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Complementarity, Ethnomathematics, and Primary Education in Bhutan

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The principle of complementarity, as used in quantum mechanics and as revealed through research on hemispheric specialization of the human brain, suggests that there are two complementary modes of knowing. It was the goal of this investigation to defend such an assertion and to portray how complementarity could be considered as a theoretical structure for the concept of ethnomathematics. The principle of complementarity states that two concepts, though mutually exclusive, are nonetheless both necessary for a complete description of the phenomenon. Niels Bohr firmly believed that complementarity had wide application outside the realm of physics and declared that one day complementarity would be taught in schools and become part of public education. Ubiratan D'Ambrosio has been credited with coining the term ethnomathematics and in this research it relates to how counting, ordering, sorting, measuring, and weighing are inherent within the songs, games, and play activities of Bhutanese children. Consequently, this research focuses upon a pedagogical process involving the complementary relationship between mathematics within the world of play and the world of school of Bhutanese children. Employing a descriptive methodology, a case study involving two lower primary classes, their teachers, the teacher trainees, and the investigator as a participant observer, was conducted during the school year of 1987 at the Teachers' Training Centre and Demonstration School (TTC/DS), Paro, Bhutan. The analysis of data presented the analytical term: propositional theme. Lastly, implications of this research are drawn for the education of the whole child, for future research focusing upon complementarity and ethnomathematics, for Bhutan's New Approach to Primary Education (NAPE), and, finally, for the survival of children in the third world.

Le principe de la complémentarité suggère qu'il y a deux modes complémentaires d'apprentissage. Ces deux concepts sont, tout en étant exclusifs, néanmoins nécessaires pour une description complète du phénomène observé. L'objet de cette recherche est de supporter ce principe et de démontrer comment la complémentarité peut être utilisée comme structure théorique dans le concept d'ethnomathématiques. Cette recherche explore un processus pédagogique impliquant la relation de complémentarité entre les mathématiques dans le monde du jeu de l'enfant et dans le monde de l'école. L'étude de cas utilise une méthodologie descriptive et implique les acteurs de deux classes primaires au Bhutan. A partir des résultats de la recherche, les auteurs en dégagent les implications sur le développement intégral de l'enfant, sur la complémentarité et l'ethnomathématiques, sur la réforme de l'éducation primaire au Bhutan et enfin sur la survie des enfants dans le Tiers-monde.

Bhutan, a tiny eastern Himalayan country, first opened its doors to the west a short three decades ago. Until that time, Bhutan remained virtually unknown to the rest of the world. Hidden among the high Himalayan mountains, this small monarchy remained self-sufficient with the exception of contact with India, its most influential neighbor.

The United Nations classifies Bhutan as one of the 31 least developed countries in the world having an estimated per capita income of U. S. $116.00 per year. In an effort to expand its economy from one solely based on agriculture and cattle rearing, Bhutan in 1961 initiated the first of a series of five-year plans. The major goal of these plans has been to effect a structural

transformation in the socioeconomic system and, more specifically, to change a barter system into a modern economy. Consequently, education has been designated by the Royal Government of Bhutan as a major focus for development (Strydonck, Pommaret-Imaeda, & Imaeda, 1984).

The total number of primary (elementary) schools in Bhutan in 1987 was 149 and this was far from enough to house all of the school-aged children. It is reported that only 25% of the primary-aged population were enrolled in schools in 1987 and this reflects the low literacy rate of 23%. This literacy level and the number of children attending primary schools form the lowest levels in the south Asia region and are among the lowest in the world (Department of Education, 1988).

The fifth development plan (1981/82-1986/87) differed substantially from the previous plans in that rather than expanding educational infrastructure, it aimed at improving existing programs and facilities by: enhancing the quality of education through curriculum reform, upgrading teacher training programs, and reorganizing technical education (United Nations Development Program, 1985).

An example of this educational reform at the primary school level started in the spring of 1985 when the Department of Education began planning for the implementation of a different approach in the pedagogy of a new primary school curriculum.

