Science and the worldview

Any attempt to provide equal educational opportunities for all must involve us in an effort to reconcile cultural differences whose existence and implications we have largely ignored.

Francis E. Dart

One evening not long ago I stood in the Nepalese town of Panga talking with a group of its citizens. For two hours or more I had been inquiring about their views of nature and of man's relation to nature, and our discussion had ranged widely over the world of familiar phenomena from rice planting to cosmology, from rainbows to moon and planets. Now as I was about to leave, we had stepped out into an enchantingly beautiful night. The houses across the square and the temple at its center were silhouetted against a brilliantly jewelled velvet black sky. Here and there a little mustard-oil lamp offered a flickering challenge to the darkness, but there was no glare of street light or neon sign. Now and then a child's voice or the murmur of a conversation somewhere accentuated the quiet of the night, but there was no sound of vehicles or sirens or other machines of civilization, and we stood silent ourselves while enjoying the night. Just as I turned to leave, a bright "Echo" satellite appeared from behind the pagoda and swept in a slow silent arc across the sky. We watched it for several moments before I took leave and departed for my lodgings in the city.

No mention was made of the satellite, but I was wondering what they were thinking while we watched it, and I supposed that they were wondering about my thoughts. I had gone to Panga seeking information only, without any intention of imposing my own ideas, and the men and women there had accepted me and responded to my questions in that spirit. Yet inevitably when very different views of reality meet, the confrontation takes on overtones of comparison and, in the mind at least, of persuasion. So I found myself wondering whether they saw in this satellite the inexorable approach of a new age even to Panga. I wondered whether they might be admitting privately to themselves this visible evidence of a new cosmology.

As I came to appreciate later, it is very unlikely indeed that their thoughts were of this sort or even that theirs and mine intersected at all. To me this satellite, this manmade moon, stands as irrefutable confirmation of our understanding of the solar system, even of the whole cosmology derived from Newtonian mechanics. It represents a powerful link between man and universe, forged by men like Galileo, Kepler and Newton and now dramatically confirmed for anyone to see. To these men and women of Panga the satellite is only a machine. Like an airplane or a jeep, it is ingenious and expensive, possibly useful to Americans, but it bears no conceivable relation to the moon, who is a deity. The satellite has nothing to do with the larger universe, and it does not concern them.

Intellectual "touring"

I recall this incident here because it has both a real and a symbolic bearing on most of what I shall present here. Geographically speaking, Panga is not very remote any more—starting from here one can easily reach Panga in two or three days of plane and foot travel. Intellectually, the voyage is considerably farther, for it involves a long journey across cultures or backward through several centuries of our own culture. Because a journey across continents or oceans is so easy, we tend to forget the real distance that separates us from the developing countries and to assume that the intellectual journey, too, will be easy. We may be dismayed to find that the airlines do not schedule this trip, which in any case is not covered by a tourist visa.

Of course many developing countries have already come part way to meet us and so already possess some of the material and intellectual gadgets familiar to us here in the West. It often enough develops, however, that here *they* are playing the part of tourists: visiting, collecting curios, learning some new words, while perhaps finding the true accent hard to master. In fact this superficial "borrowing" may make them seem nearer than they really are. Still other countries have come practically the whole way and should be considered "developing" only in a sense that applies to us all.

It is well for us to realize also that cultural distances exist within our own country. The continuing struggle to achieve equality of opportunity and equal justice for all in the US depends critically upon our ability to provide equal educational opportunities for all. We are finding that this is a tricky business not only because of the resources it

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demands, but also because it involves us in an effort to reconcile cultural differences whose existence and implications most of us have given too little attention.

Against this backdrop then let us consider a few of the problems that can arise in teaching science to children whose view of reality may differ from that of the science teacher. We like to think that science properly taught will give us understanding of the "real" world. Which real world? People everywhere believe they know what is real and what is not, and most of them fit their knowledge of reality into a coherent structure of ideas and values that serve their needs. Indeed each "reality" left to itself may serve its own inventors very well, but problems may arise when a culture changes too rapidly or when there is a transition or superposition of cultures. A number of these problems can be brought into perspective by examining the teaching of science in one or another of the nonwestern developing countries. In these countries science teaching, for the most part, has little or no connection with the intellectual life of the community outside of the school and, therefore, what is taught receives little reinforcement from that community.

