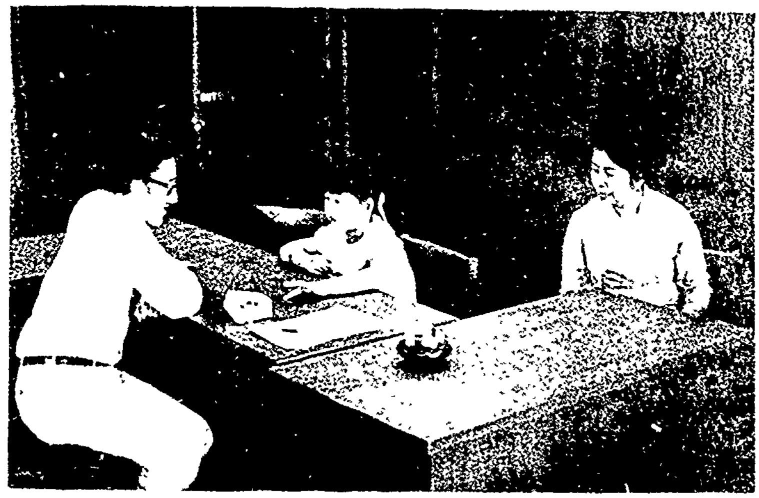
Linguistic difficulties: Although English was the second language of the children present it was nonetheless often used in a way not customary to most English speakers. The use of words or expressions such as "more", "the same as", "less" presented specific difficulties. Many of the participants felt that not only would the translation of such expressions raise difficulties but also sentence structure of some of the questions also. Great care would have to be taken in translation.

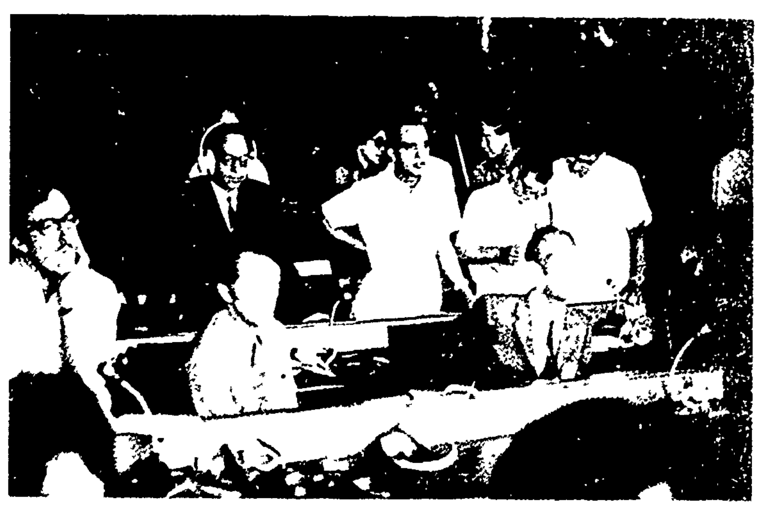
Culture-bound content: Many of the objects used to make the situation real for the child either had too much meaning within the new cultural context or not enough meaning.

The influence of tradition and custom on the interviewing technique: Many of the children were unaccustomed to be allowed to play completely freely with all the materials and had to be encouraged to manipulate them. The fear of giving wrong answers seemed to be common to all the children. This was emphasized by the fact that part of the technique of clinical interviewing is to ask the child to justify his reply. In many countries children are only asked to justify their answer if it is wrong. Also the pointing of the finger by the experimenter was interpreted by the children as signifying that they had given a wrong answer. Many of the children searched for the constant approval of the experimenter before actually adapting any strategy or taking any decision in the experiment.

At the Seminar the interview situations were somewhat formal. The interviews must take place in an informal, natural setting, if the child is to participate freely.

Even with this brief trial experiment, the participants recognized the impact of culture and language on the experiment. In view of these various difficulties the participants felt that the underlying ideas of the experiments should be clearly brought out and considered and then the cultural expression found for them.