Purpose

Pedagogy as an Actualization of Complementarity

What is of extreme importance in the development of education within Bhutan is the method by which elementary school mathematics is taught. Barcellos (1981) asserts that primary school curriculum throughout the world is basically the same but the needs of children in the third world are distinctly different from those of children from industrialized countries. This international mathematics educator also stresses the vital significance of how mathematics is taught to children in developing nations. He infers that children in the developing world find it difficult to apply the mathematics that they have learned because they have learned it from outside of their own culture. Consequently, Barcellos affirms that these children cannot see how the mathematics that they have acquired in school relates to the world in which they live.

The present research describes and examines a medium of instruction for elementary school mathematics which has a meaningful relationship to the cultural world in which Bhutanese children live: the world of their songs, games, and play activities. In addition, this investigation seeks to demonstrate that this pedagogical approach is an actualization of the principle of complementarity.

It was in the Italian city of Como, during the 1927 International Congress of Physics, that Niels Bohr initially introduced his formulation of the principle of complementarity (Holton, 1973). Bohr's proposal was that we must accept the inescapable dichotomy that the nature of light is both wave-like and particle-like depending upon how it is observed. He stated that these two descriptions of this phenomenon are complementary, that is, each perspective is required to give a complete picture of atomic reality (Bohr, 1958).

The Nobel Laureate, Niels Bohr firmly believed that the principle of complementarity had wide application outside the realm of physics and stated that one day complementarity would be taught in schools and become part of public education (Holton, 1973). Further, Niels Bohr's deep commitment to the principle of complementarity, and to the antiquity of its roots, is revealed by

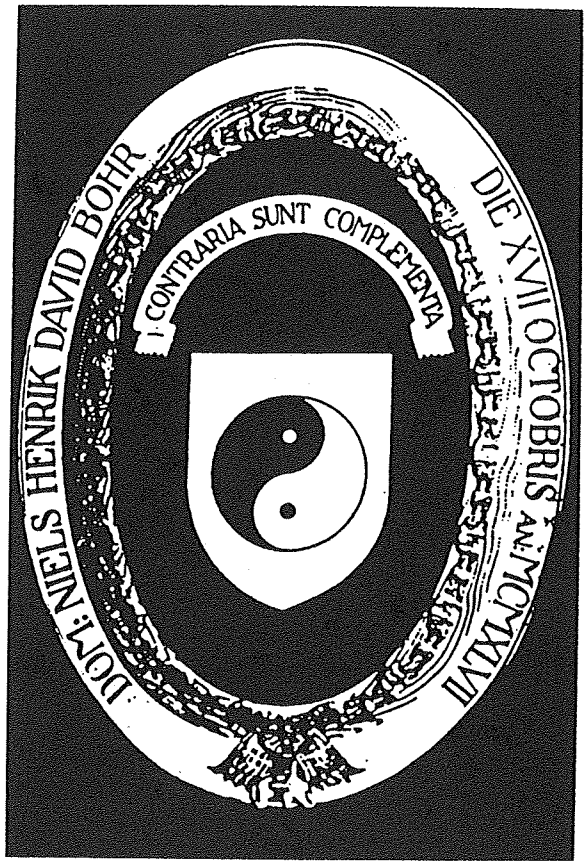

Figure 1. Niels Bohr's coat-of-arms. From Rozental, S. (Ed.). 1967. *Niels Bohr* (p. 304). Amsterdam: North-Holland. Copyright by Niels Bohr Archive. Reprinted by permission.

the fact that he chose the Buddhist t'ai chi symbol for his coat-of-arms when he was knighted by the Government of Denmark (see Figure 1). The physicist, Fritjof Capra (1983) reveals the powerful significance of this decision to be Niels Bohr's acknowledgement of the profound harmony and complementary relationship between modern Western science and ancient Eastern wisdom. Consequently, the Far East country of Bhutan, the only independent nation in the world where Mahayana Buddhism is the state religion, was an ideal setting for an investigation focusing upon the furthering of complementarity as an explanation of human behavior.