Formal and informal learning

Science education in the developing countries of Asia or Africa is, of course, only a part of a more general formal educational system introduced as a foreign import by European colonists or missionaries. This system of education, which now largely replaces or supercedes earlier indigenous schools, was introduced by foreigners intending to provide training for future colonial civil servants or to replace a "heathen" culture with a more "enlightened" Christian one. In this undertaking, little need was seen to accommodate the new school systems to the traditional ways of the native people; in fact the schools were sometimes intentionally subversive of the indigenous culture, which they were expected to alter and improve. This lack of accommodation, together with the fact that many colonial schools were first established for the children of European colonial officials or missionaries who would normally complete their schooling in Europe, led to colonial school systems that were close copies of some European prototype in both organization and curriculum.

These "European" schools in Asia and Africa, which are British or French or Dutch in origin, have been modified only very slightly during the same years that have led to independent nations where once there were colonies. The changes that have been made were too often forced changes because of inadequate personnel or insufficient finances, producing as a result schools of lower quality. These schools still follow essentially their original pattern, and where they appear to be different from their European counterparts, it is likely to be because the latter have moved ahead with the times. Many a visiting lecturer who undertakes to teach for a year or two in India or Java, Nigeria or Nepal, finds himself teaching a "visiting" school that has been too long a visitor.

The earliest and most important stages of a child's education begin and continue outside the school with informal imitative play. A man in a small jungle settlement is splitting bamboo to make a mat, when his three-year-old son picks up a knife and begins hacking at a piece of bamboo. A woman weaving a basket gives her small daughter some of the basket material to "play" with. A mother working in her kitchen in the US gives her child a spoon and a saucepan. This kind of play is the world's largest and best school system. It has more students and more teachers than any other; it enjoys a more favorable student-teacher ratio and has more class hours than any other and it is by far more effective than any other school system known. Here the most basic attitudes and concepts are learned, and a world view is developed; here children learn how to ask questions or even whether to ask questions at all; here they learn how knowledge is sought and verified and how it is depicted; here they learn what place man occupies in the universe and what manner of universe it is.

When the first formal schooling is added to this informal instruction, it makes a profound difference whether or not its teaching is consistent with the informal or at variance with it. This becomes a matter of considerable importance where a foreign system of thought is to be taught by means of an imported school curriculum, as is the case with science in so much of the nonwestern world and even in some parts of the US.

Two kinds of reality

In order to assess this more exactly a colleague and I interviewed children and adults in several Nepalese towns and villages, asking questions about familiar phenomena of nature.[1] Our questions were of three types, intending to learn:

- How do the respondents account for various commonly experienced phenomena such as rain, lightning, thunder, earthquakes and so on?

  "How do you account for rain?"

  "Where does the rain water originate?"

  "What do most people in the village think about rain?"

  "What makes an earthquake?"

- What attitudes do the respondents hold concerning the control or the ma-

Learning by imitation. A man in a small Malaysian jungle settlement (upper photo) is splitting bamboo to make a mat, when his three-year-old son, playing nearby (see lower photo) begins to mimic his father's actions. (All photos on these pages are by Francis Dart.)

School in Biratnagar, southeast Nepal. It is in schools like this one, distributed throughout the rural parts of the developing countries, that the problems of creating a viewpoint with room for "scientific" western ideas arise.

nipulation of such natural phenomena?

"How can rainfall be brought about or prevented?"

"Is it appropriate for men to influence the rain?"

"Is there any protection against lightning or thunder?"

▸ What are considered to be the origins of knowledge about nature, and what are the accepted criteria of validity of such knowledge?

"How were these things (about rain, for example) learned?"

"How does one know if they are true?"

"How might new knowledge about such things be obtained?"

With very few exceptions we were given both a "folk-oriented" and a "school-oriented" explanation of a given phenomenon within a single interview, sometimes by a single individual. Thus to account for earthquakes, one of a group of four Chetri boys said:

"The earth is supported on the back of a fish. When the fish grows tired it shifts the weight, and this shakes the earth."