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ANNEX I

OFFICERS OF THE SEMINAR

Chairman of the Seminar	: Dr. Chancha Suvannathat (Thailand)
Vice Chairmen	: U Thein Maung (Burma) Dr. J.N. Kapur (India) Prof. Byung-Kwon Ha (Rep. of Korea) Mr. Ganesh Bahadur Mali (Nepal) Dr. Mian Abdul Qaseem (Pakistan) Dr. Dolores Hernandez (Philippines)
Report Drafting Committee	: Mr. Abu Hassan bin Ali (Malaysia) Dr. Emily Miao (Philippines) Miss Kan Sou Tin (Singapore)
Rapporteur	: Mr. D.A. Perera (Ceylon)
Secretary of the Seminar	: Mr. J. Ratnaike (Unesco Regional Office for Education in Asia)
Bureau of the Seminar	: The Chairman, Vice Chairmen, Rapporteur and Secretary, together with: Miss Joan Bliss (Consultant) Mr. B.J. Wilson (Consultant) Dr. Edward Crunden (Division of Science Teaching, Unesco, Paris)

AGENDA

1. Opening of the Seminar.

2. Election of the Chairman, Vice-Chairman and Rapporteur.

3. Formation of Report Drafting Committee.

4. Planning the Schedule of Work.

5-A: Development of science/mathematics concepts in children.

   i. Presentation of research work done in some Asian Member States.

   ii. Introduction to general theoretical concepts.

   iii. Presentation of research work done in some other regions.

5-B: Developing science/mathematics curriculum for children.

   i. Presentation of curriculum work done in some Asian Member States.

6. Methodological approaches to research with children.

7. Planning of New Research Projects.

   i. Suggestions for new research projects and their design.

   ii. Relating research to curriculum development in science and mathematics.

8. Areas of inter-country and international co-operation.

9. Adoption of the final report.

10. Close of the Seminar.

ANNEX III

SCHEDULE OF WORK

Monday, 29 May:

A.M.	08.00 - 08.30	- Registration
	09.00 - 09.45	- Opening of Seminar
	09.45 - 10.15	- Break
	10.15 - 12.00	- Agenda items 2, 3, 4
P.M.	14.00 - 17.00	- Presentation of Country Reports and discussion.

Tuesday, 30 May:

A.M./ P.M.	09.00 - 12.30	- Presentation of Country Reports and discussion.
P.M.	14.00 - 16.00	- General introduction to theoretical concepts and discussion.
P.M.	16.00 - 17.00	- Presentation of Research in other regions and discussion.

Wednesday, 31 May:

A.M.	08.30 - 09.00	- Presentation of Country Reports and discussion.
A.M.	09.00 - 11.00	- A First Stage in the Development of Science/Mathematics Concepts in Children and discussion.
A.M./ P.M.	11.00 - 12.30	- Presentation of Research in other regions and discussion.
P.M.	14.00 - 17.00	- A Second Stage on the Development of Science/Mathematics Concepts in Children and discussion.

Thursday, 1 June:

A.M.	08.30 - 09.00	- Presentation of Country Reports and discussion.
A.M./ P.M.	09.00 - 12.30	- Additional Points of View (with particular reference to language) and discussion.

Thursday, 1 June: (Cont'd)

P.M.	14.00 - 15.00	- A More Advanced Stage in the Development of Science/Mathematics Concepts in Children and discussion.
P.M.	15.00 - 17.00	- Implications for Curriculum Development and for Teacher Education: discussion.

Friday, 2 June:

A.M.	09.00 - 12.00	- Open Forum on Curriculum Development and Concept Formation in Science and Mathematics.
P.M.	14.00 - 17.00	- Preparation of Draft Report - Part I.

/During the weekend participants may wish to outline in short paper the areas in which they may wish to undertake research./

Monday, 5 June:

A.M./ P.M.	09.00 - 12.30	- Adoption of Draft Report - Part I.
		- Presentation of various methodological approaches to research.
		- Work with children using specific interviewing techniques.
P.M.	14.00 - 17.00	- Discussion on above. Further work with children - participants will be requested to write a brief report on their observations.

