

A Modern Approach to Science Teaching in Ethiopia

P. Okera, & D.F. Holland

CURRICULUM REFORM MOVEMENTS IN PERSPECTIVE

Despite the confounding varieties of acronyms and mystifying initials (PSSC, CBA, Chem Study, SSP etc.), the school science curriculum innovation projects devised during the past two decades have had a stimulating and morale-boosting effect on the science teaching profession. A correct appraisal of their role lies in perceiving them, most certainly not as "curricular prescriptions" to be passively adhered to with blind devotion, but as "movements" in which science teachers play a positive part in constantly assessing their objectives, teaching strategies and materials. By using a judicious 'cut and paste approach' (1) (2) with the considerable repertoire of materials that these projects have generated, science teachers can design curriculum programs that are appropriate to the specific needs of their school regions and in the process no doubt contribute innovative ideas and materials to these "movements" *per se*.

The impact of these curriculum innovation projects has been both rapid and global. In Africa, the ESI and African Universities joint collaboration yielded the African Mathematics program in the early sixties. Science programs followed soon with the ESI sponsored African Primary Science Programme and various secondary school projects based on the Nuffield Programs in Britain (e.g. the SSP on East Africa). The effort differential in curriculum reform between mathematics and the sciences is obvious. Whereas the simple production of appropriate textual materials together with the blackboard and chalk suffice to bring the world of real mathematics to any African school, the situation is somewhat more challenging in the case of science. This last remark could pretty well be taken to summarize the situation in Ethiopia, where, notwithstanding the relative success of the Entebbe Mathematics Program, secondary school science has remained practically untouched by the modern developments.

ANALYSIS OF THE PRESENT SITUATION IN ETHIOPIA

It is not the purpose of this paper to dwell on the only too well-known general aspects of the existing situation. However, a sympathetic understanding of the problems faced by the science teacher and a realistic appraisal of the school situation is essential for the successful introduction of a new program.

The locked science laboratory, or the detailed drawings on the blackboard dutifully copied (without much thought or excitement) by the student, are all too familiar reminders of the present state of science teaching in Ethiopia. Practical experience and thought provoking discussion are often replaced by the quick and easy method of rote memorization and drill. A quick perspective of the final product (the ESLCE candidate) can be obtained from examples of performances in two questions in the 1971 Physics Paper:

Question 8 (a) Illustrate, by means of a clearly labelled diagram, the operation of a moving-coil galvanometer.

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Question 8 (a) Illustrate, by means of a clearly labelled diagram, the operation of a moving-coil galvanometer.

This question requiring only memorization was answered very well by students from some schools. It is interesting to note that students from the same school gave identical drawings!

Question 3 (b) You are given two 10-volt electric bulbs, a 10-volt battery, a single on-off switch, and assorted wires for making connections. Draw a circuit diagram showing how this apparatus should be connected in order that both bulbs light up properly when the switch is closed.

This question required some logical thought and practical experience and was answered badly.

This type of science education neither equips the pupil for technical work nor prepares him effectively for further academic studies as is evidenced by the attrition rate in the University. Its contribution to a more universal aim of *education for citizenship* is equally dubious.

It is important to isolate the specific factors that lie at the root of the situation described above, and to determine the realistic extent to which any curriculum innovation effort can go to combat or accommodate these. Indeed such a step is vital in achieving any degree of realism at all in any curriculum reform venture. These cardinal factors in our opinion are as follows:

(i) Cultural background of the pupil:

Most developing countries such as Ethiopia, have cultures remarkably rich in terms of tradition and art. Nonetheless, these cultures are basically pre-technological and rooted mostly in rural agrarian type of life with a negative bias towards science and technology. However, in a rapidly changing or development oriented society, pupils from such backgrounds must be prepared for life on mechanised farms or industrial settings. This situation inevitably leads to serious problems. Firstly, in terms of cognitive growth psychology, such pupils can be said to be deprived of the sort of environment conducive to the development of cognitive skills required in science. (3) (4) (5) (6) Much more important and far too serious however, are the attitudinal implications. Traditional cultures tend to encourage conformity at the expense of a critical or questioning attitude, and equally, a mere passive acceptance of nature and natural phenomena, in the place of an active and confident disposition that regards nature both as comprehensible and as an arena of fruitful and profitable enterprise. Furthermore, many of these cultures are characterised by an unusually high incidence of the "white collar complex" which relegates work with hands or laboratory work to a pretty distasteful level.

