Science Education Conference: focus, primary school science: 22nd June 1976

Mount Lawley Teachers College
Edith Cowan University

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Science Education Conference
Focus: Primary School Science
22nd June 1976
Mt. Lawley Teachers College
An introductory note –

Science education in the primary school is often neglected or taught in a manner similar to science in the secondary school. Should this be? What should be taught in primary school science? This is the focus of the morning session. What should be taught has implications for training primary school teachers. This is the focus of the afternoon session.

Abstracts of all papers presented are included in the programme. All participants will receive a copy of the papers presented.

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Planning Committee:

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WHY CONCEPTS

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In the quarter of a century since the teaching of science has been seriously considered at the primary school level, many schemes for teaching science have been postulated and vehemently defended.

These schemes have ranged from an emphasis on attitudes right through to content only, from a flexible plan pivoting on experience, discovery and enjoyment to a clearly directed programme which is heavily teacher centred and strongly based on factual attainment. Today it would be difficult to find a Science Educator who would seriously defend one extreme scheme against all others. On the contrary, the child and his ability, content, attitudes and activity are necessary parts of every modern curriculum in Science Education. We are obviously moving toward consensus. All that seems to remain is a small problem—refinement—but not so. Focus is still in dispute. Curriculum planners must by the very nature of curricula begin on a pivotal structure and an end point to direct all aspects of the fabric of the teaching strategy. These constraints and its implications lead logically, with the firm direction of a gun barrel, to every classroom sequence. The most insignificant classroom activity must be oriented to an overview—to the final product, the overall plan, or alternatively be doomed to the mediocrity of a hotch potch series of interesting periods of busy work.

The position adopted in this paper clearly and honestly submits that the Science Education Curriculum must have a skeletal structure, a frame and direction as clearly defined as the backbone of a fish. Furthermore, it is maintained that this central supportive grid must be a conceptual over-view. This view is embedded firmly in pedagogical, rational, structural, philosophical, linguistic and practical grounds. No other course presents itself as effectively at this time. No research adequately defends preference for other prospects.

Alternatively based schemes may be interesting, lively, busy, enjoyed, well taught and well run but they can never claim to be education in Science; only the big ideas in science—the broad, inclusive conceptual schemes in which we seek to account for the familiar facts of nature can generate an effective base plan for Science Education in the primary school.
1. WHY CONCEPTS AS A BASIS FOR PRIMARY SCIENCE?

In the quarter of a century since the teaching of science has been seriously considered at the primary school level, many schemes for teaching science have been postulated and vehemently defended. These schemes have ranged over a spectrum including emphases on discovery, process, attitudes and content. That is, a flexible open plan based on experience, discovery and enjoyment to a clearly directed program which is teacher centred and aimed at factual attainment. Today it would be difficult to find a Science Educator who would seriously defend one extreme against all others. However, focus is still in dispute. Curriculum planners must by the very nature of curricula begin on a pivotal structure, a basic philosophy, which implies an end point of a grand design. This grand design forms the fabric which directs all aspects of consequent teaching strategies. The constraints of basic curriculum philosophy and its implications lead logically, with the firm direction of a gun barrel, to every classroom sequence. Instruction must be geared to the attainment of objectives; these objectives must be both immediate and long range. Because of the hierarchy which exists in concept formation the teacher's strategy must be such that the child cannot meander on a hit and miss trail of hatch patch. The Science Education programme in the primary school must lead to the attainment of objectives that form a vital link in the later acquisition of more advanced concepts. The most acceptable supportive grid for this scheme is a conceptual overview. This view is imbeded firmly in pedagogical, rational, structural philosophical, linguistic and practical grounds. No other alternative presents itself as effectively at this time. No research adequately defends preference for other prospects. Alternatively based schemes may have periods which can be claimed to be interesting lively, busy, enjoyed, "well taught" and well organized, but only the "big ideas in science - the broad, inclusive conceptual schemes in which we seek to account for the familiar facts of nature" (Copes, 1973, p.1) can generate an effective base plan for Science Education in the primary school.

The ideal curriculum in Science Education at the primary school level has tended to become clouded by psychological issues. Empirical evidence is often cited to support concepts as being a viable basis for primary school science. Empirical evidence is also quoted to support a sequential development founded on processes. The debate goes on. The basis for curriculum structure depends on the selection of objectives. Since the evidence to date suggests that content objectives, process objectives and attitude objectives are all psychologically viable, the final selection must be based on other than psychological grounds. As Bruner (1968, p.31) noted "no theory of instruction exists". He qualified this statement by emphasising that "no theory is neutral to ends but exhaustive to means". Earlier (p.22) he argued that psychologists should be concerned with how we learn, not what we learn: "it is not a psychologist's function to decide upon education goals anymore than the ablest general decides whether a nation should wage war."

The psychologist may only tell (if he has a research evidence) Science Educators which of education's goals are beyond a student's ability - but no such research basis exists. Science Educators must get on with the job. The Learning Theorists cannot agree to the best methods for
learning. Bruner (1966) holds for discovery and (somehow) a generation of a "zest" for learning. Ausubel and Robinson (1971) developed a comprehensive case against "discovery" and "problem solving" as the basis for learning. These writers reviewed the research to that time and counter such statements as "All Real Knowledge is Self Discovered" (p. 485) by pointing out that this denies the concept of our culture and the very nature of education itself. (Although they were mainly concerned with older children their comments are relevant to discovery learning in general.) Later Le françois (1972) in reviewing learning theories takes these writers to task by noting that the arguments are highly prejudiced and that the assumptions attributed to the advocates of discovery learning are "seldom made by them" (p.143). Gagne (1970) developed a theory of learning based on a hierarchy of prior knowledges and skills. Interestingly he places the need for concepts as a prior requirement to problem solving. Often Piaget's developmental theories are cited as precluding concept development as unsuitable for primary level Science Education. This ignores the fact that his "stages" of development are not tied to the age of the child. Much contemporary research conflicts on this point. Sayre and Ball (1975, p.172) quote research involving Piaget himself where sophisticated thinking (formal stage) "emerges at about age eleven" and may vary "from one culture to another". Gage and Berliner (1975, p.457) sum up: "practice usually outruns theory, or does not wait for it to be firmly established, because activities like teaching cannot wait". The curriculum planner in Science Education must not wait. As there is no body of research to direct him he must decide his curriculum on other grounds.

The development of a logically structured program for Science Education in the primary school is a matter of urgency. Science is not held in high regard. Alford and Kerrison (1974) noted (in Hobart primary schools) that of the 200 teachers involved only 60 per cent taught science consistently once each week. They commented that of these "in most cases this involved viewing a science telecast". (A rather passive approach to an important subject!) Thirty percent taught science occasionally and ten per cent did not include science at all in the weekly programme. It is not unreasonable to expect similar figures throughout the nation. We have all sorts of people teaching all sorts of students in our schools. Not every teacher is an enthusiastic science teacher, innovative and capable of extensive energy and imagination. Most teachers however, are conscientious. To ensure an effective science program these teachers need to know what to teach, how best to teach it - and most important - why it should be taught. A meaningful structure is essential. A conceptual frame is ideally suited to meet these needs.