Tuesday, 6 June:

A.M./ P.M.	09.00 - 12.30	- One of the participants from a country already involved in research will demonstrate interviewing techniques with children.
		- Discussion of the advantages and disadvantages of certain methods in research.
P.M.	14.00 - 17.00	- Participants will be split into four small groups (each group containing one trained research worker), each group will try to carry out one or two experiments.

Annex III

Wednesday, 7 June:

A.M.	08.30 - 09.30*	- Discussion on how research may be integrated into curriculum development and teacher education programmes.
A.M./ P.M.	09.30 - 12.30	- Presentation of research plans and discussion.
P.M.	14.00 - 17.00	- Presentation and discussion (cont'd).
		- Discussion on relating research to curriculum development.

Thursday, 8 June:

A.M.	09.00 - 10.30	- Discussion continued with special reference to design of science teaching equipment and materials.
A.M./ P.M.	11.00 - 12.30*	- Discussion on Seminar Recommendations.
P.M.	14.30 - 16.00	- Presentation of research plans and open Forum discussion on them.

/* Participants may form into an appropriate number of working groups to work out the designs of research studies./

P.M.	16.00 - 17.30	- Discussion on inter-country and international co-operation and Seminar Recommendations.

Friday, 9 June:

A.M./ P.M.		- Preparation of Draft Final Report.

Saturday, 10 June:

A.M./ P.M.	10.00 - 13.30	- Adoption of the Final Report.

Inaugural Address by Mr. Bhunthin Attagara

Under-Secretary of State for Education

Government of Thailand

Mr. Director, Unesco Regional Office for Education in Asia,
Mr. Director, UNICEF Regional Office for East Asia and Pakistan,
Distinguished Delegates, Consultants and Observers,
Ladies and Gentlemen:

It is a great pleasure for me to be here with you at the Opening of the Asian Expert Seminar on the Development of Science/Mathematics Concepts in Children, jointly organized by Unesco and UNICEF and in association with the Centre for Educational Development Overseas (CEDO, U.K.). To those who have come from abroad, may I offer a very warm welcome on behalf of the Ministry of Education. I hope that when you leave Bangkok at the end of the seminar you will bring home goodwill and friendship along with the benefits derived from the meeting.

As science and mathematics are recognized as being increasingly important to the individual life in a modern society, a great deal of efforts have been made by many Asian countries to improve and reform their science and mathematics education so as to keep in pace with the rest of the world. Unesco and UNICEF as well as many other international and regional agencies have been giving considerable assistance to the various projects which aim at the development of science and mathematics education in this region. However, in the past, curriculum development in science and mathematics have mainly been concentrated on higher levels of education. Now more and more attention is being given to the primary and lower secondary levels as well. Along with this emphasis is a realization that an understanding of the process of learning in children is vitally important in developing curricula which are relevant to their needs. More research on this new concept is being carried out in many parts of this region. Still there will have to be more concerted action which may lead to curriculum and instructional development in this field for the benefit of the children of Asia.

In view of the recent trends and development of science and mathematics education in this part of the world, this Expert Seminar is most timely, and I offer my personal congratulations to those involved in the organizing of the seminar for having successfully brought together research specialists in science and mathematics concepts in children, and curriculum specialists in science and mathematics for primary and lower secondary school. To all the participants, I wish to offer my very best wishes. I understand that a comprehensive and systematic agenda has been prepared for you so that your valuable time will be well spent in the course of this seminar.

Annex IV

As an educationist who is directly responsible for the decision making regarding education of an Asian country, I am constantly aware of problems concerning reproducibility of research done in other countries. In this context of research in concept development, for example, I am particularly concerned about the function and role of the mother tongue of the child. I am very pleased to learn that you will seriously consider the implications for research of this vital dimension. You will no doubt bear in mind that the developing child responds not only to verbalizations in your research designs, but also with verbalizations, and that one practical problem in this kind of research is the valid deciphering of the child's responded verbalizations for their cognitive developmental meanings and implications, especially when the language of the child is still an unsharpened instrument of intellectual control and self-communication.