It is not surprising therefore that attempts at instituting a genuine scientific approach in a classroom may frequently cause insecurity in pupils (7) if not an out-right hostility, while disaffection and withdrawal are frequent results of laboratory activities.

(ii) Science teachers:

Despite the excellence and capabilities of some very dedicated science teachers in Ethiopia it can nonetheless, be said generally that quite a substantial number of them are underqualified or inexperienced, or both. More serious however is the cultural vicious circle which makes these teachers themselves adversely inclined

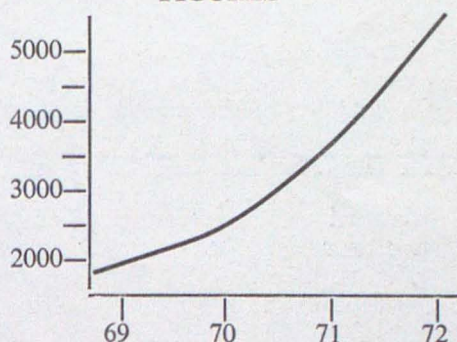
towards activity oriented course work. Confronted as they are with numerous other problems they would be inclined to take the easy way out - chalk and talk with copious notes.

(iii) *Equipment and laboratory facilities:*

The present large enrollment in secondary schools has seriously taxed their resources for providing science equipment and laboratory space. The situation may become even more serious as suggested clearly by the registration figures for the General Science section of the ESLCE.

This constitutes a serious problem especially in the lower grades where most of the pupils may never see a science laboratory.

GENERAL SCIENCE REGISTRATION FIGURES



(iv) *Time allocation:*

The introduction of the shift system with a corresponding reduction in teaching hours has reduced the time available for science teaching. For this and other reasons, teachers find it difficult to complete the present syllabus. There is no doubt that the present course content, overburdening as it is, extorts a high toll in terms of pupil activities and experience of science.

(v) *English as the Medium of Instruction:*

Words and neat diagrams instead of real experience; symbolism obscuring reality; all this is bad enough without the added hurdle of a foreign language and idiom. "Boil the water until all the molecules are killed," is not merely a slip in rote memory. It shows complete breakdown in the process of relating symbolism to reality.

THE ETHIOPIAN HIGH SCHOOL PHYSICAL SCIENCE PROJECT (E.H.P.P.)

The progress of educational reform seldom takes a systematically charted course. Our program is no exception to this rule. Its development has just as much been determined by *a priori* considerations of the type described in the previous section, as by *a posteriori* empirical factors. We therefore adopt the approach of firstly describing the program as it has so far evolved, and subsequently taking up the question of its efficacy in counteracting the negative factors already described.

Originally conceived in 1970 as a pure physics program (8) with the limited objective of simply modifying the 4-year East African SSP program for Ethiopian schools, EHPP has subsequently evolved into something decidedly different both in scope and style. The scope has been altered into a physical science program covering only grades 9 and 10 (grades 11 and 12 being left for a separate project closely following the EHPP) while the style adopted may be termed structured inquiry whose detailed description follows in the next section.

The Science Curriculum Development Centre under the Ministry of Education has the overall responsibility of science curriculum development in Ethiopia. Towards the end of 1970, a "Physical Sciences Panel" was formed under the SCDC to advise on physical sciences curriculum development in secondary school. Accordingly, policy and general aspects of the EHPP are decided by the Physical Sciences Panel some of whose members (two from the Physics Department, one from the Faculty of Education, one from the SCDC and one from the Faculty of Education Laboratory School) are actively involved in materials production and trials.

Most recently the Technical Education Department of the Faculty of Education has joined in to fulfil the vitally needed role of designing kits from local materials. Three Faculty of Education students majoring in Physics are at present working on their senior projects in the context of the new program. Two secondary schools, Asara Hawariat and Tafari Makonnen, are co-operating with the trials of materials.