A conceptual scheme gives guidance to the teacher, it lets him know where he is going, what is next -- where it fits. According to Jurd (1973, p.4) a concept is learnt when it can be named and the "subsuming attributes" (properties of the concept) distinguished from non-attributes. Once a concept is understood it has the advantage of forming the basis for the clustering of meaningful associations. If some children have difficulty in understanding a concept the number of operational definitions (examples of the concept) can be extended until the general notion - the concept, is known. These examples can be presented in a variety of ways to cater for individual differences. Experiential learning is enhanced by an informed teacher well oriented to later objectives. Structure allows endpoint expectations to be developed, equipment needs to be pre-planned and important diagnostic programmes (the feed-back strategy of good teaching) generated. Without these aspects science education in the primary school will continue to flounder.
Some critics of a conceptual based curriculum in science argue that it pre-supposes every student will become a scientist. Obviously very few students will become scientists in the future, but they will all have to live in a technological society. They will need to be scientifically literate, not only for everyday living but also to be intelligent voters and involved citizens. They may not have to be electricians, but they must know of the possible dangers of electricity (well before adolescence). They may not have to be atomic scientists but they must daily sift through increasingly technical reports on environmental aspects of technology and develop opinions about these questions (based on objective knowledge). Their kitchen most probably contains advanced radiation equipment, their lounge room already contains a sophisticated cathode ray oscilloscope. They do not have to fix it, but if education is oriented toward understanding their environment, they must be literate in terms of their own everyday equipment. In general the gaining of knowledge is important and pleasurable. They like to see where it "fits". They like to know where they are going. Students are inclined to need encouragement to make an effort to learn something worthwhile. Astronomy dominates the news, they will enjoy learning about it. Children cannot learn this by discovery nor have they the time or the inclination to repeat centuries of history.

The education administration plays its part. A superintendent automatically asks for reading, writing and arithmetic records - not necessarily science! This has an immediate effect on what the schools consider important. But -- what can they ask for in science: do they enjoy it? What innovation have you got? Increasingly he is subject to pressures of cost/benefit. Where is the money going? What does the increasing proportion of the tax dollar earn in educational returns? How do we account for "good attitudes to science"? In the present situation, science is not taught nor liable to be taught in the future with an approach reliant on random selection of topics and the creative abilities of the average teacher.

Conceptual schemes satisfy all the needs for successfully introducing Science Education at the primary level. Indeed, in one sense, Science Education cannot be taught without concepts. Discovery techniques must be oriented to concepts, processes pre-suppose concepts upon which to base the problem to be solved. Attitudinal schemes need a concept about which to have an attitude!

Writers such as Symington (1974, p.62) in discussing the problems of why primary science has difficulties suggest we wait until research is available before developing curricula. As stated earlier -- teaching can't wait. If science is important enough to be taught in the primary school, it must be taught now and it must be taught well. A conceptual scheme is the most suitable model, ready for immediate use. A conceptual scheme allows structure and guidance for busy and possibly under educated teachers; this type of scheme subsumes discovery methods and experiential learning; it provides strategies for enrichment and a more pedestrian pace. A conceptually based curriculum in science education creates a basis for the evaluation of educational gains and above all prepares children to be informed adults in a modern world.


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WHY PROCESS

Mr. L. McKenna
Vice Principal, Mt. Lawley College

In surveying the possibilities of a curriculum subject in the classroom there are three important considerations. The nature of: (i) the subject and what it might contribute to general objectives of education; (ii) the educator—the classroom teacher; (iii) the educated—the child. Science, we are told by those authors deigning to define it, has a threefold meaning—knowledge of the physical and biological environment, an attitude and, finally, a method of problem solving. In the English language, the word Science conjures immediate connotations of chemistry, physics, biology or other knowledge areas. Seldom is it associated with the other meaning: method in logic—a way of solving problems. In other languages, German and French for example, science is associated with all three meanings.

Among science educators there is a general consensus that the objectives of Elementary Science lie in the areas of concept development, interest, attitude, appreciation and problem solving. I believe that under the guise of concept development, our primary school teachers have concentrated on content to the detriment of problem solving. This over emphasis on acquisition of science knowledge has often led to the divorce of method, so much so that teachers often yield to the temptation of teaching science rather than leading children to acquire information through activity. Other teachers, overwhelmed by the enormity of the task of teaching scientific knowledge, have virtually opted out of the programme. Numerous researches have shown that primary school teachers generally come from arts orientated matriculants, and have themselves received scanty formal science instruction.

The Process Approach puts the emphasis squarely on problem solving, where I believe it belongs. Acquiring knowledge of the processes and the methodology involved in presenting them lies far more in the capabilities of teachers and student teachers to acquire than the massive verbal programmes of other approaches. Other important objectives need not be ignored. Appropriate concepts and children's interest are brought about by careful topic selection and teacher enthusiasm. Attitudes and appreciations are a natural outcome of planned classroom science activity.
WHY PROCESSES?
(A BASIS FOR PRIMARY SCHOOL SCIENCE)
L.N. McKenna

It is my considered opinion that the quality of instruction in primary science has made little if any progress in the last thirty years. This is surprising, to say the least, when one considers the post-sputnik emphasis on science and the enormous injection of talent and money that culminated in the sixties with the United States nationally funded projects like the Elementary Science Study, the Science Curriculum Improvement Study and Science -- A Process Approach.

There are undoubtedly many reasons for failure but it seems obvious that program designers have failed to allow for a major limiting factor -- the classroom teacher. To this I would add an appalling lack of direction for primary science instruction apparent even in curriculum design.

In surveying the possibility of a curriculum subject in the classroom it would seem of prime importance to consider the nature of the subject and then to ascertain what it might specifically contribute to the general objectives of education. There would appear to be common agreement that "science" has a three fold meaning,

(1) knowledge of the physical and biological environment,
(2) an attitude and
(3) a method of problem solving.

Where should the major stress be placed, acquisition of knowledge or process and attitude? There seems little doubt where the teacher places...
it. Smith and Cooper, reported by Knight (1970), found that teacher reading and discussion of the text book was the most frequent method of primary science method. Knight (1970) conducted a survey in Western Australia and found that a lecture type presentation followed by children writing notes was the most frequent method. Knight adds that "individual child participation was not a noticeable feature". The Queensland Department of Education Research Branch (1975) reports a similar situation in Queensland schools -- teacher dominated lessons had a high frequency, child activity and experimentation was low.