All agreed, but another added,

"There is fire at the center of the earth. It seeks to escape and sometimes cracks the earth, causing an earthquake."

All agreed to this as well. The pattern is repeated again and again. Thus

"The deities break vessels of water in the sky, causing rain."

and

"The sun evaporates water from the sea, producing vapor, which is cooled by the mountains to make clouds and rain."

Again

"Lightning comes from the bangles of Indra's dancers."

and

"Lightning comes from the collision of the clouds."

or

"It rains only in the summer (monsoon) season because we need the rain then. In winter we do not need rain."

and

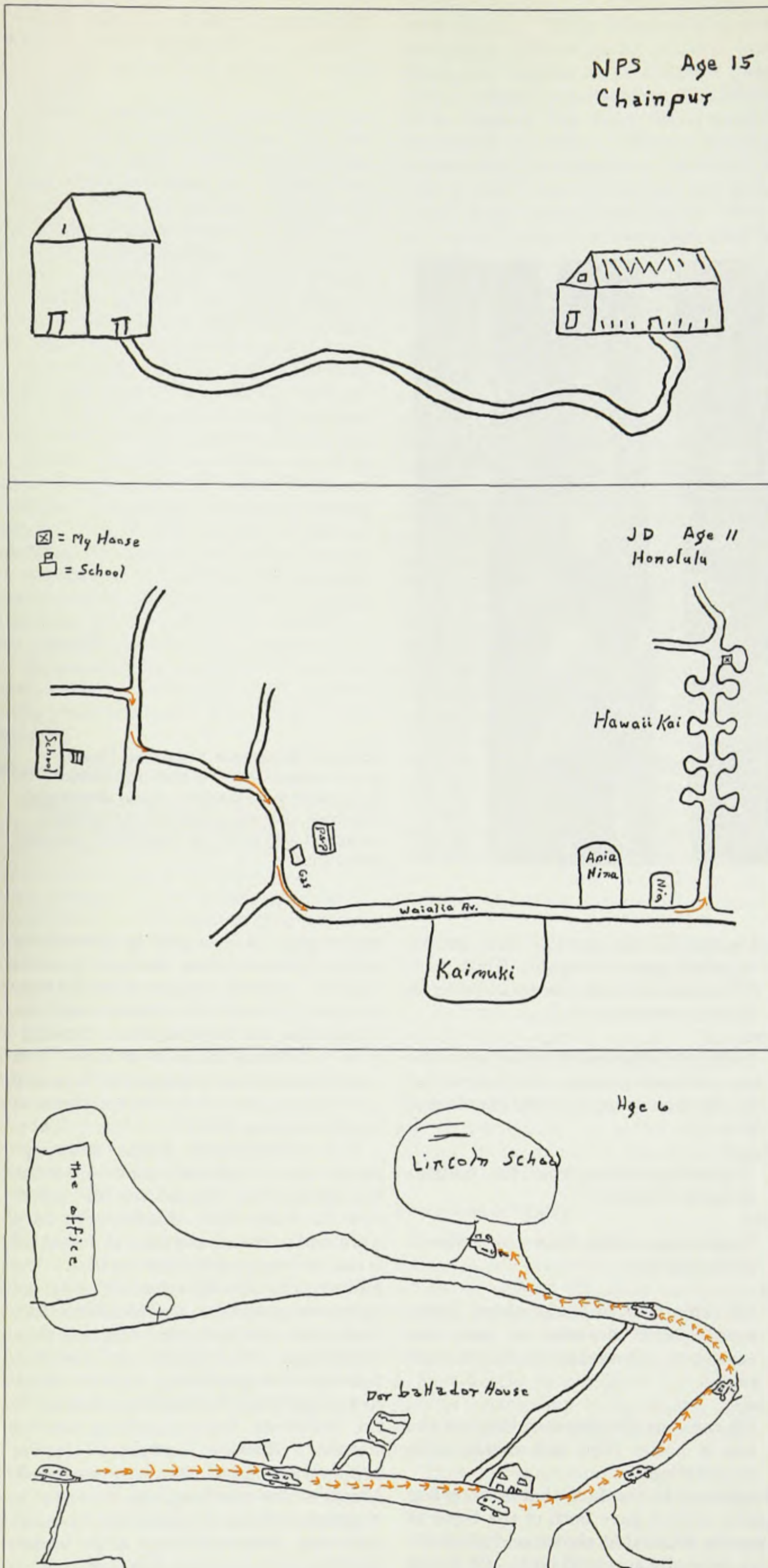
"It rains in the summer because the sun is hotter then and causes more evaporation."