Textual materials for ideas connected with Physics and those connected with Chemistry are at the moment being produced separately, although some degree of integration (in connection with units that are amenable to this process) is envisaged in the future. The textual materials comprise (i) EHPP Student Guide in which more than half of the work has been accomplished and (ii) EHPP Teacher's Guide in which a bare minimum has been achieved, pending feedback from trials and integration of the Physics and Chemistry components. The Students' Guide takes the form of carefully structured questions and problem-solving situations with blanks for the pupils to fill in the results of their inquiries. This is interspersed with some informative materials, summaries and further exercises, so that the pupil gets the satisfaction of synthesising his own "text book", as it were, from the results of his inquiries.

It was clear at the outset that in a majority of Ethiopian secondary school, grades 9 and 10 never have the chance to go to the laboratory on account of their numbers. The stance we adopted was that the laboratory (or lab activities) must be brought into any typical class room. A typical EHPP lesson therefore takes the form of a joint investigation (JI approach) by the entire class, led by the team leader, the teacher. A Prototype kit box with peg-board demonstration front and all the necessary materials designed to go with the Guide, is now in the process of being developed by the Technical Education Department of the Faculty of Education. The kit box should be very easy to carry to and from class, and its materials list would be comprehensive enough to include weighing and heating devices and possibly its own water supply. This JI approach should not be confused with simple demonstrations insofar as the whole style and tempo here is that of a genuine investigation team with pupils helping with the setting up of apparatus and the actual experimentations. In many cases (e.g. in measurements, pendula, levers, molecular models, etc.) the kit box would contain enough materials to be given out to groups of students to carry out their own investigations. The ideal still of course, remains the full participation approach (PP approach) in which sufficient materials would be available for most of the investigations to be carried out by the pupil themselves. This PP approach could be tried out in some of the well-equipped schools while a school with a JI approach could switch over to the PP approach any time it feels, equipmentwise, able to do so.

With the help of the 4th year education students majoring in Physics, trials of the JI approach have been started in grade 9 of the Asara Hawariat School. A somewhat less structured approach of the program is being tried out at the

Tafari Makonnen School. Results so far have been most encouraging and on occasion positively inspiring.

