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ABSTRACT

A research strategy is presented which enables the development of science and mathematics curriculums for American Indian and Alaska Native children of diverse cultures based on existing subsistence knowledge and skills. This strategy assumes that American Indian and Alaska Native adults implicitly make use of many formal science and mathematics principles while engaging in subsistence activities, and that their children acquire a latent ability to understand these formal concepts by observing and participating in these activities. Recent studies in cross-cultural psychology and psychological anthropology are cited in support of the position that children learn complex cognitive skills based on participation in common cultural activities. Ethnographic and Piagetian research methods are proposed for a 2-year study to assess the existing science and mathematics knowledge among the Tlingit Indians of southeast Alaska where a pilot project is now underway. Discussion is limited to an analysis of the ways of researching indigenous physics knowledge. However, the research design can be adapted to any cultural group and be utilized to develop procedures for teaching the formal aspects of any subset of Western physical science or mathematics knowledge in classroom situations. A five-page bibliography concludes the document. (NEC)

American Indian and Alaska Native Education for High Technology: A Research Strategy for Creating Culturally Based Physical Science and Mathematics Education

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ABSTRACT

A research strategy is presented which enables the development of science curriculums for American Indian and Alaska Native children of diverse cultures based on existing subsistence knowledge and skills. This research strategy assumes that American Indian and Alaska Native adults implicitly make use of many formal science principles while engaging in subsistence, and that their children acquire a latent ability to understand these formal concepts by observing and participating in these activities. The author proposes that ethnographic and Piagetian research methods can be utilized to assess the existing science knowledge in any given Native American community and develop procedures for teaching the formal aspects of this knowledge in classroom situations.

AUTHOR'S STATEMENT

George M. Guilmet is an Associate Professor in the Department of Comparative Sociology at the University of Puget Sound in Tacoma, Washington. Being both an engineer and a psychological anthropologist, he is interested in the psychological aspects of technological change.

This article presents a research strategy which enables the development of culturally-sensitive science and mathematics curriculums for American Indian and Alaska Native students. This research strategy assumes that American Indian and Alaska Native adults implicitly make use of many formal science and mathematics principles while engaging in subsistence, and that their children acquire a latent ability to understand these formal concepts by observing and participating in these activities. I will propose that ethnographic and Piagetian research methods can be used to assess the existing science knowledge in any given American Indian or Alaska Native community and to develop procedures for teaching the formal aspects of this knowledge in classroom situations

In order to present this future research strategy as clearly as possible, two restrictions on our discussions will be made. First, the research strategy will be presented as if it were to occur among the Tlingit Indians of southeast Alaska where a pilot project is now underway.[1] Second, the discussion will be limited to an analysis of the ways of researching indigenous physics knowledge. However, the research design can be adapted to any cultural group and to any subset of Western physical science or mathematics knowledge.

Introduction

Few Tlingit students ever learn mathematical physics. Although every Tlingit village in Alaska has a hign school, no physics courses are offered. This is true of Angoon, Hoonah, Kake, Hydaburg, Klawock, Klukwan, etc. Eldon Denis, the sole high school physics instructor in southeast Alaska over the last ten years, states that he has not had one Tlingit student in his physics courses during this period. This is amazing, given the fact that his school, Douglas High School in Juneau, is not only located in the heart of Tlingit country, but is the largest high school in southeast Alaska. Donald Greenberg, Assistant Professor of Physics at the University of Alaska, Juneau, has likewise not had one Tlingit student in his college physics courses since he began teaching there in 1975. Finally, the most recent Alaska High School Seniors' Survey Report (Alaska Commission on Postsecondary Education 1982) shows that not one Alaska Native preferred a career which required the study of science.

Further, when exposed to mathematical physics, Tlingit and other Alaskan Native American students do miserably. Greenberg interviewed one Tlingit student recently who attended the University of Wash ngton in Seattle. This student said she wanted to pursue a medical career but her nonexistent physics background is making it difficult to successfully complete the required physics courses. During another interview, Greenberg was told by a Tlingit educator that 85 Alaska Native students have enrolled in his introductory physics course at Western Washington State University in Bellingham during his time there. Only one of these Alaskan Indian and Eskimo students completed the course.