Surprising is the fact that each group nearly always gave both of the types of answers illustrated above, and all members generally accepted both. Of course there is nothing unusual in the thought that a given phenomenon may result from either of two different causes and hence that in general each of these causes may be accepted as potentially valid. However, here the two types of "causes" offered appear to be qualitatively so different as to be mutually incompatible, for they suggest conceptually very different ideas of nature. It is as difficult for us to accept both as real alternatives as it is to accept them as simultaneously true.

The contradiction is far more apparent to us, however, than to our respondents, who showed no discomfort over it, a fact that should serve as a warning to the science educator that all is not as it appears on the surface. The philosophies and literature of Asia use paradox a great deal, and to Asians, contradiction may be more intriguing than disturbing. We should not therefore discount the possibility of very deep-rooted patterns of thought not limited to the "either–or" logic underlying western science. However, a much simpler explanation must also be considered: Much of the teaching and learning in Nepalese schools involves rote memory only and demands very little understanding or conceptualization. It is quite possible that the way in which early "scientific" concepts are taught in school combines with a tradition-oriented home environment to produce no *necessary* distinction between myth and science. In any case this dual view of nature is a matter that needs to be considered in the planning of revised science teaching methods.

Open and closed societies

In a country where schools and science classes are relatively recent innovations, we were also interested to see how much stress new ideas may have brought about between generations or between those who go to school and those who do not. In general we found rather little tension that might be identified directly with the introduction of new ideas, but our observations would indicate that stress is more likely to be felt in a society that is open to ideas from the outside than in one which is not. Two extreme examples may serve to illustrate this truth. The Newar town of Panga, although not far distant from a large and rather cosmopolitan city, is itself intellectually and philosophically conservative and isolated. Its citizens adhere rigidly to a self-consistent and inclusive social and philosophical orthodoxy that provides a firm answer to every question. They were hospitable to us as visitors and very willing to answer our questions, but they showed no curiosity whatever about the outside world or our experience of it. Although there are a primary and a secondary school in the town, less than one-fourth of the school age children



Children's maps show the way "from your house to the school." Fifteen-year-old Nepalese boy is apparently describing the "process of going" rather than spatial relationships (top); in fact, the house and school are on different paths. An eleven-year-old US boy includes spatial and directional clues, as well as symbols, in his map (center). Even a six-year-old US boy, living in Kathmandu, appears to grasp the abstraction of spatial relationships (bottom) better than the Nepalese boy.

attend school. The adults show little interest and no concern about what their children are learning.

In contrast to Panga, the Gurung and Chetri community of Armala Dihi in West Nepal is very open. In common with most Gurung villages it has a number of members who have returned from service abroad in the British Gurkha forces. These returned soldiers bring with them a rich experience of other ways and other lands, and they are highly respected members of the community. Although the adults identify themselves with an old order they are intensely curious about the new. They seem not to tire of asking questions that range widely over a world of ideas just visible to them over a still distant horizon. They welcome schools and urge or require their children to attend. Yet they are engaged with the children in a continuing and sometimes strenuous dialog in defense of the old ideas and cosmology, a dialog in which both the adults and youth did their best to enlist our participation. It did not on the surface at least reveal any lack of rapport between generations, but I left wondering how long this would continue to be true. Even where no stress is evident, as in Panga, it must be considered as latent and potentially divisive wherever really new ideas or new approaches to knowledge are being introduced. Of course this is not limited in any way to Nepal nor to so called "developing" countries, and the possibility should be kept in mind whenever new educational programs are being designed.

When our Nepalese informants were asked to give the source of their knowledge about nature they invariably said that it came "from books" and "from old people." When we asked how the old people found out or how knowledge got into books they told us it came from earlier generations of "old people" or from other books.