This emphasis on a "knowledge" approach is the more unsatisfactory when one considers the background of primary teachers, Kuhru (1973) believes that, "The preparation of elementary teachers in the sciences is usually minimal." The Queensland Research (1975) reports that tertiary science units have been taken by less than three percent of teachers. Knight (1970) reports that a lack of formal science qualification and experience in Western Australian teachers is clearly shown by the few science passes at Leaving Certificate Standard.

There can be no doubt that poor science background affects the teaching of Science. Kuhn (1983) reports that the studies of Berryess (1959) and Liner (1957) show a positive relationship between science background and science teaching competency. Knight (1970) notes a similar finding in Western Australia.

I believe that a primary science program that emphasises "knowledges" no matter how carefully constructed, is doomed to failure at the level of a great number of classrooms. It is of little use stressing concept development. This translated by many teachers means a series of facts, and facts are more conveniently "taught" than acquired by children's activity. Other teachers are reluctant to teach science at all due to a feeling of inadequacy. If on the other hand science processes are stressed, a number of
positive outcomes result. Instruction of necessity becomes child-centred and the science background of teachers becomes a minor factor.

The latter is born out by the A.A.A.S. studies (1970) reported by Kuhn (1973),

"It was found that there was little relationship between the amount of science background of a teacher and her ability to teach the Science -- A Process Program."

Further, it is an easier task for teachers to learn skills of process development than it is to acquire the large amount of science detail required in a knowledge centred approach.

As an example of the effect of this change in emphasis by the process approach, consider a simple classroom science lesson -- the domestic cat. If the stress in such a lesson is on knowledge, the teacher must prepare by "boning up" facts about cats. Because a cat is a well known creature, she may have to "expand" the topic by procuring pictures of varieties of cats. She may attempt to show how a domestic cat is related to other animals in the genus. Its doubtful if she would bring a cat into the classroom for observation. After all, hasn't everyone seen a cat? Now apply the process approach.

"Today boys and girls you are going to make a number of observations of the pet that each group has. When you have done this, you will make inferences concerning how the cat performs its life activities; how it moves; how and what it eats, how it protects itself, etc."

Such a lesson still achieves the General objectives in the "knowledge" area. Indeed knowledge acquisition is enhanced by the child-centred
activity. The specific objectives are process objectives (i.e. making observations using different senses, distinguishing an observation from an inference, etc. Look at the obvious advantage to the teacher. She is no longer placed in the position of being an authority on the subject of "cats". Instead she is the arbitrator of procedures.

"Are your sure your observation was correct?"
"Did you use senses other than that of sight to make your observations?" "Are you sure that observation is not an inference?"
And so on --

Any questions of "fact" that arise are referred to another authority -- text, encyclopedea, letter to the museum, etc..

Unfortunately in the English language the word "science" has connotations that favour solely the aspect of knowledge acquisition and this is one further reason why process and attitude are neglected. I submit to you that in the primary school, where the "intangible objectives" should outweigh the "vocational" the exercise of the logic offered by a science program may be of prime importance. A.A.A.S. Miscellaneous Publications (1965) has this to say

"It is no mean pedagogical feat to teach a child the facts of science and technology; it is a pedagogical triumph to teach him these facts in their relation to the procedures of scientific enquiry. And the intellectual gain is far greater than the child's ability to conduct a chemical experiment or to discover some of the characteristics of static electricity. The procedures of scientific enquiry, learned not as a canon of rules but as ways of finding answers, can be applied without limit. The well-taught child will approach human behaviour and social structure and the claims of authority with the same spirit of alert scepticism that he adopts toward scientific theories. It is here that the future citizen who will not become a scientist will learn that science is not memory or magic but rather a disciplined form of human curiosity."
Not only are the processes and procedures of science a means by which the child finds "new" science knowledges for himself but as Freedman et al (1958) points out the Science Method is applicable in all avenues of learning, all study and all experiences and activities.

So called scientific attitude develops from the practice of scientific method and this too has important effects beyond the "science" area. Huber (1957) claims that there are many desirable human qualities which can be derived. Children can learn to be cooperative. They can learn to be open minded, willing to alter an opinion in the light of new evidence. They can learn to be constructive in point of view, look for logical explanations and solutions to problems.

The contention is that the practice of primary science extends beyond the knowledge area of the discipline. The logical procedures and attitudes are best developed in science because as Freeman et al (1958) again points out,

"Data can be more easily and extensively gathered, more readily manipulated and controlled, and more completed checked than in other areas of the school curriculum. The natural environment is, in general, more provocative of questions and more stimulating to the child's curiosity than any other area."

The practice of science in the primary school then has very far reaching effects. Taking into account the background of the typical classroom teacher I am convinced that the emphasis must be on procedure and this by a "process" approach. Nothing else need be sacrificed, indeed concept development and appreciations of the natural environment will be enhanced and children's interests heightened.
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The science taught in local primary schools is deficient in both quantity and quality. Perhaps this neglect is due to teachers lacking confidence in the area and to the difficulties of obtaining and organizing sufficient suitable materials. It is suggested that much of the antipathy teachers have towards teaching science comes from the inappropriate expectations they have for the subject. If science is taught with the more traditional objectives of most other subjects it suffers in comparison when the effort involved is considered.

These comparisons do not apply if the objectives chosen show concern for the special attributes of science and the needs of children. In this way the effort involved in teaching science becomes much more worthwhile. Before such objectives will be selected and given serious attention it is necessary to change the attitudes that teachers have towards the place of science in the primary school. It is necessary for the colleges to give students a philosophical base which will support more appropriate objectives.
There is not a lot of science taught in local primary schools, and very little of this is taught in a manner and with results that teachers and other observers are enthusiastic about.

One of the major reasons for this is the difficulties teachers experience in obtaining an adequate supply of suitable materials. There are ways of reducing the difficulties but the basic problem is still there. This is not the only difficulty to overcome. For some years past I have actively sought to lend equipment and to give consumable materials to particular primary school teachers. Very rarely have I succeeded in doing so. There are other factors which cause teachers to lack confidence in their ability to teach science, or to be dissatisfied with the end result of the science that they do teach.

I have observed science lessons given by student teachers which I note as highly successful in that the children are very active and involved in the lesson and clearly indicate a wish to pursue the work further. Usually such lessons introduce the children to new materials and a new topic. Rarely do they result in much clear evidence of "learning" on the part of the children. Typically teachers when discussing these afterwards admire the student for a skilful creative effort, but also indicate that they do not regard this sort of thing as much more than an occasional educational novelty. In some cases it is said that the children are merely playing around, and that this has little to do with learning. I have received similar reactions to demonstration lessons given by myself.

Students themselves sometimes express similar views, but more often have other complaints. A common one is the lack of time. Class timetables do not allow sufficient time for many of the lessons planned, and this often is the cause of much stress. Students feel obliged to stop children's work and to fulfil the performing role that they feel is expected. They have a need to produce verbal evidence, regardless of whether sufficient time is available or not. I do not know how commonly these needs affect practising teachers with their own classes, but it is a common complaint of students after long term practices.