In addition, this research intends to extend the principle of complementarity through the results of the most recent research on hemispheric specialization of the human brain. The Nobel Laureate, Roger Sperry, and his colleagues proved that the corpus callosum unites the special talents of both hemispheres. Their ingenious tests demonstrated that humans are undoubtedly of two minds, one specializing in analytical and verbal skills, the other adept in space and pattern perception. The left hemisphere deals with the abstract symbols of language and numbers. It is

> logical, linear, and sequential in processing information. The left hemisphere sorts out parts. In contrast, the right hemisphere was found to grasp things as a whole. It generates mental images of the senses and movement. It is holistic and simultaneous in its processing of information. (Fincher, 1984; Restak, 1984; Springer & Deutsch, 1985)

Most recently, what has emerged from the hemispheric specialization brain research is the realization that the cerebral hemispheres function in a complementary manner (Capra, 1983; Levine, 1984; Ornstein, Thompson, & Macaulay, 1984; Silverstein & Silverstein, 1986). Rather than viewing one hemisphere as being major or minor as in the theory of cerebral dominance, scholars are proposing that the intuitive, holistic thinking right hemisphere complements the analytical, linear processing left hemisphere (see Figure 2).

It has been shown that there are two complementary modes of knowing which have been most strongly revealed through the study of science and religion (Ornstein, 1972).

Recently, these two complementary modes of knowing have been given further support by contemporary research on hemispheric specialization of the human brain. Paradoxically, our brain is structured and functions in a complementary manner: our brain is structured and functions as a whole.

Complementarity as a Theoretical Structure for Ethnomathematics

The second purpose of this investigation centers upon how complementarity could be considered as a theoretical structure for the concept of ethnomathematics. The Brazilian mathematics educator Ubiratan D'Ambrosio (1981) is credited with coining the term, ethnomathematics. He created this concept in the context of developing countries which are striving

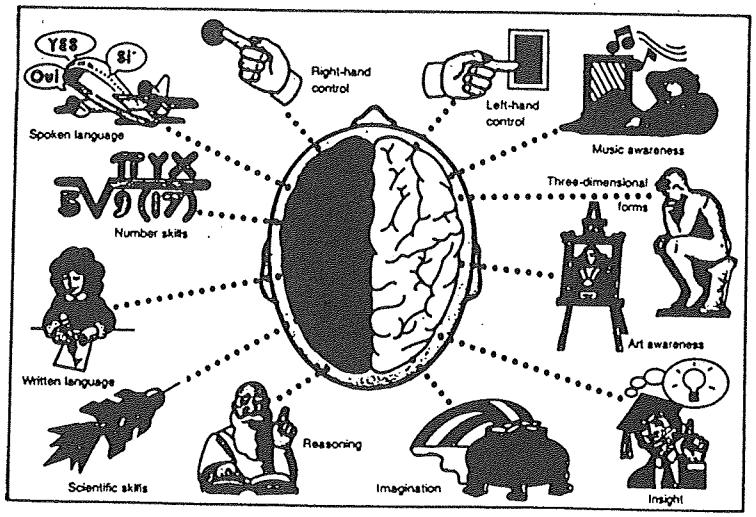

Figure 2. The complementary functions of the brain's two hemispheres. From Fincher, J. (1984). *The brain: Mystery of matter and mind* (p. 32). New York: Torstar Books. Copyright Marshall Editions. Reprinted by permission.

for a more meaningful way to instruct their children in the field of mathematics.

Scott (1985) indicates that ethnomathematics lies at the meeting place of cultural anthropology and mathematics. He states that it has been referred to as math in the environment or community and focuses upon how specific cultural groups go about the tasks of counting, ordering, sorting, measuring, and weighing in their daily lives.