We went on to inquire how new knowledge, hitherto unknown to anyone, might be acquired or how it might be sought. We were always told that such new knowledge is not to be expected. The predominant view pictures human knowledge about nature as a closed body, rarely if ever capable of extension, which is passed down from teacher to student and from generation to generation. Its source is in authority not in observation. In fact, experiment or observation was never directly suggested to us as an appropriate or trustworthy criterion of the validity of a statement nor as its source. Given this concept of knowledge it is no surprise that the schools rely heavily upon rote memory; memorizing would appear to be the easiest and most efficient way to deal with a closed and limited body of unvarying facts. There are also other well known and frequently criticized forces embedded within the formal educational system that strongly reinforce this natural tendency.

Abstractions of reality

The real world is very large, incredibly complex and for the most part very indirectly perceived. Within a short afternoon's walk one may encounter a bewildering array of events and objects and yet miss the greater part of what might have been observed. To see it all and put it all into an orderly description would be an impossible undertaking. Yet one would have encountered an insignificantly small part of reality, which extends itself to include a whole state, a continent, a solar system and indeed countless galaxies of stars and planetary systems spanning unimaginable distances and vast intervals of time.

A tiny chip of this great universe, say a chromosome, contains within itself unbelievable complexity and order. A living cell with its intricate interactions of molecules and atoms, electrons, protons and who knows what still smaller and quicker objects forms a micro-universe no less complex and infinite in its smallness than is the macro-universe in its bigness. How can the science teacher encompass all this! What hope can be offered to a student who wants to commit it all to memory?

Science, as the scientist thinks of it and would like to see it taught, does not consist of a body of more or less isolated facts to be memorized but a system of empirically verifiable relationships between abstract concepts. Although the concepts are derived from the real world of phenomena, the relationships of science connect concepts, not real objects, and the theories of science are built around "models" that portray in abstract, often mathematical, terms a selectively idealized representation of the real world of phenomena. It is essential for the physics student to learn to be at home, at some level of sophistication, with this process of abstraction, which must surely appear even to the western layman to be extraordinarily indirect. Much attention is given to this in the recently developed or improved science courses in the US, which take great care to give students systematic training and practice in skills of abstraction and inference while striving to maintain contact with the real world by subjecting all conclusions to observational verification. Of course informal learning plays a part in this process. The toys children manipulate, the games they play, the activities of adults that they watch and imitate, the conversations they listen to, all contribute to the attitudes and skills they develop. In everything the child does in school there is an echo of his environment at home.

How much more difficult science must be then for a child who lives in an Asian or African village or small town, immersed in a very different environment with its own pervasive but non-western influences. Here he lives close to nature in a direct, particularistic relation of planting and harvesting, with little or no abstraction and little need to generalize. Certainly his society or any society contains a great many abstractions, ranging from spoken or written language (which plays an important role in developing modes of thought) all the way to a very complex religious cosmology, but these are not all particularly useful in preparing the way for science, which wants to hold a rather special and verifiable relation to nature. Thus for example every Nepalese child will be familiar with abstract representations of certain Hindu or Buddhist deities and heroes of religious myths and legends. Yet these are not subject to direct or even indirect observational verification after the manner of science, and they may not be conducive to a scientific approach.

To assess tentatively their readiness to make and use abstractions, we asked our subjects to sketch rough free-hand maps showing how to get "from your house to the school." A map is a fairly simple example of a scientific model: It preserves a verifiable one-to-one relation to reality, and yet it is an abstraction, useful for what is omitted no less than for what it includes. It lends itself to great variety in the way a given reality is represented, and the relationships and inferences derived from it, although not totally unrelated to reality, nevertheless actually refer to the model and not to the real world. We believe that the maps drawn by children or adults to represent a route or neighborhood well known to them will reveal with some accuracy their readiness to understand and use other scientific abstractions.