Much dissatisfaction with science occurs when it is compared with other subjects where the more traditional objectives concerning knowledge and understanding or skills and habits are emphasized, and the evaluation used is mainly of a formal type. On this basis when the effort involved is considered, science does not compare favourably with other subjects. Children do not know as many important facts, understand as many significant concepts, or demonstrate as much development of skills. Teachers require better reasons for making the effort needed to teach science.
There is a great deal of time available in all the years that a child spends in primary school; far more than is required for those things which a child must learn. It is suggested that much of this time should be used for activities that children enjoy. More science should be taught in primary schools because it offers an opportunity for teachers to give children more enjoyment.

Children's enjoyment of science should be seen as a worthwhile aim in itself. Where we are concerned with using this enjoyment as motivation for other educational achievement we are less likely to structure really enjoyable work. If this emphasis is given to enjoyment in children's science several other aims and directions become apparent and many of the more common problems become less important.

If science is to be enjoyed it must be material or activity centred. An enquiring approach is required. Only in this way can children's psychological and developmental needs be filled in a manner which is both enjoyable and educationally viable. Such an approach inevitably leads to the use of large amounts of time, and to the attitudes described earlier, since much of this use is without apparent progress. Children require much more time to become familiar with and confident in this type of work. If this use of time is accepted then teachers get much more mileage from the effort involved in supplying materials. On an average in the introductory stages of a topic perhaps three times as much work is done with materials. At the same time the teacher is relieved of the need to accelerate or push the work more rapidly towards formal evidence of learning.

Much of what children learn from materials is of a non-verbal nature. That is it cannot be displayed by any formal mechanism. However, such learning is valuable and important, and can probably only be accepted on faith, or by observing the sorts of things that children do when free to pursue their own interests. Activities based on materials and leading to relatively informal learning, require repetition. This leads to even more extensive use of materials.

Teachers have also to accept that even with much time used children will rarely produce or learn major scientific facts or generalizations. To do this requires very considerable direction and use of exposition by the teacher. Neither of these adds much to children's enjoyment. Most of the inappropriate directions that teachers take in their discussions with children or in presenting children with a choice of activities, occur because they forget that children are primarily interested in the objects studied. Their interest in answering specific questions about these things is only secondary, and often focuses on details and properties with which the teacher is not concerned. Rarely are they concerned with the major principles, laws, or facts that match adult conceptions of science. Many of us inadvertently use science that is meaningful to children as motivation for achieving ends which have meaning only to adults. If we accept this and act accordingly we are less likely to be disappointed in the learning which is achieved. It is
suggested that teachers should, within the limitations set by material and safety limitations, let children structure their own directions for learning or select them from as wide a variety as can be provided. Decisions taken on whether to curtail or extend an activity or tapes should be based on the extent to which children enjoy it, rather than for its potential to produce formal evidence of learning.

It is not suggested that children should work without structure, but that structure should be minimal and used only as necessary. Children must also be slowly educated to provide an increasing part of the structure needed.

Enjoyment is not seen as the only worthwhile aim for attitudes. There are many others listed in most curriculum material.

I am not making a plea for a radical change in teacher objectives so much as for a change in emphasis. I believe that even slight changes in this direction will produce worthwhile results. For most teachers there is a comfortable point somewhere between a traditional content or process orientation and an approach directed mostly at children's enjoyment. However regardless of the objectives chosen teachers will achieve these better if they adopt a more relaxed attitude towards achievement, and a less dominant position for themselves in science classes. I suggest that a marked reduction in the performing role of the teacher is required for successful science teaching with children.

The implications of the above for student teachers and those who train them are both simple and few. Students need a philosophical base which enables them to see and justify enjoyment as a worthwhile aim. They need to be given realistic ideas about what children can achieve with materials and encouraged to evaluate the success of their science teaching on children's reactions to it, rather than on the more readily observable and measurable evidences of learning in a verbal or formal sense. Students also require criteria by which to decide when and how much structure should be used, and some training in the means by which children can be involved in the decision making processes that develop their programmes in science.
HAVE YOU GOT A MATCH?

Dr. M. Nelson
Senior Lecturer, Churchlands College

Science can always be taught to primary school children, but will they always learn?

An analysis of the structure of science reveals content, processes and attitudes as knowledge forms to be taught. Examining the nature of children from a Piagetian framework reveals their view of the world is quite different from an adult’s. Interacting these two elements in the crucible of curriculum results in a semi-miscible solution. To effect a better interaction, a more perfect match is needed.
HAVE YOU GOT A MATCH?
Dr. Miles A. Nelson, Senior Lecturer
Churchlands Teachers College

Have you tried teaching science to people who believe in natural laws but find for every example of the law just as many exceptions? Or perhaps you have tried teaching science to people who believe seagulls are birds, and birds are animals; but seagulls are not animals because seagulls cannot be animals and birds at the same time. Maybe you have tried teaching science to those who perceive events only from their viewpoint and refuse to admit another point of view. You say no? If you have taught science in primary school, then you have taught people who see things as I've just described. This is perhaps the greatest challenge a primary teacher has when teaching science: children view the world differently from adults.

With this perspective is it possible to match what we want children to learn with what they can learn? This question will be examined in the light of current research on learning and by making two assumptions. The first assumption is the children have repeated contacts with the content to be learned. This is in contrast to the current practice of one shot lessons. Research evidence indicates varied and repeated contacts with an idea reinforces it and makes possible generalizations (Nosenshine, 1976). Second, in accord with Piagetian theory it is assumed the best way to communicate the content to be learned is through direct experiences and social collaboration (Duckworth, 1964). Piaget argues these two ingredients are essential to helping learners find the structure of their own actions on the direct experiences. Most of the newer primary science curricula stress a hands on approach in accord with this theory.

If direct experiences are needed and provided, can all science content be effectively communicated to children enabling learning to take place? This complex question has two parts. First, what science might be taught? Science educators generally agree content, processes, and attitudes should be taught. Within these domains specific knowledge forms are to be found. I shall examine in depth what these knowledge forms might be. The second part of this complex question hinges on the meaning of the term 'learn'. Educators do not want children to just remember ideas but to 'understand' them. The meaning of these terms 'learn' and 'understand' are ambiguous but a workable and researchable definition will be given.

Science Content

The first domain to examine is content. What science knowledge forms may be taught in primary school? Five possibilities exist. First are observations or facts. Direct observations are made by the unaided senses. 'This apple is red' or 'This animal has six legs' are assertions which may be verified by calling in another observer and asking him to confirm the statements. Another type of observation requires the use of an instrument designed to extend the senses. Telescopes, microscopes, thermometers etc. change previously undetectable phenomena into observables (Gardner, 1975).