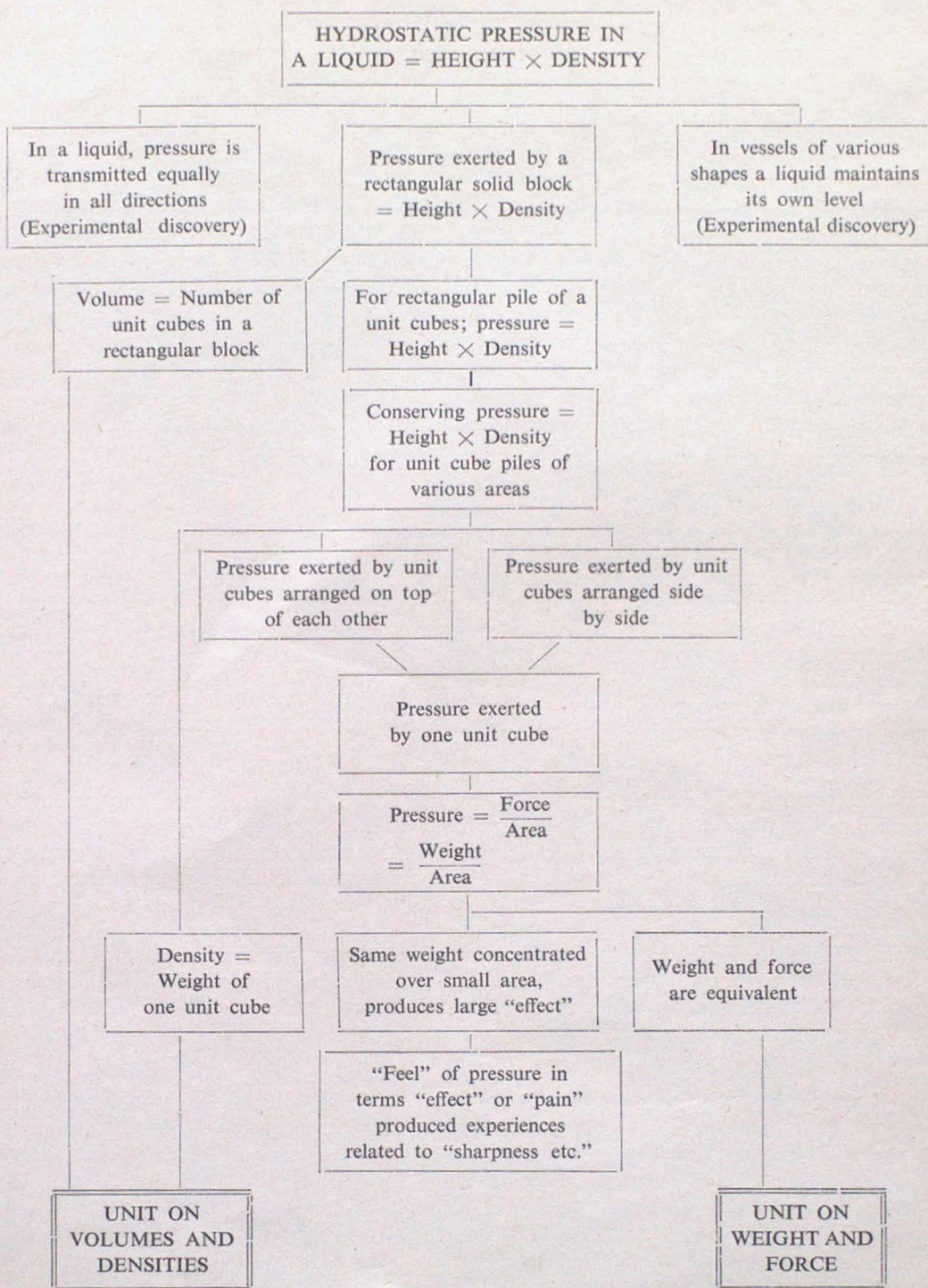
STRUCTURED INQUIRY MATCHED TO "PROCESS APPROACH" IN SCIENCE TEACHING

The structured inquiry approach is basic to the new science program. Although an ultra-heuristicist would reject any notion of structure in the context of scientific investigation, the majority of us nonetheless appreciate the difference between real research activities at the frontiers of science and their classroom analogues. As Thier has succinctly summarised, the objective of science teaching should be that 'the [pupil] must have a conceptual structure, and the means of communication (literacy) that enable him to interpret the information as though he had it himself.' (9)

Generally speaking, a structured course can be matched to cognitive development of the pupils. We have come a long way from the simplistic and rather stated objective of teaching science for understanding,' (10) commonly encountered in treatises on PSSC or Nuffield-type projects. A more definite and concrete one has emerged that in the cognitive domain, science education objectives lie in fostering the growth of process skills (or cognitive skills) in their occurring hierarchy towards the attainment of conceptual schemes. The involved by Jean Piaget (11) which establishes clearly defined growth stages of mental development has been found most useful in elementary science pedagogy. A similar approach in recent work (12) suggests its usefulness to much higher levels. A similar approach on these lines has been worked out in much greater detail by Gagné (13) on whose works the elementary school program 'Science-A Process Approach' is based.

In the structured inquiry approach that we have adopted for EHPP presentation, we put great emphasis on the growth of these process skills. Each unit aims at one or several cognitive processes, starts by giving the pupils the "feel" (14) of a concept. This is followed by a sequence of problem-solving situations (mostly experimental) which encourage pupils to work their way towards some "conservation operation" or discovery. An example would be conservation of weight per unit cube of a substance (density) or in electric circuits, the conservation of electric current around the circuit. Needless to say the rather sophisticated language used here never appears in the simple classroom activities, where the pupil learns to conserve without ever hearing the word "conservation." Finally, the conceptual schemes are introduced in an order similar to Gagné type process hierarchies such that the processes or concepts lower down the conceptual pyramid precede those further up this is illustrated by the process-diagram in connection with the EHPP unit involving hydrostatic pressure.