The "maps" we obtained are very similar to each other and to the top map shown on page 52. Always they include a recognizable *picture* of "my house" and of "the school" connected by a line that appears to denote *the process of going* from one to the other, not the spatial relationship of one to the other. Thus in the case shown, the two buildings in fact are not on the same street or path, being separated by several street intersections and other landmarks, none of which appear on the map. In contrast, the middle map is typical of those drawn by US children in response to the same instructions. Here both house and school are represented by abstract symbols, not pictures, and there is a clear effort to show spatial relationships and to provide needed spatial clues. Each of these maps was made by a school-age child who was old enough to draw reasonably well; in fact the Nepalese map was drawn by a fifteen-year-old boy. Lest we be tempted, nevertheless, to attribute the difference to a lack of skill in drawing, I include as the last a map drawn by a six-year-old boy from the US who happened to be living in Kathmandu when I was there.

The propensity of the Nepalese for making maps (whether verbal or graphic) that are *sequential* rather than spatial constructs is not limited to school children: In a land of foot trails, where literacy is too low to justify road or trail signs, it has been a source of consternation to more than a few travellers of western upbringing! We too, in reply to our inquiries as we travelled, were given instructions or "maps" that, like a string of beads, list in correct sequence the places we should pass through without giving any clues as to distances, trail intersections, changes of directions, and so on. Our interest is not in the accuracy nor potential usefulness of this different kind of model but in the light it may shed on a way of thinking that extends far beyond mere map making. The villagers use no other kind of map; they do not use drawings in constructing a building or a piece of furniture—in fact they hardly use drawings or spatial representations at all, and lack of spatial models is very natural. The question remains, however, whether the teacher will have this in mind when he presents a "model" of a molecular or solar system, or when he uses a variety of other common and "useful" visual aids.

Science as a second culture

The observations I have been discussing are very limited and should certainly be extended. Where this has been done, for example by John Prince[2] in New Guinea and by John Gay and Michael Cole[3] in Liberia, very similar conclusions are reached, although the detailed observations differ from one culture to another. These observers suggest changes in elementary-school curriculum to incorporate a "pre-science" program designed to give children more experience with observation, classification, abstraction, and so on.

Programs of this sort intended for primary-school children have been developed during the past five years in the US; an example is "Science: a process approach."[4] (Information about this program is available from the American Academy of Science Committee on Science Education.) I will not take time here to describe these but will instead comment briefly on the spirit in which such a pre-science program may be taught.

It appears to me that this early science, or pre-science as I would prefer to call it, should in no way be offered as a substitute or replacement for what a child learns at home but rather as a "second culture," valid in its own right and taught in much the same spirit as a second language is taught. When an Urdu-speaking boy or girl begins to learn English, there is no suggestion that Urdu is wrong nor that English will totally replace his native Urdu. He learns English without establishing any conflict with his native training and understands from the beginning that he will use English at his own discretion when it is useful and appropriate. Recent experience appears to indicate that the same attitudes and techniques are most effective in teaching a standard English to children in Hawaii or Georgia, for example, who speak a substandard dialect of English at home. It is easier for these children to learn standard English when it is presented as a second language, not as a substitute for their own "incorrect" dialect, which of course they continue to need in their own community. Science taught in this spirit as a "second culture" can be learned without the stress and conflict set up by attempts to unlearn an alternative set of relationships. It can be more easily learned in this manner, and the relationships of science can be called upon and used by the student when he himself feels them to be appropriate.

Of course some kind of accommodation between the scientific revolution and a nonwestern culture such as that of Nepal must and will eventually be reached if science is introduced at all. This is a complex matter that must evolve slowly within the Eastern cultures as it did in the West. Experience suggests that this accommodation will not be most easily achieved simply by substituting the one for the other and particularly not during the school years when the children are immersed in the intellectual and physical environment of the village. It is important to them and to the village that they remain at peace there. Moreover an eventual accommodation should be based upon real science, well learned, rather than on a set of memorized facts and formulas learned under stress.

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References

1. F. E. Dart, P. L. Pradham, Science **155,** 649 (1967).
2. J. R. Prince, *Science Concepts in a Pacific Culture,* Angus and Robertson, Sydney, 1969.
3. J. Gay, M. Cole, *The New Mathematics and an Old Culture,* Holt, Rinehart and Winston, New York (1967).
4. R. N. Gagne, Science **151,** 49 (1966).