A second knowledge form which might be taught is concepts. A little thought reveals two types of concepts; those having perceptible instances and those which do not. The first are called 'empirical concepts'. Some examples are insect, mammal, rock, soil, mixture, pendulum. The second type are called 'constructs'. Examples are atom, density, molecule, momentum, energy, heat. All concepts are really definitions. The defining attributes of an
2.

An empirical concept may be induced by examining many examples. The defining attributes of a construct, however, cannot be induced from examples because no perceptible instances are available.

A fourth knowledge form which could be taught in primary schools are laws or generalizations which are expressions of relationships occurring under certain circumstances between empirical concepts (Presley, 1960). "Green plants grow towards the light", or $PV = NRT$ are examples. Theories are a fifth knowledge form which might be taught. Theories are needed to explain natural phenomena and offer explanations to answer the question "Why?" Quite often, scientific explanations of natural phenomena use constructs to answer "Why". In other words, observations are explained in terms of unobservables (Nagel, 1961 pg 81-85). The kinetic theory, the atomic theory, the theory of evolution are examples.

Can all of these knowledge forms be communicated to children with direct hands-on experiences? Obviously not, the outstanding examples being theories and constructs. Even if these two forms could be represented with direct experiences there is some doubt whether children would be able to learn them. Piaget's criteria for determining learning is if mental structures are developed which are permanent and which make generalizations possible (Piaget, 1961). The key to inferring these mental structures is whether or not generalizations can be made long after learning.

An important characteristic of children in the first five or six years of primary school, is their dependence on empirical reality (Flavell, 1963). These children, called "concrete thinkers", are dependent on concrete learning aids which subsequently limit their ability to grasp and manipulate relationships between abstractions (Ausubel, 1964). If generalizations are required of concrete thinkers, these are made only as simple extensions of reality. Just these two characteristics - 1) theories and constructs cannot be directly represented with concrete aids, and 2) concrete thinkers cannot generalize very well - should eliminate theories and constructs from inclusion in a primary school science syllabus.

Observations, empirical concepts and laws can be represented to children by direct experiences; however can children learn them? To rephrase the question what can children do with these knowledge forms to show learning? Laws are careful descriptions of nature which may be used to predict future events (Presley, 1960). Learning a law may be demonstrated by describing new phenomena using the law, or by making predictions. Both of these actions involve generalizing the law to new situations.

Piaget (1965) has noted three stages in children's conception of law. To six or seven year old children generality is non-existent. If laws exist in children's thought, there are numerous exceptions which occur as 'miracles' or which are explained as mysterious forces such as monsters or gods. Between the ages of seven and eleven, children begin to admit events may happen by chance. However, the idea of generality, otherwise called natural law, does not exist. Finally, after the ages of eleven or twelve, children may discover the regularity of a physical law. These findings indicate the learning of laws - using them to make predictions or to describe new phenomena - to be limited to years six and seven in the primary school.
Empirical concepts are used to describe and identify phenomena. Knowing the defining attributes of an empirical concept, new and old observations may be classified. For example, the defining attributes of 'insect' (an empirical concept) are animals with no backbone, having three body parts, three pairs of legs and zero to two pairs of wings. Once knowing these rules a large number of animals can be identified as insects or noninsects. Children may show learning of an empirical concept by (i) stating the defining attributes and (ii) identifying known and unknown phenomena as examples or non-examples.

From a learning perspective researchers have identified four sequential levels of concept attainment (Klausmeier & Hooper, 1974). An individual recognizing an object presented in the same orientation as previously encountered, is said to have attained to the concrete level. This, by the way, is a significant learning task for most children and many adults. Concept attainment at the identity level is inferred when an individual recognizes an object when observed from a different perspective or sensed in a modality different from the one encountered during instruction. A lower limit to the classificatory level is inferred when the individual responds to at least two different instances of the same class and identifies them as equivalent, even though he may not be able to describe the basis for his response. A formal level of concept attainment is inferred when the individual can name the concept, state its societally accepted defining attributes, accurately designate instances and non instances and state the basis for the inclusion or exclusion in terms of the defining attributes. These levels are sequential and children attain lower levels before mastering the higher ones. It is only through repeated contacts with a concept that children who are concrete thinkers attain mastery levels higher than the concrete level.

To attain the classificatory or formal levels children must be able to generalize. Concrete thinkers cannot generalize to the extent formal thinkers can. Thus concrete thinkers may be limited to the attainment of a concept at the classificatory level, i.e. identifying unknowns but not able to give reasons for the identification. Only through much experience with an empirical concept would children be able to identify unknowns, state the reasons for an unknown being an example or non-example of a concept, and make a statement regarding the defining attributes of a concept. Thus with empirical concepts, we find limits to children's learning. This limit is a direct result of their level of intellectual development and experience.

Observations or facts cannot be generalized because they refer to singular events. Thus children can demonstrate learning only by remembering and stating facts. In the Piagetian sense, true learning cannot take place because no generalizations are possible. In summary empirical concepts and laws are two knowledge forms which children may master to some extent. These knowledge forms can be completely mastered by learners who are approaching the formal level of thought and only when varied and repeated encounters are provided. Most primary texts, syllabi and methods book make no distinction between these knowledge forms and children's ability to learn them. From this analysis I conclude, a better match is needed between the science content taught and the learners level of intellectual development before learning takes place.
Science Processes

Up to this point only one aspect of science has been examined, namely science content. Would a similar analysis hold for other science domains such as process and attitudes? Let me now turn to the science processes. There are many science processes. Some of the more commonly known are: observing, classifying, interpreting, modelling, experimenting. The reader, it is assumed, is well acquainted with these processes. How can children demonstrate learning of these science processes? Quite simply, through performance. Asking children to observe, classify, or experiment is a valid method for determining learning of these processes.

Most children in the primary school are using or developing concrete operations. These are actions which must be performed on actual objects. For young children, logic of action is more important than logic of words. This suggests observing is an important process which children can effectively demonstrate. It is by feeling, tasting, touching, smelling and looking at objects that children gather information about them. This is exactly what observing is, therefore young children can learn to observe effectively.

During the first year of school certain mental abilities are developing in children concerning classification of objects (Beard, 1972). These abilities include adding and multiplying together groups of things. For example adding the group of all boys to the group of all girls results in the group of all children. In mathematical terms this is the union of two sets. The group of blonde boys is the intersection (multiplication) of the group of blonde people and group of boys. From Piaget's research adding classes can be done by any school age child. On the other hand, multiplication of classes is just developing during the second or third year of school (Beard, 1972). In other words not until this time can children develop classification schemes based on two or more variables. For example, given a set of colored geometric objects, it is not until the ages of seven or eight that children can classify using the characteristics of shape and colour. Thus as with concept learning there are different mastery levels for the process of classifying. Classifying by one property is something most children can do. However, classifying by two or more properties is mastered only by older children.