This situation places Tlingit and other Alaskan Native students at an extreme disadvantage. The growth careers in the future (technicians, engineers, physicists, medical professionals, and computer scientists) all require an extensive background in physics (Changing Times 1983). The research strategy to be presented was developed to address this need.

Two years are required to complete this research. In the first year, the participant-observation methodology of cultural anthropology is used to assess the physics concepts implicitly utilized by Tlingits during their everyday subsistence activities. Of particular concern is the extent to which

Tlingit children and adolescents observe and participate in these activities. In the second year, culturally-relevant Piagetian-type experiments are used to assess the extent to which Tlingit children and adolescents have acquired a latent ability to learn physics based on their involvement in subsistence. This methodology is borrowed from the field of cross-cultural Piagetian psychology.

The Piagetian-type experiments created in the field to assess Tlingit childrens' and adolescents' existing understanding of physics show the potential of being used in classroom situations to teach Tlingit children the formal mathematics of physics. These culturally-sensitive, physics experiments could be utilized in appropriate high school and college settings to illustrate the formal mathematical concepts which must be learned by the Tlingit child.

Theoretical Background

Western physics education is heavily dependent upon the use of mathematical definitions of formal relationships between physical properties of nature (Bueche 1969, Wall and Levine 1962). For example, velocity and acceleration bear explicit quantitative relationships between time and distance in space. Heat is quantitatively related to the energy content of a particular type of physical system. And, force is defined in terms of measurable and predictable interactions between defined phenomena.

Tlingit Indian children, in contrast, learn knowledge about the physical world within their communities through the observation of others' interactions with the physical world and through subsequent trial-and-error practice of the activities they observe (Cazden and John 1971, John 1972, Scribner and Colde 1973). The child's developing ability to predict and manipulate the natural world is acquired by watching others who intentionally or unintentionally model the skills they are to master and by attempting to replicate these skills. Oral instructions by the "teacher" to the learner are minimized. Even more critical from the perspective of Western physics education, mathematical definitions of physical processes and entities using relationships between defined and quantified properties of the physical world are virtually nonexistent in Tlingit culture.

Yet, ethnographic descriptions of traditional Tlingit culture tell us that Tlingits excelled at the manipulation of the natural world (Krause 1955, Oberg 1973, Oswalt 1973 and Swanton 1908). Of more direct relevance to children's physics learning today, recent descriptions of Tlingit and other Alaskan Native cultures reveal that Native American children are still deeply involved in subsistence activities, and that these activities offer the child numerous opportunities to manipulate physical processes within his/her environment (Environmental...1983, Nelson 1973 and 1969, Ray 1962).

Based on the above recent ethnographic information and preliminary observations in Angoon, Alaska by Donald Greenberg, the following appear to be among the subsistence activities that a Tlingit child experiences and observes. A few boats are manufactured from wood so they are water-tight, sturdy and buoyant. Western-style houses and fish-drying sheds are constructed with skill. Fish nets are selected and adjusted to the water velocity and force they are exposed to during use. Fishing lines and hooks are selected to withstand the forces they are expected to encounter. Fish are cut, dried and smoked for specific lengths of time in selected environments of given humidities to preserve them. Rifles are selected and used to suit particular sizes and speeds of waterfowl and terrestrial mammals to be killed. Sharpening stones and files are used to maintain cutting edges on knives and axes.

Appropriate clothing is chosen to maintain body temperature in rapidly changing environments. The sounds of game are interpreted to determine direction and distance. The tracks of animals are read in varying types of ground and weather conditions to assess their age. The cloudiness of water through which game have travelled is analyzed to determine the time since the water was muddied. Game calls are constructed to achieve the right pitch to mimic the sounds which will bring a particular animal species closer. Snares are constructed of the right quickness and strength to capture appropriate game. The hardiness of the crust of a snow cover is tested to determine its ability to support travel by walking or by snowmobile. The hardiness of the crust also indicates the age of animal tracks found while tracking. Deadfalls are constructed of varying sizes and weights to kill appropriate animals. Traps of given strengths and form are selected to suit ..rticular sizes of game.