To reiterate, the two research questions that were examined by this investigation are: (a) how pedagogy, which involves teaching elementary school mathematics through the songs, games, and play activities of Bhutanese children, could be an actualization of complementarity; and (b) how complementarity could be a theoretical structure for ethnomathematics.

The Value of this Research for Bhutan

The two primary teacher training institutions in Bhutan, namely, the National Institute of Education (NIE), Samchi and the Teachers' Training Centre and Demonstration School (TTC/DS), Paro, jointly planned and implemented the same primary teacher education curriculum in July of 1986. This curriculum recommended teaching primary school mathematics through such physical activities as: sand play, mud play, stone play, rhythm and movement, circle games, running games, and marble games as well as through the national sport of archery and the indigenous games of "khuru" and "dego."

Further, a new primary school curriculum and pedagogical approach was implemented by the Department of Education in 12 pilot schools along with the Demonstration School of TTC/DS in March of 1986. This curriculum development project, entitled the New Approach to Primary Education (NAPE), stresses the active involvement of children in the learning process and the children's immediate environment becomes the focus and stimulus for subject matter studied. At the first NAPE conference in August of 1986, the former Director of Education of Bhutan asserted that the challenge for teachers within the NAPE program was to integrate learning effectively by memorization with acquiring knowledge through active participation—truly a complementary task.

Lastly, in Bhutan one-quarter of school aged children attend primary schools and of this one-quarter, only a further one-quarter will complete class six (Beyon & De Spiegeleer, 1985; Department of Education, 1988). The government of Bhutan, with this knowledge, believes that the NAPE project has the potential to help children acquire necessary life enhancing mathematical and language literacy skills prior to returning to their farm villages. More specifically, these skills will enable children to increase their knowledge in the areas of hygiene, sanitation, and nutrition before returning to their homes. The government of Bhutan believes that these children can help to prevent the greatest killer of children in Bhutan, that being dehydration due to malnutrition and diarrhea. Therefore, by assisting children to gain mathematical literacy through an integrated pedagogical approach utilizing activities personally meaningful to Bhutanese children, Bhutan's educators believe that schooling will be more life enhancing. It was the intention of this research to support such a belief.

Methodology

Within a naturalistic paradigm, a case study, with the researcher as a participant observer, was chosen as the means by which to investigate how pedagogy could be an actualization of complementarity and how complementarity could become a theoretical structure for ethnomathematics.

Guba (1981) and Guba and Lincoln (1982) indicate that educational research during the past decade has increasingly made use of the naturalistic paradigm. They additionally reveal that the distinguishing features of this paradigm are that it is carried out in a natural setting which utilizes the case study format and that it relies strongly on qualitative or ethnographic-type methods.

The Research Setting. Approval was granted to the investigator by the Department of Education, Royal Government of Bhutan to conduct this research during the 1987 school year. The Teachers' Training Centre and Demonstration School (TTC/DS) was an ideal setting for this investigation based upon the criteria delineated by Spradley (1980), which are: simplicity, accessibility, unobtrusiveness, permissibleness, and frequently recurring activities.

The Subjects. The New Approach to Primary Education (NAPE) and its curriculum were implemented at the Demonstration School of TTC/DS in March of 1986. Since this new pedagogy and curriculum only went up to class three, two teachers from preprimary to class three who had expressed a keen interest in the study were chosen along with their classes (PP A and II B) to participate in the investigation. In addition, the 24 second year and 29 first year primary teacher trainees, referred to respectively as "Batches XI and XII," acted as facilitators in the teaching of elementary school mathematics through the songs, games, and play activities of Bhutanese children.

Collection of Data. The primary research instrument in a case study is the researcher as the participant observer (Eisner, 1981; Herriott & Firestone, 1983; Merriam, 1988; Wilson, 1977). The data collected were primarily in the form of field notes which were equivalent to 247 typewritten pages. These field notes were complemented and supplemented by 25 hours of audio-visual data, 251-35 mm slide film frames, and six hours of audio data.