Another important class operation being developed in junior primary children is the logic of relationships. From Piaget's work most children up to nine years of age have difficulty in understanding the relationships between classes. For example after nine years of age children can line themselves up in order of height, or by alphabetical order. However, some children, even after primary school find difficulty with these tasks (Beard, 1972). As another example: if a boy has a brother he readily admits it; however, asking if his brother has a brother, results in a 'No' answer. It is only after the age of eight that children can correctly answer this question. These observations suggest the ability to interpret data (to see relationships between variables) is a process which gradually develops beginning about the third or fourth year in primary school.

Concrete operations, based on a manipulation of objects, are childrens means for structuring immediately present reality. As they grow intellectually, they are increasingly able to deal with probable relationships which can later be verified. Only in the late concrete
stages of development do we find children able to isolate variables, and to see possible relationships between variables. The formal thinker, on the other hand has a generalized orientation to problem-solving involving organizing, data, isolating and controlling variables, looking at the hypothetical, and considering logical justifications and proofs for their hypotheses (Inhelder & Piaget, 1958). Modelling and experimenting, are science processes which require children to manipulate abstractions, suggesting these processes can be learned only in the upper primary school or for children making the transition between concrete and formal thought.

As we have seen, the child's level of intellectual development limits the extent to which he may learn science processes. As with concept learning so there are various levels in mastering science processes. It has been illustrated earlier how children are able to first classify objects only on one property. Later they are able to build classification schemes utilizing two or more variables. As a further example of mastery levels consider the science process of experimenting illustrated by a Piagetian task. Children are given five bottles of a colourless, odourless, liquid (Inhelder & Piaget, 1958). Each bottle is labelled 1, 2, 3, 4, and G. The children are shown a test tube full of some combination of the liquids 1, 2, 3 or 4 to which a small amount of "G" is added. The solution turns yellow, and the children are asked to reproduce the colour. Pre-schoolers or early junior primary children will have no plan in solving this problem. Liquids are randomly put into one test tube and in any order. When the colour is not reproduced the children give up. About age 8 children have plans but they are not comprehensive. They consist in adding liquids together in various combinations of two. For example, 1 and 2, 1 and 3, 1 and 4, 1 and G. After exhausting all the "two" combinations and no yellow colour has appeared the child will give up having no other ideas on how to proceed further. Formal thinkers plan in advance and include all possible combinations of 2, 3, 4 and 5. The process of experimenting then has various mastery levels. The lowest level involves very simple experimenting, namely play. The second level is demonstrated by an incomplete plan. While the highest level illustrates a plan which includes all of the possibilities, all variables identified and manipulated one at a time in order to find an answer. This level by the way occurs only after the learner is well into high school.

Again examining primary science texts, syllabi & methods books we find little distinction between the various processes and children's ability to acquire them. We conclude after this examination that our ambitious objectives for teaching science processes do not match what primary school children can learn.

Attitudes

Does the affective domain suffer from a mismatch too? Victor (1970) has identified many different attitudes which should accrue as the result of a primary school science programme. Some of these are curiosity, using reliable sources, being open-minded, persistent, reluctance to generalize from just one example, respect and/or tolerance for another's ideas, not superstitious, willingness to co-operate. Blough and Schwartz (1951) list these same attitudes, but include one more - willing to look at a matter from many sides before drawing a conclusion. We again ask the question "Can children acquire these attitudes?"
Returning again to Piaget's research, children in the concrete stage of development and younger are egocentric (Ginsberg & Opper, 1969). How then can children be open minded or examine matters from many sides before drawing conclusions? Learning to be rational is a noble aim; can children who cannot solve this puzzle until after 12 years of age be rational? Edith is fairer than Susan. Edith is darker than Lily. Who is darkest? (Beard, 1972). Of course children daily demonstrate their curiosity by asking questions and by touching, tasting, smelling and feeling things. This objective is perhaps the most realistic of those in the affective domain. Again we must conclude a better match between what we teach and what children can learn must be affected or our efforts at teaching science will be wasted.

Evaluation

The ideas which have been presented should be familiar to any student of Piaget. Let me now examine an area little discussed from a Piagetian framework - assessment or evaluation. Piaget has long distinguished between logic-in-action and logic of words (Flavell, 1963). This distinction resulted in his changing assessments of intellectual development from paper and pencil forms to performance tasks. Science Educators should make a similar change.

Burner (1964) has noted children represent content to themselves in three ways - enactive, iconic, and symbolic. An enactive representation occurs through motor actions; iconic representation through pictures or other images of the actual objects; symbolic representations occurs through symbols such as words, numbers, etc. Extrapolating this terminology to instruction we find content can be represented to children in three modes paralleling the above.

Imagine now the situation in which we matched the science content to be taught with the children's level of intellectual development. Suppose further we presented the content enactively, the children had repeated contacts with the content (in accord with sound pedagogy), and there was much social collaboration. All these elements are important if children are to learn. Suppose after instruction the teacher wanted to assess learning using an evaluation task which represented content symbolically. Would the evaluation task measure what was learned? My answer is no for this reason. Children in the concrete stage of development or who have had little experience with the content cannot generalize except as simple extensions of reality. Representing content first enactively during instruction and then symbolically during assessment requires a considerable amount of generalization. Consequently concrete thinkers will not perform as well. On the other hand representing content in an enactive mode both during instruction and assessment will ensure a more accurate assessment of children's learning. This analysis holds no matter how the content is represented to children during instruction. The mode of representing content during instruction and assessment must match.

I may have painted a rather bleak picture for primary school science. The reader has probably concluded it is not possible to have primary children learn science, therefore why have science at all. To reiterate: the aims and objectives for teaching science must better match children's level of intellectual development in order to affect learning. There is some science content, processes and attitudes which children can learn well.

Our grandiose statements of objectives should better reflect the learner's intellectual development which in turn directly affects his learning. If we are to adequately assess children's science learnings our evaluation tasks must provide a better match between how science content is represented during instruction and evaluation. All around we simply need a better match.
References


ELEMENTARY SCIENCE TEACHING AND ITS IMPLICATIONS
FOR TEACHER EDUCATION—A PERSONAL VIEW

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One way of teaching is preferred by most teachers. In its most important characteristics the preferred way varies little from teacher to teacher or from subject to subject. This assertion is generally rejected by those who are committed to upgrading the quality of science education in the primary school. Classroom teachers claim they teach differently from one subject to the next. Curriculum developers claim instructional strategies used in curriculum "X" are fundamentally different from instructional strategies used in curriculum "Y".

Research evidence on this subject is remarkably ambiguous. In a number of studies comparing one approach to another, the overwhelming portion, whether specific teaching strategies are compared or whether different approaches to curriculum design are compared, show few, if any, significant differences between approaches. The reason for this derives in part from a tendency to focus on relatively unimportant variables in teaching.

The key to change in teaching rests in identifying important instructional variables and manipulating them for desired instructional ends. Research has revealed the identity and influence of some of these variables as they relate to the teaching of science, and the training of science teachers.