I am also deeply concerned about the applicability of the research findings and their implications for the complex decision-making processes in education. For example, what are the implications of the research for diagnostic assessment of individual pupils vis-a-vis the school programme? What are the implications for structuring the curriculum content in terms of a normative developmental timetable? What are the implications for teaching methodology in particular, and teacher education in general, or for a national decision of the period of primary education?

I am certain that, all of you being experts as well as practical educationists in your countries, these and similar issues will find prominent places in your deliberations.

Ladies and Gentlemen, I believe that this meeting will serve as an excellent platform for exchanging experience and knowledge among the participating experts, and I have great pleasure in declaring it open. I very much hope that during this seminar you will not only identify common problems and arrive at useful solutions, but also will find ways and means of translating the outcomes of the research into the practical action in our respective countries.

Thank you.

Address by Mr. Raja Roy Singh
Director, Unesco Regional Office for Education in Asia

Mr. Under-Secretary, Distinguished Guests, Ladies and Gentlemen,

On behalf of Unesco, its Regional Office for Education in Asia and its Headquarters Division of Science Teaching, and on my personal behalf, it is my privilege and honour to extend you a warm and cordial welcome to the Seminar and to Bangkok.

The Seminar is devoted to an important theme; but apart from that, it represents a unique example of co-operative action. It was made possible by the financial support given by UNICEF; in its intellectual preparation the Centre for Curriculum Development Overseas of the U.K. Government has joined hands with Unesco and the participating Member States in Asia; many Organizations and individual scholars have given of their time and thought in support of the Seminar and are attending it as observers; the Member States and the United Nations Development Programme have made it possible for some of our Unesco specialists to be present here today; and most importantly the Government of Thailand and its Ministry of Education, and the Thailand National Commission for Unesco have, with their characteristic generosity, provided the venue for our meeting. To all our partners and co-sharers in this endeavour, I, on behalf of Unesco, pay our tribute of appreciation.

I thank UNICEF and its two Regional Offices in Asia for their encouragement to our effort to convene this Seminar. We in Unesco, specially the Regional Office for Education in Asia, have had close and co-operative relationship with UNICEF and its various Offices in a common endeavour to serve the children and youth of Asia. The present Seminar is one in a fairly long series which started as far back as 1962 in which our two Organizations have collaborated.

I should like to make grateful acknowledgement of the assistance extended by the Centre for Curriculum Development Overseas and extend a warm welcome to our two consultants who have over the last few months given a great deal of their time and labour towards the preparation of the Seminar.

I thank the Governments of the Member States and the participants therefrom who have responded to our invitation and who will place the wealth of their experience and knowledge at the disposal of the Seminar during the next few days.

I should like to take this opportunity to render special thanks to the Development Support Communication Service for its assistance to us in the preparation of the Seminar, in the form of materials, expert advice and a wealth of information that it places at our disposal.

I wish also to thank the Organizations and scholars who are with us in the Seminar today. We deeply appreciate the interest that they have shown and will profit greatly from the contribution that their presence will make.

May I, on behalf of my Organization, express our gratitude to you, Mr. Under-Secretary, for responding to our request to inaugurate the Seminar. You have just returned from a long and arduous mission. We deeply appreciate your giving us of your time in spite of the very many calls that the duties of State make on it. I should like to take this opportunity to express also our gratitude to the Government of Thailand, the Ministry of Education, and the National Commission for Unesco, and all the various Departments and agencies of the Government who have helped us unreservedly in preparing for the Seminar. These most agreeable premises in which we are holding our Seminar have been placed at our disposal by the Government of Thailand and are an expression of the abiding interest of the host country in promoting the cause of education and in particular fostering regional co-operation.