During a typical week of data collection, four lessons were observed. Two lessons involved the trainees assisting Mr. U. T.'s or Mr. T. N.'s children (pseudonyms for the teachers of PP A and II B) to more fully understand a mathematical concept or problem by using a medium that involved songs, games, or play activities. The second lesson that each group of children experienced was to be a follow-up to the initial lesson and was intended to enable the children to repeat, practice, and apply what they had learned. The classroom teacher was the primary facilitator in the follow-up lesson.

The credibility and trustworthiness of this research was enhanced by the fact that the researcher, on four separate occasions during the period of the investigation, received guidance and consultation in the collection and interpretation of the data from F. Pommaret-Imaeda, an anthropologist (University of Paris, Pantheon-Sorbonne, 1985) who conducted her dissertation research in Bhutan. F. Pommaret-Imaeda is now working as the history consultant for the Department of Education in Bhutan and is currently writing Bhutanese history texts for the elementary and secondary schools (Pommaret-Imaeda, 1988, personal communication).

Moreover, "triangulation" (Merriam, 1988) was additionally achieved during the investigation through numerous discussions with Mr. T. N. and Mr. U. T. concerning the researcher's collection and interpretation of the data. The audio-visual and slide-film data collected also served to create a triangular check on the researcher's interpretation of the data.

Analysis of Data

As recommended by Merriam (1988) the analysis of data has three hierarchical levels: the case record, the creation of themes, and the development of theory.

The Case Record

This case record focuses upon an image-filled description of the data and has as its major objective the transporting of the reader to the research setting. By presenting the case record in a nonevaluative, comprehensive, and descriptive manner, the researcher believes that a context can be provided for the theoretical analysis contained in the next section.

As previously mentioned, the research was conducted at the Teachers' Training Centre and Demonstration School, (TTC/DS), Paro. Two classes , PP A and II B, were observed by the researcher for a total of 91 sessions over the Bhutanese school year from 9 March to 18 December, 1987. Each week the teacher trainees, batches XI and XII, taught one mathematics lesson to either PP A or class II B. This lesson was complemented by a follow-up session by the class teacher, Mr. U. T. or Mr. T. N.

During the course of the year, Mr. U. T.'s PP A class and the trainees covered the topics of matching, making numerals, addition and subtraction of single digit numerals, and measurement. The trainees and Mr. T. N.'s class II B were exposed to the mathematical topics of place value, decimals using money, measurement, fractions, multiplication, and geometry.

All lessons by the trainees involved activities high in movement as well as utilizing the kinesthetic and the tactile modalities. For the majority of cases the sessions took place out of doors. The trainees made use of the existing environment, using stones, sticks, and sand as tools for instruction. However, it was soon discovered by the trainees that the most important teaching aid was always at their disposal: the children themselves.

While focusing on the topic of matching, the trainees involved the children in a series of activities promoting body mirroring, where the trainees would do a particular action and the small PP A children would eagerly attempt to imitate the action they saw. The techniques of stone and sand formations, and the kinesthetic application of drawing numerals in the air or on the children's backs, were used to instruct the PP A children in the formation of numerals.

A running game called "Fire on the Mountain" was used with Mr. T. N.'s class for teaching multiplication. The children would run around and around an imaginary mountain until the caller would shout a number. Upon hearing the number, the children, squealing with delight, raced to group themselves into the number which was called. The groups were then used to introduce multiplication facts through repeated addition. This game was used later in the year to reinforce the geometric concept of shape to class II B.

The indigenous stone game called "Boodeem" was used with Mr. U. T.'s PP children. This game, as most Bhutanese games, involved stones which were always readily available. Ten stones were given to each pair of students and the game began with little explanation as Boodeem was a very popular game among the children.

Small clusters of children could be seen sprinkled around Mr. U. T.'s bare wooden floor, tossing and catching the stones on the backs of their hands in an intricate sequence. The children took turns and at the end of a complete round they would record how many stones each had gathered and then add these numbers to get the sum which was always equal to 10.