My response to the question "how does science teaching and the training of science teachers change?" will be approached from the standpoint of trying to offer a few practical suggestions which may be implemented.

Let me begin by trying to answer the question "What is science teaching like?". My contention would be that it is "like all other teaching" with the exception that science is given a lower priority than almost all other subjects in the primary school curriculum.
SCIENCE TEACHING AND THE VERBAL DIMENSION

OF CLASSROOM INSTRUCTION

In looking over the paper I have prepared for today I have a suspicion that I may stand accused of the same frustrating practice as that displayed by the first year Health Education student with whom at least some of us are familiar. In response to the examination question "Diagram and label the parts of the eye" he answered "I don't know the eye but here's the ear!".

The brief which I received for this paper indicated that it should have a two-fold purpose:

Firstly that it should provide a current picture of science teaching in W. A. primary schools, and

Secondly that it should provide a personal statement of how teachers might change and how their training might be improved to bring about this change.

(It was only after I had accepted the invitation to speak that the additional requirement of making the presentation "scholarly" was added.)

The questions to be addressed then were these:

"What is science teaching like?"

"How might science teaching and the training of science teachers change?"

I must begin with the admission that, in specific terms, my answer to the question "What is science teaching like in W. A. primary schools?" has to be "I don't know". I don't have the facts and figures which might normally be expected to support a statement on "what something is like". What I do have, however, is a fairly well defined model of teaching into which "science teaching", along with all other teaching, fits. My statement on what science teaching is like therefore will be presented within the more general context of what teaching generally is like in schools.

My response to the question "How may science teaching and the training of science teachers change?" will be approached from the standpoint of trying to offer a few practical suggestions which may be implemented.

Let me begin by trying to answer the question "What is science teaching like?". My contention would be that it is "like all other teaching" with the exception that science is given a lower priority than almost all other subjects in the primary school curriculum.
I would contend that all teachers develop a preferred method of teaching. In its essential elements this method differs little from teacher to teacher and even less from subject to subject. Easily the most dominant method, in my observation, is one which is called the "expository method" (a seductive title used to describe the teacher telling children things). This method places the teacher at the centre of the learning process and with only minor and, I would claim, insignificant alterations is applied to the entire range of curriculum subjects.

How is this method revealed in elementary science teaching? If you step inside a classroom where elementary science is being taught in this state, the chances are better than 60% that you will hear someone talking. If someone is talking the chances are that it will be the teacher more than 70% of the time.

Western Australian elementary science classrooms are places where the teacher talks more than all of the children combined. I make this assertion not on the basis of specific data collected for the purpose of analysing science teaching in this state, but by extrapolating from the enormous volume of data which is now available on classroom verbal interaction.

A more detailed analysis of the verbal interaction you encounter would reveal the following characteristics:

1. The pattern of verbal interaction is predominantly "inquisitorial". That is, teachers do virtually all of the question asking, structuring and reacting, while the student role is confined almost exclusively to responding.

2. Teaching is marked by the asking of a very high proportion of questions. On average, the number of questions teachers ask amounts to approximately 3 per minute.

3. Of all the question types available to teachers, the ones most often used are those which are normally associated with lower levels of cognitive demand. The type of questions asked call mainly for fact stating and the reporting of observations.

4. The rate of instruction is very fast indeed. It is controlled by the amount of time a teacher is prepared to wait after asking a question and after receiving a response. On average, teachers are prepared to wait slightly less than one second (.9 sec) for a child to begin response. If a child does not begin a response within one second the teacher usually repeats the question or calls on others to answer. After receiving a response teachers are again prepared to wait less than one second before commenting on the response, asking another question or moving to a new topic.

5. With some variation between teachers, about 15% of total
teacher talk falls into the category of sanctioning behaviour. Science classes are places where teachers spend a great deal of their time offering some sort of verbal reward. They are also places where reward schedules are ambiguous and rewards are just as likely to follow incorrect responses as correct responses. They are places where slower children are instructed to "think" when they fail to answer, but are given less time to do so than those who are rated bright and fast. They are also places where bottom ranked children receive more verbal praise than top ranked children but where the reasons for the praise are less clear.

6. Finally, analysis of the verbal interaction in primary science classrooms would reveal that a moral dimension is attached to both rightness and wrongness and quickness and slowness. Elementary science classes are places where right is good and wrong is bad and where quick is good and slow is bad.

In summary, I would contend that science teaching is like all other teaching in this state. It is marked by rapid teacher dominated discourse which has a low level of cognitive demand and is punctuated by high and ambiguous reward schedule.

To consider the question "How might science teaching and the training of science teachers change?" I would like to suggest that one place to start would be with an attack on the verbal dimension of classroom interaction and that the thrust of our efforts should be directed at reducing the conflict between a teacher's verbal behaviour and the characteristics of student inquiry which are generally sought in elementary science programmes. It would be my contention that until harmony is affected between these two elements of the interactive process there is little or no likelihood that the desired outcomes for science teaching will be achieved.

Let me look briefly at some of the desirable qualities of teachers as seen by the developers of the three major programmes S.A.P.A., E.S.S. and S.C.I.S.

In "Science - A Process Approach" the following comment is to be found under the heading "Strategy for Teaching". If the classroom teacher is to be successful, he must assume the role of "guiding children in asking good questions and discovering answers for themselves". (p. 1) To pose their own questions children must be prepared to speculate. Answers to questions which are posed may be found directly through experimentation, or, as is more often the case, such questions go through a refinement procedure which involves the consideration of many possible alternatives. To be effective, such a procedure necessarily involves the child in many arguments and much discussion.

Robert Karplus, director of the Science Curriculum Improvement Study, devotes an entire chapter of his book "A New Look at Elementary School
Science" (Karplus and Thier, 1969) to the role of the teacher in science instruction. A large proportion of this chapter focuses on the role of the teacher in manipulating the verbal interaction which takes place during an instructional sequence.

Karplus emphasizes the need for situations to be created which provide "loose ends - ambiguities, uncertainties, disagreements" (p. 82) so that children will suggest and explore alternative interpretations and explorations.

As with S.A.P.A. and S.C.I.S., the Elementary Science Study emphasizes the role of the teacher in manipulating classroom verbal interaction. Hull, writing in the E.S.S. Newsletter of October 1969, offers a series of questions which are designed to help the teacher with evaluation, while at the same time "reflecting some of the values that members of the E.S.S. project staff share". Some of the questions are as follows:

"Do students talk with each other about their work?"
"Can they deal with differences of opinion or differences in results on a reasonably objective basis?"
"Do they challenge ideas and interpretations with the purpose of reaching deeper understandings?"
"Are they willing to argue with others?"

From the questions drawn from the E.S.S. and from the statements taken from S.A.P.A. and S.C.I.S. if is evident that all three programmes seek to develop student inquiry characteristics which may be summarized as speculation, conversational sequences, alternative explanations and arguments over the interpretation of data.