As a result of children's involvement in the above subsistence activities, Tlingit children appear to have acquired a latent understanding of formal physics principles. Tlingit children learn how to judge velocity by experiencing the velocity of water while net fishing. They experience the relationship between vibratory frequency and harmonics while constructing game calls. Experience with the properties of matter is gained while hunting and fishing: the solid, liquid and gaseous phases of water in relation to temperature; the relationships between size, density and weight of materials in deadfall construction; and the flexibility of wood in relationship to size and dryness while making snares. The concept of force is experienced when selecting nets, hooks, and fishing lines for appropriateness. The relationships between friction, force, and heat are experienced during metal sharpening. Curvilinear motion must be mastered when learning to aim a rifle over large distances.

Wave phenomena are observed during travel on lakes, rivers or the ocean. The relationships between heat dissipation and insulating materials are experienced when selecting clothing during subsistence activities. The relationship between impulse force, object size and momentum is observed while using hammers in housing construction and maintenance. Acceleration is experienced while travelling by boat or snowmobile.

A series of recent studies in cross-cultural psychology and psychological anthropology support the position that children learn complex cognitive skills based on participation in common cultural activities:

1) Gay and Cole 1967. In their monograph on mathematical abilities among the Kpelle of Liberia, Gay and Cole made a number of enquiries related to indigenous skills in this area. For example, Kpelle subjects were asked to estimate the number of stones in a pile. This problem was chosen because Kpelle naturally use stones to itemize and count sets of objects. The Kpelle also know constructions which in our society would be dignified by the name "theorem". They can construct a circle by using a rope fixed at one end; a stick is tied to the other end, and rotated around the center with the rope as radius. A Kpelle man needs such a circle when he makes a round house or a "palaver" house.

2) Cole, Gay, Glick and Sharp 1971. In a later book, the Cole team continues much of the same kind of work, as for example, when they analyze how Kpelle sort leaves. However, they go beyond this by trying to determine the conceptual style of the Kpelle, when they probed the way in which their subjects best clustered verbal material. The Cole team found out that learning and retention was best performed when the task was in a story context, thereby aligning the task with the traditional manner in

which Kpelle handled verbal material in their own culture.

3) Gladwin 1970. Another way to approach the kind of information desired is to focus on one skill such as navigation, which Gladwin has done with the inhabitants of the Pacific atoll of Puluwat. Gladwin exhaustively collected all the lore about navigation among these people, and analyzed the underlying logic involved in this skill. He asked: how is it learned, what classificatory systems are involved, and so forth? In a final chapter entitled "Perspectives on Thinking" he relates this set of cognitive abilities underlying the skill of navigation to the question of intelligence generally, taking navigation as not only a technological attitude, but as an exemplar of purposeful thinking.

4) Price-Williams, Gordon and Ramirez 1969. Again, this study was focused on natural abilities of people, but different from the Gladwin study in that two groups of Mexican children in the province of Jalisco were compared in terms of their abilities to perform Piaget's conservation tasks (conservation of number, liquid, mass, weight and volume). The hypothesis here, which was confirmed by the results, was that the conceptual operations underlying the pottery skill (with its attendant logic of following through a formless mass of clay to a permanent structure) should aid children in the understanding of at least one kind of conservation ability, that of mass or substance. The finding that in one set of children in a relatively primitive village the ability to conserve mass extended to all the other types of conservation raises the question of transfer, which may have to be investigated more thoroughly in ensuing studies.

5) LeVine and Price-Williams 1974. Yet another way of tackling the "natural" ability of children's cognition is to do what LeVine and Price-Williams

did in a Hausa village (Malunfashi,Zaria Province, Nigeria). Here, children's concepts of kinship were studied. Children were asked a variety of questions: Whom do you know in your compound? How are you related to each? How are these people related to one another? and so forth. The advantage of such a scheme is that another source of information about the compound's kinship was available - from an adult informant, collected in the traditional anthropological manner. Researchers were thus able to compare children's versions at different ages with an adult's version and able further to trace, in the Piaget manner, egocentricity through non-self orientation of a network of relationships. By taking a Hausa population a certain exotic quality was added to the usual Piaget situation. The Hausa have large polygynous extended families in which, due to the fact that Hausa children tend frequently to be fostered out to non-biological mothers, the children have a complicated network of family relations to be worked out.

6) Jahoda 1969. The purpose of this study was to discover the native's knowledge of the mechanism of bicycles, in a Ghanaian population. It was done by having the boys involved assemble a cardboard model of a bicycle, and to then explain its functioning. The intent was not merely to apply an aptitude test but to represent a situation in which problems of scientific principle could be probed (for example, the principles involved in how a lever works; mechanical notions of causality).