The schedule of work of the Seminar is a heavy one and I should like to apologize in advance to all the participants and observers for the exacting burden that it may put on their time and also for the fact that our opening day, to-day, coincides with a public holiday. But at the same time I must confess that in making this heavy programme we at the organizing end felt assured that we were only responding to your expectations. In recent years the patient labours of research are uncovering gradually, piece by piece, the map of the human mind from its infancy to maturity. These discoveries are undoubtedly a landmark in the development of human knowledge about itself, even though they may fail to catch the bannerlines of newspapers in the way that engineering spectaculars in space do. But they are perhaps more important for a future where human mind must understand itself in order that it may be able to cope with the forces it has generated.

Our particular Seminar is concerned with children; how they learn. The insights of research have to be pooled. But to know is not enough. Therefore the second aim of the Seminar is to see how the knowledge that has been acquired so far can be translated into those activities which serve to prepare a brighter future for our children.

Research has pointed up conclusively the decisive importance of childhood years in the formation of those basic patterns which seem to regulate so much of human conduct. These pointers provide us the third term of reference of our Seminar, namely to see what forms and transmutations take place in the growth of thinking in children in the environmental context of our own countries in Asia. Research in this subject in the Asian context is by no means abundant; a beginning has been made in some countries and this Seminar will provide an opportunity to pool what we know relative to our own special circumstances and to chart out what more needs to be done and in what directions. I feel that the ultimate success or otherwise of the Seminar is to be judged by concrete action that it may generate. From this point of view this Seminar is only a starting point; the other end is awaiting you in the countries when you go back.

Though the schedule of the Seminar is a heavy one, I hope that you will give yourself time to get acquainted with the culture and people of Thailand and to have experience at first-hand of their graciousness.

May I in conclusion once again extend to all the participants a warm welcome and express my Organization's gratitude to you, Mr. Under-Secretary, for your presence with us this morning.

Address by Mr. Yehia H. Darwish
Regional Director, UNICEF East Asia and Pakistan Region

Mr. Under-Secretary, Distinguished Guests, Ladies and Gentlemen,

It happened that some thirty years ago I started my professional career as an educationist. It happened also that I was responsible, with a small group of junior educationists for the pioneering implementation of a new methodology in teaching in my developing country and it was gratifying later to see that this new method has become an integral part of the educational system in my country - hence the interest in this field which we are now trying to explore in this part of the world.

The International Development Strategy for the United Nations Second Development Decade states that "Developing Countries will formulate and implement educational programmes taking into account their development needs. As appropriate, curricula will be revised and new approaches initiated in order to ensure at all levels expansion of skills in line with the rising tempo of activities and the accelerating transformations brought about by technological progress. Increasing use will be made of modern equipment, mass media and new teaching methods to improve the efficiency of education." It also states that "developing countries will adopt suitable national policies for involving children and youth in the development process and for ensuring that their needs are met in an integrated manner." The target as stated is to achieve enrolment of all children of primary school age, the improvement in the quality of education at all levels and the reorientation of educational programmes to serve development needs.

If the total strategy of the United Nations System is to help the developing world to establish priorities and balanced development, sectoral sub-strategies will be necessary if the development is intended to lead to growth and abundance. We are getting to realize that the educational problems of the world cannot be solved by the methods now in use. The number of illiterates, estimated at 800 million, increases every year by tens of millions. The number of children is growing even faster than the available number of school places.[1] Although it is the right of every child to be educated, it is becoming a fact that millions every

1. The World Development Plan - A Swedish Perspective By Ernest Michanek - The Dag Hammarskjold Foundation.

year cannot get it. In this situation, new systems and new methods of learning must be devised and utilized to full advantage if we are to meet that tidal wave of population growth. The International Institute for Educational Planning in Paris has done much to shed light on what its former director has referred to as the world educational crisis.

I could think of no better group to discuss "The Development of Science/Mathematics Concepts in Children" than you who are here today. The perspective emerging in this area of learning involves conceptual linkages within other perspectives, linkages within psychology to the whole area of motivation and personality, linkages to biological endowment and linkages to the proximal environment as well as the larger social structure. In extending thanks to the Ministry of Education of our host country Thailand, I feel indebted to you and to the Unesco Regional Office. You all have so readily and kindly received the idea and assisted in implementing it. I consider each one of you as a human resource, as a producer and shaper of new ideas to face a situation with a growing dimension.