Singing became a favorite teaching tool for both groups of trainees as well as the class teachers of PP A and II B. The PP A children enthusiastically sang numerous counting songs taught to them by the trainees. The songs often involved actions and focused upon number sequence in ascending or descending order. The II B class were taught songs, composed by the XI and XII batch of trainees, focusing upon fractions and decimals.

The number line was used effectively by drawing it on the ground out of doors and by having the children jump in order to add single digit numbers. It was further utilized in the pedagogy of subtraction of single digit numbers, as was the versatile game of Boodeem. A new, board game called "Pema Lotto" was introduced to PP A by the trainees (XII batch) to focus upon addition and, later, subtraction.

The trainees made use of sticks and the carved images of clocks in the ground to help the class II B children understand the concept of time. The trainees also introduced fractions to Mr. T. N.'s class through the use of the game "Am I Right?" The game involved a court divided into eight equal parts. The children made a diagram of the court in the classroom before going out to measure and divide the actual court on the dusty football ground at TTC/DS.

Mr. T. N. began the topic of measurement which included the concepts of area, perimeter, volume, capacity, and weight. The children used indigenous forms of measurement such as hand spans and finger widths to measure the perimeter of various objects within Mr. T. N.'s classroom. The II B students placed stones, the indispensable teaching aid, inside containers of different sizes to discover the difference between volume and the previously taught concept of area. Capacity was illustrated by having the children use water as well as something solid like stones or dirt to fill containers. Fine motor skills were always called upon, especially when constructing cubes and cuboids from pieces of paper.

One of the activities used in teaching measurement by Mr. U. T. with his PP A was having the children distinguish between light and heavy by lifting two different objects such as stones or themselves. Gross motor skills were used to introduce the idea of measuring distances; for example, the children, grouped in pairs, did standing broad jumps and then checked to see who had jumped the longer distance.

The Propositional Themes

The strategy of the interpretation focuses upon the use of the analytical

term: propositional theme. Three such themes are derived from the data.

Developing a theme involves interpreting the data by searching for recurring regularities and it may be conceived as a behavioral pattern that actually characterizes the case study. Additionally, the term propositional is used in its mathematical sense and denotes a formal statement of truth to be demonstrated. Thus, in the context of this investigation, a propositional theme is a recurring behavioral pattern which denotes a fundamental truth that will be shown through demonstration to be an actualization of complementarity.

This leads the interpretation to its final stage of analysis, that being the development of and building upon the principle of complementarity as a theoretical framework for a form of pedagogy that exemplifies ethnomathematics.

Explicitly, the analysis for each propositional theme follows this pattern: (a) the propositional theme is stated, (b) the working hypothesis is developed through establishing a connection between the properties of the theoretical research and the pedagogical activities, and (c) the demonstration of the working hypothesis is depicted through a descriptive account. The one descriptive account is intended to act as a representation of the many activities that were used to demonstrate the fundamental truth put forward by the propositional theme. It is beyond the scope of this paper to report all descriptive accounts for each propositional theme; however, the interested reader is referred to Turner (1989) for additional demonstrations of the working hypotheses.

Propositional Theme I
Complementarity: The Voices of Bhutanese Children

Development of the Working Hypothesis

As the Bhutanese religious historian Rigzin Dorji (1983b) has stated, religion plays a significant part in almost every single facet of life within Bhutan. "From archery contests to the painting of murals, from the phenomenon of birth to that of sickness and death, almost each significant moment in the life of a Bhutanese is, in one way or another, linked with religion" (p. 40). A characteristic of any religious event or festive ceremony in Bhutan is the recitation of Buddhist prayers, the chanting of religious mantras, and the singing of Buddhist songs.

Further, in an article entitled "Spiritual Living: Enthusiastic Enjoyment—Daily Life and Entertainment," Dorji (1983a) speaks of the customs that are involved in the building of a house in Bhutan. When a house is built, it is traditional for neighbors to assist in the construction. "While the men-folk engage in the more strenuous activities, the women pound mud or help carry it to the allotted places. As in almost every public occasion, these tasks are

accompanied by much singing" (p. 8-9). As one can see, religious events or public occasions in Bhutan are marked by singing.