7) Berland 1982. Berland focused on the differences in cognition between nomadic and sedentary groups in Pakistan. He developed a theory about the relationship between social experience and mental growth as measured by Piagetian conservation tasks that suggests that the flexible social system and highly specialized individual skills characteristic of nomadic

living contributes to the acceleration of the cognitive development of individuals living in this way. A unique contribution of Berland's work was its inclusion of the effects of the social environment on cognitive development.

The general direction of these new studies is to be admired. We do need to understand the situational causes of a child's cognition. Yet, it must be recognized that many such ecological-cognitive studies lack a consistent theoretical psychological model to account for children's learning. On the other hand, more traditional psychological enquiries into the development of children's cognition (such as verbal or nonverbal intelligence testing) have run into trouble because their theoretical basis tended to ignore the situational causes of children's learning.

Somehow a theoretical position regarding children's learning must be used which has the diverse learning situations of children as its central focus. Although a ready-made theory of this nature awaits formation, a beginning can be made by paying attention to ecological and occupational causes of children's cognition and by assessing the impact of these factors on children's learning using culturally-relevant, Piagetian-type experiments. I will outline this approach in the following discussion.

Piagetian theory accounts for the gradual development within the child of the ability to perform formal operations. Formal operations is defined by Piaget as the ability to use propositional logic (reasoning on possibilities or hypotheses instead of real situations only), combinatorial operations (working out all the possibilities), or of devising scientific experiments (e.g., holding all factors constant except one) (Dasen and Heron 1981:302). In Piagetian theory this ability is the end-product of the child's cognitive development through a series of three prior stages (Ginsberg and Opper 1969).

The first stage, the preverbal sensori-motor period (birth to two years) is characterized by the development of coordinated actions that constitute the basis of later representational thought. The child performs only overt actions on his/her environment. The appearance of semiotic function marks the beginning of the second stage, the preoperational period (two to seven years). During this stage, although the child can imagine the actions he/she wishes to perform, and consequently can think of those he/she has already performed, he/she cannot describe them in words. The child's understanding is strongly limited by egocentrism, a self-centered approach to the world, and personal-idiosyncratic analysis dominates the child's reasoning. With the absence of deductive reasoning, intuition and explanations based on psychological motive predominate.

During the third stage, the concrete operations period (seven to twelve), the first operations appear. An operation is defined as an internalized action that modifies the object of knowledge. The child is thus able to put objects into one-to-one correspondence, to seriate, to classify, to use addition and subtraction. However, the child can perform such operations only with perceived or imagined objects and not yet with symbols, that is, only in a concrete level of reasoning.

Piaget's theory has been tested in many diverse cultural situations. Several specific reviews of the results of its application in cross-cultural research are available (Ashton 1975, Carlson 1976, Dason and Heron 1981, Greenfield 1976, Lautrey and Rodriguez-Tome 1976, Price-Williams 1980a). The qualitative aspects of the theory (the sequence of stages and substages, their structural properties, the types of explanations given by respondents) have been supported by a great majority of the studies. However, the quantitative aspects (the rate of progress through the stages or the chronological age at which these are attained) show considerable intercultural variability. A discussion of Piaget's modification (1966a and 1972) of his theory to suit the mounting cross-cultural evidence that the cultural environment of the child can significantly affect the rate at which and extent to which the child acquires Piaget's increasingly complex mental structures is available in Jahoda (1980).

For our purposes, we need to realize that Piaget's model of cognitive development provides an excellent cross-cultural model for physics learning (Dasen 1977, Price-Williams 1980a). The transition of Tlingit children from the sensori-motor stage through the preoperational and concrete operations stages to the development of formal operations is exactly what must occur if these children are to be able to learn mathematical physics. What we don't know is the level of cognitive functioning Tlingit children achieve with respect to physics as a result of their participation and observation of subsistence activities.

After reviewing the cross-cultural evidence, Dasen and Heron (1981) conclude that different cultural experiences can increase or retard the rate at which a child progresses through Piaget's stages. I believe, based on the recent cross-cultural studies reviewed earlier, that a Tlingit child acquires a latent understanding of formal-mathematical physics because of his/her involvement in common subsistence activities. By latent understanding, I mean knowledge understood on a practical level and used during concrete manipulation of objects which is recognized and expressed in a formal-verbal way to varying degrees depending on the individual.