Thank you.

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Annex V

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ANNEX VI

LIST OF DOCUMENTS

For Participants and Observers

UNESCO-UNICEF/SCD/1	- Agenda
UNESCO-UNICEF/SCD/2	- Schedule of Work (Provisional)
UNESCO-UNICEF/SCD/3	- Country reports (detail given at the end of the list)
UNESCO-UNICEF/SCD/4	- Concept Formation and Cultural Background in West Africa, by Bryan Wilson
UNESCO-UNICEF/SCD/4 (b)	- Research into the Understanding of Visual Symbols, by B.J. Wilson
UNESCO-UNICEF/SCD/INF/1	- General Information
UNESCO-UNICEF/SCD/INF/2	- Provisional List of Participants
UNESCO-UNICEF/SCD/INF/3	- List of documents

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Annex VI

Bulletin issued during the Seminar

Bulletin of 29 May 1972	- Election of Vice-Chairmen and members of the Drafting Committee.
Bulletin of 31 May 1972	- Definition of Key Words.
Bulletin of 1 June 1972	- Concepts and Concept Learning, by Paul L. Gardner, Senior Lecturer in Education, Monash University, Victoria, Australia
Bulletin of 2 June 1972	- Abstracts of relevant studies undertaken in Thailand by Dr. Weerayudh Wichiarajote.
Bulletin of 5 June 1972	- Draft Research Outlines
Bulletin of 8 June 1972	- Notes on Piagetian Intervention Experiment, by Emily Miao, University of the Philippines.
Bulletin of 9 June 1972	- A Model of the Curriculum Development Process, by P.L. Gardner (based on work by P. Hughes).

COUNTRY REPORTS

Burma	- Report on Proposed Plan of Teaching New Mathematics in Secondary Schools and Research Project in Science Concept Formation in Primary School Children of Burma
Ceylon	- Report on Curriculum Development in Science at the Junior Secondary School Level, a report of work done at the Curriculum Development Centre, Ministry of Education, Ceylon, prepared by K.U. Attygalla
	- Child Studies Relating to the Development of Selected Mathematics Concepts, a report of work done at the Curriculum Development Centre, Republic of Sri Lanka, prepared by D.A. Perera
India	- Some Questions About New Mathematics'Answered
Korea, Rep. of	- The Status, Problems, Research and Results of the Korean Science Education Project, by Prof. Byung-Kwon Ha (National Project Director, Professor of Seoul J.N.C., Member of Texbook Compilation Bureau Writing Panel)
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Malaysia	- Projek Khas, The Special Project for the Improvement of Science and Mathematics Teaching in the Primary Schools, Ministry of Education, Malaysia
Nepal	- Curriculum Development (UNESCO-UNICEF/SCD/3 - Nepal)
Pakistan	- Development of Science and Mathematics Curriculum in Pakistan, by Dr. Mian Abdul Qaseem, Assistant Educational Adviser, Government of Pakistan, Ministry of Education, Islamabad
	- Research Studies in Learning Process in Science and Math Conducted in Pakistan

Annex VI

Philippines	- Research and Curriculum Development in the Philippine Setting, Paper read by Dolores F. Hernandez, Director, University of the Philippines Science Education Center
	- A Report on the Research Projects at the Child Development Center of the College of Home Economics, University of the Philippines (UNESCO-UNICEF/SCD/3 - Philippines)
	- First Five Years of Piagetian Research; Some Implications for Training Research and Education For the Young Child, by Emily Miao, University of the Philippines
Singapore	- Report on the Primary Pilot Project and Curriculum Development in Singapore (UNESCO-UNICEF/SCD/3 - Singapore)
Thailand	- The Institute for the Promotion of Teaching of Science and Technology, Bangkok, Thailand - Curriculum Development in General Science (UNESCO-UNICEF/SCD/3 - Thailand - A)
	- Research Activities in the Area of Concept Development of Thai Children (UNESCO-UNICEF/SCD/3 - Thailand - B)