PROCESS DIAGRAM



It may be correctly pointed out that the joint investigation approach by its very nature, tends to under-cut the vital activities at the pyramidal base. There is no doubt that the initial play phase where the pupil messes about with materials and ideas, acting freely on hunches or guesses, is an indispensable stage in concept formation. Absence of such pre-formal experiences may deprive the pupil of experience necessary for the subsequent stages and thus force him to 'codify at formal symbolic level' (4). However, one cannot escape the fact that the only way to do full justice to the above considerations is to embark upon the pupil participation approach to the full, with experienced teacher favourably disposed towards the messing about activities. Meanwhile, in the joint investigation approach, there is some scope for initial play games. Indeed, this is incorporated in the actual write-up at the beginning of every inquiry activity. Considering that we are trying to get away from the present situation of almost all rote memory with no inquiry, activities with, due modesty and defence to realism, one cannot honestly complain.

EHPP AND THE PROBLEMS UNDERLYING THE PRESENT SITUATION

We described the causal factors associated with the present dilemma of the science teaching situation, and the EHPP program its approach and philosophy, as it has evolved so far. One can now venture to look at the efficacy of the new program in mitigating the negative factors discussed previously.

Cultural background of pupils

Here the joint investigation and process approach pay heavy dividends. In general the process approach has a vital bearing of the cultural aspects of science education in a rural nontechnological society. Activity oriented science programs are very likely to fall on their faces by engendering insecurity in the pupil if the latter has neither the cognitive skills required for the activities nor awareness of style or mode of an inquiry process. The structured inquiry approach takes the pupil "by the hand" as it were, through a vital phase in his personal development during the first two years in a secondary school, when he acquires both the cognitive skills and the style of scientific inquiry. This endows him with confidence and prepares him for a more open-ended approach in grade 11 and 12 or in further studies in science and technology.

The objectives of science teaching in the developing countries in the final analysis, boil down to what may be termed "acquisition of modernity and scientific outlook." Stated in educational terms this implies that there is a need for extensive transfer from science education to other areas of culture and life. The process approach is known to be one of the vital pre-conditions for such transfer. Also, the joint investigation approach enhances pupil confidence in scientific inquiry, thereby enabling him to discover the true joys of science and hence increase his commitment to the subject. This fulfills the other and more important condition for extensive transfer viz. emotional involvement with the subject. In general therefore, the style of the structured inquiry adopted by the EHPP would seem to enable it to meet the cultural demands for the injection of modern thought, skills, and outlook into the present rural and non-technological society in Ethiopia.

Science teachers:

An experienced, well-qualified, and enthusiastic teacher could engender concepts and activities of the new program in his own style, considerably deviating from

the structure suggested in the guides. In fact such a teacher does not need the EHPP or any of the other lot, except as sources of ideas or innovations. On the other hand, clearly structured and programed materials can boost confidence of the relatively inexperienced teacher, or even of the experienced teacher given to the habit of chalk and talk. Since the guiding questions, strategies etc. are programed in the student guide, the teacher can devote his whole attention to the activities, and to giving personal attention to the pupils. In our trials we used teachers (undergraduates) with little or no experience who, more or less, simply followed through the materials. The built-in inquiry method in the program in most cases, does not fail to unfold itself in a manner otherwise impossible for a novice teaching in the traditional style. We therefore maintain that the program is amenable to being tackled by any typical science teacher in Ethiopia after a brief orientation course.

Equipment and laboratory facilities:

The EHPP course work has been designed in conjunction with a kit set that is prepared mainly from local materials. Of relevance here is not only the consideration that these are very cheap and the costs to the Ministry of Education of introducing the program only minimal, but also the fact that the savings thus affected are in terms of valuable foreign exchange reserves. The simply made part of the kit are easily replacable and in our experience we found their use highly conducive to extemporisations and a general feeling of selfreliance on the part of both the teacher and the pupil. In a rural, non-technological background, complicated apparatus can induce formidable awe which may lead to the "locked lab syndrome." The pedagogical value of materials simple and familiar, to the extent of inviting pupils to produce their own version at home, is certainly inestimable. This liberation of science teaching from the tyranny of technical gadgetry, or what has been previously referred to as the "de-technologisation" of science education (8) is an important part in our program. We believe the way to industrialisation and technology is through cultivating relevant understanding, process skills and attitudes in the young minds rather than the old-fashioned method of converting science lessons into workshop drill.