In other words, it appears that by adolescence, Tlingit children have acquired at least Piaget's concrete operations stage with respect to physics. That is, they can perform operations, internalized actions that modify the objects of knowledge, on objects at hand in their environment. Further, it appears that most Tlingit adolescents will have acquired some abilities corresponding to Piaget's formal operations stage. That is, they will be able to some extent use propositional logic, combinatorial operations and devise scientific experiments in familiar subsistence situations. Culturally-relevant, Piagetian-type physics experiments will be created to test this hypothesis.

In summary, two key questions arise concerning the ability of Tlingit Indians to learn the formal-mathematical principles of physics in classroom situations. First, precisely what formal physics principles are made use of implicitly during the subsistence activities currently ongoing in Tlingit communities in Alaska? Second, to what extent do Tlingit youths of any given age acquire a latent understanding of formal physics while observing and participating in these subsistence activities? Each year of the two year research strategy to be described is designed to answer one of these questions. The methods to be used are the participant-observation study of ongoing subsistence behavior in the first year, and the use of culturally-relevant, Piagetian-type experiments in the second year.

Justification of the Research

The knowledge to be gained is important for two reasons. First, it will discredit the view that Tlingit children are somehow living in an intellectually deprived subculture. Indeed, it appears that Tlingit individuals acquire a vast number of cognitive skills as a result of their involvement in the subsistence activities which are so important to their culture. This research is designed to specify the actual cognitive skills in physics children learn within their own cultural context.

Second, the Piagetian-type experiments used in the second year of the research show the potential of being converted into useful and culturally relevant laboratory procedures for teaching the formal models of mathematical physics to Tlingit children in the classroom. One could select the culturally-relevant, Piagetian-type experiments which have successfully elicited a latent understanding of formal physics in the Tlingit field site and modify them for laboratory use. Then, the formal mathematics which is illustrated by each of these experiments could be presented to the student after or before exposure to the Piagetian type experiments.

In the future, an evaluation study could be initiated with Tlingit students in order to assess the effectiveness of traditional methods of teaching physics versus the modified Piagetian-type methods. A high school exists in each Tlingit community offering excellent contexts for such a project. It is a sad but factual circumstance that physics is not taught in any of the high schools in Tlingit villages. This research might motivate an interest on the part of administrators, teachers, and the Tlingits themselves to develop such courses using culturally-familiar, Piagetian-type, physics experiments.

On a more general level, the research methods to be outlined show the potential of evaluating the naturally occurring cognitive competency of ethnic students from any minority group of interest. The methods would remain the same although the naturally occurring tasks to be studied would vary with each cultural group. Each cultural situation presents the child with a different set of culturally-relevant skills. Further, if the culturally sensitive Piagetian-type experiments used in the field can be adapted for classroom use, they can be developed for any given set of ethnic children to help them learn mathematical physics. I believe the best way to help these children is to know what physics knowledge they already possess and to build within them an understanding of the formal principles using culturally sensitive, Piagetian-type experiments.

Plan of Research - First Year

The initial year of the research is to be spent conducting a participant-observation study of Tlingit subsistence in order to determine: 1) precisely what subsistence activities are currently in practice, 2) what physics knowledge is implicitly used by Tlingit adults in their routine performance of their subsistence tasks, 3) to what extent do Tlingit children and adolescents observe and participate in the ongoing subsistence tasks? Those subsistence activities of interest include sealing, hunting, fishing, spruce-root weaving, food preservation and preparation, clothing manufacture, boat building, housing construction and maintenance, outboard and snowmobile repairing, and others. It is important to conduct this study for an entire year to document the complete set of subsistence activities as they occur with changing ecological conditions.

The participant-observation study of subsistence skills is composed of the following research strategies (Foster 1979, Naroll and Cohen 1973). First, the researcher becomes intimately involved in the subsistence activities of the Tlingit adults both male and female. As each time of year presents new hunting and gathering activities, the researcher not only observes, but attempts to learn the "correct" performance of skills. "Correctness" is defined by the accomplished Tlingits who model and explain the skills to the researchers. In essence, the researcher tries to learn as much about the subsistence activities as the Tlingits know themselves. This is rarely achieved in reality. However in the process of learning the skills to be studied, the researcher discovers the complexities involved in the performance of the tasks.