One can only applaud the intention of the curriculum developers in their desire to enhance the occurrence of student inquiry through teacher intervention. I am certain, however, that as long as science teaching in this state continues to be marked by rapid teacher dominated discourse which has a low level of cognitive demand and is punctuated by high and ambiguous reward schedules, none of the aforementioned outcomes is possible.

One characteristic which must change is teacher wait-time - that is, the time a teacher is prepared to wait after asking a question and after receiving a response (or, as I prefer to define it, "the length of the silent period before a teacher's utterance").

While no one would suggest that any one variable acts in isolation in the dynamic classroom environment, the evidence is now irrefutable that wait-time is a significant factor in developing the type of student inquiry characteristics which form a part of the desired outcomes for elementary science instruction.
We know, for example, that in classrooms which are maintained on a short wait-time schedule, patterns of verbal interaction are characterized by rapid question-answer sequences with the question coming almost always from the teacher.

By contrast, in classrooms where a teacher's wait-time is increased from 3 to 5 seconds, the following outcome variables are evidenced (Rowe 1973 pp. 258-259):

1. The length of student responses increases.
2. The number of unsolicited but appropriate responses increases.
3. Failures to respond decrease.
4. Confidence, as reflected in fewer inflected responses increases.
5. The incidence of speculative thinking increases.
6. The number of evidence incidence statements increases.
7. The number of questions asked by children increase.
8. Contributions by slow children increase.
9. Disciplinary moves on the part of the teacher decrease.

We also know that over time, a classroom on a prolonged wait-time schedule takes on other proportions. Three teacher variables change:

1. Teachers' responses exhibit greater flexibility as indicated by fewer discourse errors.
2. Teacher questioning patterns become more flexible.
3. Teacher expectations for students rated as relatively slow improve.

There is no doubt in my mind that the ability to achieve a 3-5 second wait-time is an important skill which should form part of the pedagogical repertoire of all teachers. Accordingly, I believe that our training programmes should be modified to accommodate this need.

The next variable in science teaching which I would like to consider for a moment is the teacher's sanctioning behaviour. As Francis Lawlor (1971) says

"Essential to all of the new elementary science programmes is the child's encounter with problems which can be solved by the systematic observation of the properties of objects in systems. The child is led to experience the regularities of nature and to investigate the apparent anomalies. The cognitive conflict produced by the clash between the expected and the experienced, between data produced by one child and that of another, or by questions posed by the teacher is intended to produce manipulation of the world where tentative answers can be found." (p. 10)
Training of science teachers: Teacher education programs must give
attention to student ability. There is no doubt in my mind that in the
final variable which I would like to mention is the teacher's
should foster.

Another characteristic which I believe worth-while training pro-
grammes under some circumstances to low and consistent in others, becomes
Thus the ability to vary one's reward schedule from high and consistent
our own work and the work of others. To explore more alternatives, to objectively evaluate
experience, it is in presenting our results the right
experience that the best possible to explain and new
research and finally evaluated in new questions and new
make of our experiences that ideas multiply, become
new, we have done and observed and in arguing about what we
very well established. It is in learning about what
and the fear of teacher reference, free of the notion of cheat-
and a great fear of shared experience, the notion of cheat-
In a scientific thinking system takes time and a great
"Exploration and inquiry requires students to put together
she says (p. 3):

Behavior.

For the place of reward in the development of student inquiry,
Hume's very eloquent statement highlights nicely the concern we should
performance which is first carried out by another child.

between students since somehow else could negate the place for a
highly active reward schedule discourage the sharing of ideas
encourage premature termination of search and a disposition
In addition, a high reward schedule is
Evidence to suggest that high levels of reward tend to undermine creativity.
concert. In addition, many of the desired outcomes for science teaching.
There is a growing body of evidence to suggest that sanctioning behavior
Reward giver.

The system. We must therefore re-appraise the role of the teacher as
source of motivation, motivation is to flow from the manipulation of
education. Information is important in the system. How is the teacher the
Teacher in this scheme is not intended to be the source of informa-
much more attention to developing the teacher's questioning skills.

Science teaching is concerned with the exploration of relationships which exist in the real world. To be able to explore these relationships the student must develop a facility in the use of varying complexities of thought processes. On some occasions the thought processes involved may only require the simple recall of facts. On other occasions it may require more complex thought process abilities in the form of an exploration of the facts recalled. On still other occasions it may require the formulation of an opinion or justification. Whatever the thought process involved, there is continuing concern in science education with the need to develop more complex thought process abilities in students.

There is now ample evidence to support the claim that the type of thinking children do is influenced to a marked degree by the type of questions teachers ask. The old adage "If they get anything at all teachers get what they ask for" is as true today as it ever was.

Bellack and his associates (Bellack, Kliebard, Hyman and Smith, 1966) found that in 86% of all cases they studied, the type of answers a student gave was determined by the type of question a teacher asked.

Sanders (1966) also gives primacy to the importance of teacher questions in determining the type of thinking children do. Sanders maintains that "a certain type of question leads to a certain type of thinking" (p. 8).

As we have already seen, the need is not for more questions -- the "Inquisition" pattern to which I have alluded, conservatively places the number of questions a teacher asks (and conversely, the number of questions a student may be required to answer) at about 2,000 per week. I would suggest that the science teacher has to develop the ability to ask fewer questions of a much more selective nature. Questions must shift in purpose from being designed only to elicit factual information and must be used to perform the more important function of exposing children to the whole range of their thought process abilities.

In my view, training programmes must acknowledge the importance of a teacher's question asking ability and must organize experiences which will both sensitize the student teacher to the influence of his questions and to the range of question types he is able to draw on. For the student teacher, the approach which should be fostered is "How does this variable influence my teaching?".

Let me conclude by summarizing the points I have tried to make.

1. Science teaching is like all other teaching in this state. It is marked by rapid teacher dominated discourse which has a low level of cognitive demand and is punctuated by a high and ambiguous reward schedule.
2. Training programmes must direct their efforts at, reducing the conflict between a teacher's verbal behaviour and the characteristics of student inquiry which are sought in all elementary science programmes.

3. Three teacher variables deserve attention. They are:

(a) teacher wait-time,
(b) teacher sanctioning behaviour, and
(c) teacher questioning ability.

Until such time as harmony is affected between these variables and the desired student outcomes in elementary science, there is little or no likelihood that the desired outcomes will be achieved.

Finally, a point which I have not elaborated but one on which I would like to close: the training of science teachers must change so that teachers may embrace two understandings.

1. That errors are a necessary part of the learning process, and

2. That the most desirable form of intellectual activity may not be the one which results in an immediate student response.

My hope would be that primary science classrooms will develop as places where children can indeed "preserve for themselves the right to be wrong" and where rightness and wrongness, quickness and slowness in the inquiry process are separated entirely from any form of moral judgement.
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