Time Allocation:

The process approach implies that process skills rather than content have priority in any science program, which in itself excludes a lot of "deadwood" content. Furthermore in our trials, process-based units, allowed to develop at natural pace are being presented in a normal school situation, with normal school examination, holidays, etc. Results so far convince us that the normal time allowance for Physics and Chemistry (3 periods per week) is quite adequate for the satisfactory completion of the EHPP course work by the end of grade 10.

English as a medium for instruction:

In the structured approach, the class (or the pupils regarded individually) cannot proceed forward except through carefully programed stages, each full of activities. Questions, problems and guidelines are phrased in simple but nonetheless modern science English, and are *intimately* related to these *activities*. The language thus acquires its true function as a symbolic representation of experiential realities. In other words the structured aspects of the program necessarily fosters *co-development* of conceptual schemes and the means of their communication (scientific literacy)

side by side. This is true of the English language presently used in the program, and certainly truer for Amharic, should this language come to replace English in secondary schools, and the present program be translated into Amharic. Even at the present stage copious use is made of Amharic during classroom discussions in the program. A society aspiring to modernity and scientific outlook must incorporate these characteristics into its language, particularly the language of its future citizens, and only locally-based science education programs such as the EHPP (or others that might develop in the future) can effectively accomplish this.

EVALUATION OF THE EHPP

Methods of evaluation comprise a complete spectrum from simple common sense to esoteric theoretical considerations. We have speculated on what the EHPP can do in the various problematic areas characterising the present situation. At present, our considerations are based on common sense. We can say this: Here is a program that can certainly not be accused of ivory tower academicism for the simple reason that it is now being accomplished in a chika grade 9 classroom at a very poorly equipped school with inexperienced undergraduates as teachers, making their own equipment. This feature is infact the main characteristic that distinguishes EHPP from other similar but somewhat elitist programs elsewhere in Africa. The SSP in East Africa for example can only be adopted by certain schools that satisfy equipment and other criteria, a requirement that leaves Kenya's Harambee schools in a quandary. We view this characteristic as a positive factor that makes the EHPP compatible with the realities of Africa.

From the theoretical point of view, the problems of evaluation of science curriculum programs are only too well known (1) (16). A modest attempt could be made to look at the program from the point of view of the Cognitive, Affective and Sensori-motor domain objectives (17) whose relevance to the problems of culture and development has already been pointed out in the previous sections. In the design of the EHPP course structure, it is obvious that a maximum premium has been placed in the cognitive domain objectives. The activities in the program, partly limited in the JI approach, but otherwise fully realised in the PP approach, can be said to fulfil the sensori-motor objectives to the extent possible under existing varieties of school situations in Ethiopia. Finally the realisation of objectives connected with the affective domain, most crucial in the context of the developing countries, is strongly coupled to rewards and reinforcements in the other two domains, and also depends heavily on the style and general atmosphere cultivated in the program. The latter point is also heavily emphasised in the EHPP program (e. g. the pupils are throughout addressed as "young scientists" or encouraged to carry out their own separate investigations at home, etc.)

The question still remains of how to evaluate this program. There is of course *pupil evaluation* in the form of examinations such as the ESLCE. The ESLCE would need no doubt to be changed to accomodate the new program. This could be done by providing an EHPP alternative to the present examinations. At present, however, the ESLCE is already evolving gradually towards the necessary type of examinations thereby encouraging teachers to become activity and logic oriented.

In the case of *program evaluation* a graduate assistant has started work on interest and attitude analysis both in pupils and teachers prior to the EHPP introduction, with the eventual hope of comparing schools using the new materials with the others. A more specific but empirical approach is envisaged whereby a

panel of experienced teachers will compare classroom performances of EHPP methods with conventional methods. A third idea which is still in a budding stage and confronted with numerous problems is the use of properly adapted Piagetian tasks to measure cognitive growth.