This may lead to the situation where the researcher is considered childlike. The native wonders how any adult could be so stupid as to make obvious mistakes or not know the proper method of accomplishing a "common" task. However, when the researcher is placed in this novice role, he/she is flooded with information about the correct way to behave and think. It is this information which gives the researcher an understanding of the complexities of the native's knowledge, and it demonstrates to the researcher the methods used by the natives to "teach" skills and concepts.

In bilingual communities, language differences between the researcher and those skilled in subsistence may become a problem in this type of research. Those most skilled in hunting and gathering are typically the older members of the community, those least skilled in English. To overcome this problem, the researcher must learn the native language to the extent possible within the year of the study and pay interpreters to help translate the oral statements of those who speak the native language exclusively.

An examination should be made of the existing native classification systems for objects and behaviors relevant to subsistence activities. The ethnoscience method of cultural anthropology has made it clear that different cultures attach different linguistic labels to objects or behaviors in their environment (Price-Williams 1980b). Cultures create an elaborate number of linguistic categories (for example, different types of fish, plants, animal behaviors, weather conditions) if the objects or behaviors are important for survival in their environments (Basso 1972, Kessing 1972, Tyler 1969). Further, the depth of the native hierarchical classification system used to cognitively organize classification of external objects and behaviors varies with the relevance of the activity for survival.

An understanding of the native language categories is relevant because it may give the researcher some indication of traditional causal explanations for events which occur during subsistence. If Tlingits have an elaborate number of linguistic categories to describe the different appearances of animal tracks.

for example, this gives some indication of the native beliefs concerning the causes of the observed track conditions and forms. Certain track forms may mean a specific animal of a given age was running fast or wounded. Other tracks may indicate to the native that a given animal passed by a place a short time or a long time ago depending on present weather and ground conditions.

Two excellent models exist for this first phase of the research. Richard Nelson has conducted similar studies among two different Alaskan Native cultures. In Hunters of the Northern Ice (1969), Nelson gives a detailed account of the cognitive skills involved in the subsistence of Eskimos of Wainwright, Alaska. This study was funded by the United States Air Force and Navy to give enlisted men the information needed to survive the Arctic if stranded or stationed there. This work consists of a detailed account of Eskimo knowledge regarding subsistence, survival, and the manufacture of technology.

In Hunters of the Northern Forest (1973), Nelson gives a similar account of Kutchin Indians' designs for survival along the upper Yukon River in northeastern Alaska. The complexity of the Kutchin's subsistence knowledge and skills is truly amazing. A reading of this and the above work make it impossible to believe that intellectual competence is the sole property of Western culture.

Nelson stresses the need for active participation in subsistence activities on the part of the researcher to learn the extent of the native's knowledge:

> The present study utilizes the technique of "active participation," in which the ethnographer attempts to replicate the behavior involved in the activities he is documenting and to learn to perform each technique at least at a minimal level of proficiency. In other words, he participates to the fullest possible extent; and by learning each skill, he is able to do a far more complete job of documentation, for he learns not only by observing others, but by observing himself as well. (1973:9)

He states that he generally wrote notes late at night, just before retiring, when the day's information could be put down all at once. During the day, he made brief sketch notes and detailed records after long and very productive conversations. Field notes were bound in notebooks. At the end of his Kutchin study, which took fifteen months, he had 450 pages of field notes.

The <u>second</u> part of the participant-observation study consists of analyzing the formal physics concepts implicitly used by Tlingits during subsistence activities. The researcher makes an explicit list of the formal physics principles which are implicitly utilized by Tlingit adults during subsistence activities. As each new subsistence task is learned by the researcher, it is analyzed to discover the physics principles it illustrates. For example, when knives or axes are sharpened using a file or a stone the relevant definitions of friction, force and heat which describe the phenomenon are identified and listed.

Then, the Tlingits engaged in the activity are questioned to determine the extent to which they can verbalize the formal physics principles involved. Questions like the following are appropriate in the case of the sharpening activity. Does this sharpening produce heat? Why or why isn't it produced? How is it produced? If you press harder or grind faster is more or less heat produced?