In addition to the complementary relationship that exists between singing, as a part of Bhutan's culture, and elementary school mathematics, there lies support for this proposal within hemispheric research of the human brain. Studies focusing on hemispheric specialization have discovered a right hemispheric superiority for singing and the musical qualities of melody, pitch, and timbre; left hemispheric superiority has been shown for the analytical musical quality of rhythm (Bever & Chiarello, 1974; Gordon & Bogen, 1974; Goodglass & Calderon, 1977; Gates & Bradshaw, 1977). Therefore, it is hypothesized that the teaching of elementary school mathematics through songs of Bhutanese children will be an actualization of the principle of complementarity.

Demonstrative Account

Mr. T. N.'s Children, the Trainees, and Songs of Place Value. On 30 April, 1987 during the first class period, the researcher and the trainees (XI batch) met and discussed mathematics methodology, specifically the teaching of place value and the function of the decimal point with money. Afterwards, the trainees were divided into two groups, A and B. Group A was subdivided into two groups each of which was to create a song integrating the decimal point, place value, and money (rupees and paise). These groups would teach their songs during the second half of the period with Mr. T. N.'s children. Group B was divided into six pairs and discussed an activity in which each child of their group would represent a digit and change places in order to alter the value of the number. Each pair of trainees had six children to work with in their respective areas and each pair approached the methodological problem similarly by having the children physically change places in order to create the numeral given.

After 25 minutes the trainee groups, who were to teach the song that they had created, subdivided into four groups and subsequently went to each of the areas for teaching purposes. One group had created the following song which was sung to the tune of "I'm a Little Teapot."

Zero to Nine

We are learning about maths, 0 to 9
If we learn it nicely, that's very fine
Oh! When we use the decimal, we get confused
But the decimal there can be used
Here is an example showing to you
1.25, example for you.

The other group taught the following song in which the lines within parentheses were each sung twice:

Meeting Place is Decimal Point

If we move figure one place left
(It will be 10 times big)
If we multiply that by 10
(It will move, to next place value)
If we divide that by 100
(It will move to right place value)
Meeting place is decimal point
(For it separates rupees and paise).

Mr. T. N. decided to continue singing the songs during the next period within his classroom. The researcher observed this singing period and the lesson concluded with the children copying the songs into their exercise books while pronouncing and singing the lyrics.

Propositional Theme II
Complementarity: The Indigenous Games of Bhutanese Children

Development of the Working Hypothesis

The use of Bhutanese children's games in the teaching of primary school mathematics displays a complementary relationship between their world of play and their world of school. If Bhutanese children are educated to see how mathematics is an inherent part of their indigenous games, then a bridge shall be constructed between these two worlds that appear to be separate. By recommending that children learn mathematics through such physical activities as: stoneplay, running games, marble games, and other traditional games, Bhutanese curriculum developers are intuitively suggesting that children can and should learn mathematics through an ethnomathematical medium.

Inherent within the indigenous games of Bhutanese children lie the ethnomathematical operations of counting, ordering, sorting, measuring and weighing. D'Ambrosio (1981; 1985) points out that teachers must adopt a different role in the holistic education of children in the developing world in order to assist children in their perception of reality. This reality for children is what is of value and interest to them; hence, it can be their indigenous games. D'Ambrosio asserts that the teachers' role must be one of stimulating critical reflection by the student upon the student's perceived reality (see Figure 3).

Metaphorically speaking the role of the teacher advocated by D'Ambrosio (1981; 1985) will be the same as the role of the corpus callosum within the human brain. That is, the corpus callosum's major function is to transmit information between the two complementary hemispheres of the human brain as the function of a teacher shall be to allow the perceived world of children's play to communicate with and be part of children's perceived world of schooling. Thus, D'Ambrosio is proposing that what is of most importance for a teacher in the developing world is to be able to sense a child's perception of reality and a child's drive toward action. This chain of reasoning leads

D'Ambrosio to conclude that mathematics must be a part of the context in which the child lives or it will become a useless appendix to the educational experience of children.