A LOOK TO THE FUTURE

A program such as this one essentially derives its force from optimism. We believe our optimism to be without illusions and firmly resting on extra-polation of the present very encouraging atmosphere. Firstly the Ministry of Education has expressed an interest in introducing an integrated physical science program into the ninth grade next year. At the very least, this means that more schools will be trying out the EHPP materials as from then. Orientation courses for teachers working with the new materials should involve more teachers with the program, who would in turn make their indispensable contribution in the further development of the project and in the vital areas of feedback and evaluation. Secondly the Haile Sellassie I University has given a positive encouragement to the project through an allocation of a research grant which would enable expansion and extensive study of the new materials. This step no doubt demonstrates the recognition on the part of the University of such "action research" projects through which it can play an active role in the nation's development.

The EHPP is thus a promising co-ordinated effort between the Ministry of Education, high school directors and teachers, and the H.S.I. University. Although soundly based on the extensive experience of other countries, it primarily stems from genuine Ethiopian experience. The materials now being produced are not a finished product but a point of departure based on sound theoretical and practical considerations. Their future growth and development should give administrators, teachers and scholars the satisfaction of creating materials suitable to the needs and conditions of a developing country. As such the EHPP is much more than a modern curriculum; it is a new concept; a new direction in science teaching in Ethiopia.

REFERENCES

- 1) Zukowski J. 'Introductory Physical Science' NEWSLETTER Portland Project Winter, 1971.
- 2) Dyrli O.E. 'The cut and paste School Science Curriculum' SCHOOL SCIENCE AND MATHS LXXI (6) p. 525, 1971
- 3) Dart F.E. & Pradhan P.L. 'Cross-cultural Teaching of Science' SCIENCE p. 649-656, Feb., 1967.
- 4) Macdonald T.B. 'A Suggested Program in Preformal Science Experiences' SCHOOL SCIENCE & MATHS LXXI (4) p. 347, 1971.
- 5) Billeh V.Y. & Pella N.O. 'Cultural Bias in the Attainment of concepts of the biological cell by elementary school children' JOURNAL OF RESEARCH IN SCIENCE TEACHING vol. 7 p. 73-83, 1970.
- 6) Lovell K. "A follow-up Study of Inhelder's and Piaget's 'The Growth of Logical Thinking.'" BRITISH JOURNAL OF PSYCHOLOGY vol. 52 p. 143-155, 1961

- 7) Payeur J. Seminar paper Faculty of Science, HSIU, 1970 .
- 8) Okera P. Seminar paper "Ethiopian High School Physics Project (EHPP)" Faculty of Science, HSIU, 1970.
- 9) Karplus R. & Thier H.D. 'A NEW LOOK AT ELEMENTARY SCHOOL SCIENCE' Rand McNally & Co. Chicago Illinois, 1967.
- 10) Rogers E.M. 'The Aims of Science Teaching, Teaching Science for understanding' NUFFIELD PHYSICS TEACHERS GUIDE I Longmans Penguin Books London, 1967.
- 11) Inhelder B.& Piaget J. 'The Growth of logical Thinking from Childhood to Adolescence' BASIC BOOKS, NEW York, 1958.
- 12) Karplus E.F. & Karplus R. 'Intellectual Development Beyond Elementary School' SCHOOL SCIENCE AND MATHS LXX p. 396,-408. 1970
- 13) Gagné R.M. 'The Acquisition of Knowledge' PSYCHOLOGICAL REVIEW, Vol. 69, p. 355-365.
- 14) Bruner J.S. 'The Process of Education', VINTAGE BOOKS, New York, 1963.
- 15) Quarton G.C. 'Evaluating New Science Materials; Thoughts on Methods and Goals', ESI QUARTERLY REPORT, Spring Summer, 1966.
- 16) Welch W.A. 'The Need for Evaluating New Science Programs' PHI, DELTA, KAPPAN, May 1968, p. 530.
- 17) Bloom Benjamin S. et al 'TAXONOMY OF EDUCATIONAL OBJECTIVES' David Mckay Company New York, 1967.