No similar participant-observation research has been conducted. A few good ethnographies of native subsistence skills and knowledge do exist as we have seen. However, none of these attempt to compare these skills with the formal physics principles they illustrate. Nor has an attempt been made to establish the extent to which the skilled native can verbalize the physics principles involved.

This aspect of the research is a unique contribution to the understanding of the manner in which formal physics knowledge develops in individuals because it documents its unfolding in persons from another culture. It can also lead to a better understanding of effective ways to teach individuals from ethnic cultures the mathematics of physics. If we can identify the situations common to a culture which illustrate a formal relationship, this situation can be used to explain the formal mathematics involved. This line of research can lead to naturalistic experiments illustrative of mathematical physics which can be transferred into classroom laboratory contexts.

The third part of the participant-observation study focuses on the extent to which Tlingit children and adolescents observe and participate in the ongoing subsistence activities. The researcher keeps detailed notes of observations of children's and adolescents' behaviors regarding subsistence. He/she seeks to answer the following questions: At what ages do children become involved in subsistence? What activities can they observe prior to participation? What oral-descriptions of activities are heard by children of differing ages? Do adults give oral instructions to the young regarding correct subsistence behavior? Do adults intentionally or unintentionally model correct subsistence behavior? Do the young practice subsistence activities during play? Do older children or peers help children to learn subsistence tasks?

The above general information about the participation of the young in subsistence makes possible the understanding of the processes through which latent physics knowledge is acquired by the young during development. The researcher is able to observe and record the manner in which children gradually acquire increasingly complex understandings of their physical world. This work makes possible the understanding of the results of the Piagetian type experiments to be conducted in the second year of the study. Further, this approach gives the researcher information regarding the methods used by the Tlingits to teach the skills we are observing. These traditional "teaching" methods may also be transferable into classroom situations. All three of the above aspects of the participant-observation study are carried on concurrently.

Plan of Research - Second Year

Based on the information acquired during the first year, culturally-relevant, Piagetian-type experiments are created to assess the extent to which Tlingit students acquire the latent ability to understand the formal models of mathematical physics through their involvement in subsistence activities. The researcher designs a small number of Piagetian-type experiments which reflect directly the subsistence tasks routinely observed and/or performed by Tlingit youths. Finally, he/she selects a representative sample of Tlingit youths stratified by age and sex to participate in these naturalistic experiments. The sample is stratified by age to document the development of Tlingit youths' understanding of the formal physics principles underlying each Piagetian-type experiment. The sample is stratified by sex to determine whether or not children of different sexes are able to understand different physics principles due to their exposure to diverse subsistence tasks. Females are more often than males involved in clothing manufacture, food preservation and preparation, and local fishing. Males are more often than females involved in sealing, hunting, and trapping.

It is not possible to define the precise Piagetian-type experiments to be created prior to fieldwork. To do so would be to impose on the Tlingit tasks which are potentially unfamiliar and irrelevant to the cognitive skills they learn in subsistence. As Cole and Means (1981) make vividly clear, it would be a dubious strategy to draw inferences about latent physics knowledge among Tlingit students based on experiments which are alien to their culture.

However, experience in cross-cultural Piagetian research has shown repeatedly that existing Piagetian tasks can be modified to suit specific cultural contexts, or culturally-relevant, Piagetian-type tasks can be created based on his broader theoretical model of cognitive development (several reviews of the cross-cultural application of Piagetian-type experiments are available: Ashton 1975, Carlson 1976, Dason and Heron 1981, Greenfield 1976, Lautrey and Rodriguez-Tome 1976, Price-Williams 1980a). Indeed, we will see in the discussion that follows that Piaget has specifically addressed the development of the child's knowledge of physics. Further, many of his experiments show the potential of being directly utilized among the Tlingit.

The beginnings of Piaget's "revised clinical" approach (Ginsburg and Opper 1969) to studying the development of the child's understanding of physics was first outlined in The Child's Conception of Physical Causality (1969a), published originally in 1930. Experiments in physics were carried out by and before the child, and he/she was questioned. This gave first-hand information about the thoughts of the child regarding the physics experiment of interest.

Examine one of Piaget's early experiments which shows the potential of being adapted to Tlingit culture. First, Piaget presented the child with bits of wood, stones and nails, etc., and asked him/her whether these objects will or will not float and why they do or do not float. Then, the researcher helped the child to build little boats of clay or wood so as to study the child's knowledge of the relations between form, volume, and the capacity for floating. Most important, when the child said that wood floated because it is light, Piaget brought forward two equal volumes of wood and water and asked the child to say which will be heavier.

Piaget found that roughly four stages appeared in the development of children's explanations for floating. During the first stage, which ended at about five years, floating was explained by animistic and moral reasons: "It will lie on the water, because they always must lie on the water" or "The boat is cleverer than stone" (1969a: 136). During the second stage, which extended on the average from ages five to six, children thought that boats floated because they were heavy: "It stays on top because it is heavy" (1969a: 137). During the third stage (average ages six to eight), the children stated that boats floated because they were light, but not realizing the precise relationship between flotation and displaced water: "Because the wood is light. They (the boats) can stay on the water" (1969a: 144). Finally, at about nine years of age, the children began to understand the true relation between the weight of the boat and the weight of the displaced water: "They (the boats) are hollowed out inside. There is air. The air prevents them from going to the bottom of the water" (1969a: 153).

This work on floating was accomplished prior to the development of his conservation experiments and first publication in 1942 of his previously discussed stage theory of cognitive development in the Psychology of Intelligence (1966b). Thus, the stages just described bear only a loose resemblance to his later and more well defined ideas. Yet, this experiment documents the development in physics of what Piaget later calls formal operations.

Einstein suggested to Piaget in the early forties that it might be of interest to investigate the child's understanding of time, velocity and movement. He published two books on these matters in 1946, The Child's Conception of Time (1969b) and The Child's Conception of Movement and Speed (1970).

These works along with his 1948 work The Child's Conception of Space (1967) contain a wealth of physics experiments which can potentially be adapted to research among the Tlingit. Among the experiments given in these works and others are those assessing the conservation of time, number, liquid, mass, weight and volume; alternative directions of movement; velocity; codisplacement; the projection of lines; geometrical sections; the rotation of surfaces; the measurement of time; and simultaneous events. The researcher should not choose the experiments to modify to model familiar Tlingit subsistence activities until the first year's participant-observation fieldwork is well under way.

Further, Piagetian-type experiments not invented by Piaget can be imagined. For example, it might be possible to assess the development within Tlingit children of the idea of curvilinear motion in two dimensions: the curved motion of a body in a force field. In this hypothetical case, one could shoot a bullet, a common hunting activity, and ask why one must aim above objects located long distances away. However, the researcher must create such experiments after the first year of this study has been completed in order to insure their relevance to Tlingit children.

Conclusions:

Using an example of researching indigenous physics knowledge among the Tlingit, we have seen that the purpose of this two-year research strategy is threefold: 1) to study the formal concepts of physical science and mathematics implicitly utilized in the subsistence activities of American Indians and Alaska Natives, 2) to create culturally-sensitive Piagetian-type experiments to assess the extent to which any native youth of any age has acquired a latent understanding of the formal concepts of physical science and mathematics through his/her observation and participation in subsistence activities, and 3) to lay the theoretical and methodological foundations for developing culturally-sensitive, classroom-instructional procedures for teaching physical science and mathematics to children and adolescents of culturally diverse populations.

I believe that children of all ethnic communities acquire physical science and mathematics knowledge at least on a concrete level based on their involvement in everyday activities. Even children in urban areas have a wealth of interaction with the physical world which illustrates physical science and mathematics principles. If ethnic youths are to be successful in careers in high technology, they must be able to learn the formal aspects of their concrete knowledge. If the latter is to occur, the knowledge they acquire in their own communities must be understood and translated into culturally-sensitive experiments for use in classroom situations. The two year research strategy outlined makes this translation possible.

NOTE

1. This research strategy was developed in collaboration with Donald Greenberg, a physicist with the University of Alaska, Juneau and Douglas R. Price-Williams, a cross-cultural psychologist with the Departments of Psychiatry and Anthropology at the University of California, Los Angeles. Donald Greenberg is in the process of conducting a pilot study funded by the Research Council of the University of Alaska, Juneau. A copy of a fully developed research proposal can be acquired by writing George M. Guilmet, Department of Comparative Sociology, University of Puget Sound, Tacoma, Washington 98416-0130

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