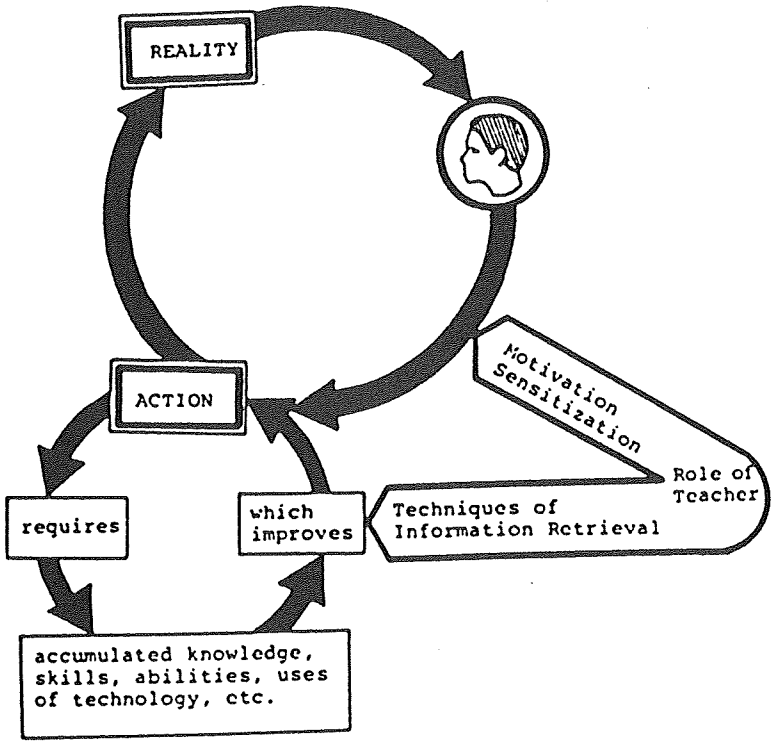

Figure 3. The new role of the teacher in the education of children in the developing world. From D'Ambrosio, U. (1981). Uniting reality and action: A holistic approach to mathematics education. In L. A. Steen & D. J. Albers (Eds.), *Teaching teachers, teaching students* (p. 40). Boston: Birkhauser. Copyright 1981 by Birkhauser. Adapted by permission.

Mathematics is primarily associated with the left hemisphere because of the left hemisphere's analytical, sequential, and logical predominance in the processing of information (Restak, 1984). In contrast, the right hemisphere is referred to as being the nonverbal, nonmathematical, minor hemisphere which has its own perceptual, mechanical, and spatial mode of apprehension and reasoning (Sperry, 1983). However, researchers have recently advocated that the two halves of the brain work together in all our activities, each contributing their own special skills and thus complementing each other (Capra, 1983; Levine, 1984; Ornstein, Thompson, & Macaulay, 1984; Silverstein & Silverstein, 1986). Therefore, it is hypothesized that the teaching of

elementary school mathematics through the indigenous games of Bhutanese children will be an actualization of complementarity.

Demonstrative Account

Mr. U. T.'s Children and the Stone Game of "Boodeem." For the purpose of assisting his children in learning to add single digit numbers and learning to record the addition algorithm in a horizontal manner, Mr. U. T. decided to make use of a stone game called Boodeem. This game was chosen because many of the preprimary children as well as some class ones had been observed playing this game in their free nonclass time.

On Tuesday, 16 June, Mr. U. T. began by dividing the class into pairs while distributing to each partnership one pencil, ten stones and two pieces of paper. Speaking in Dzongkha (Bhutan's national language) Mr. U. T. explained that each child should put his or her initial at the top of one column and the partner's at the top of the second column. Mr. U. T. or the researcher had written on each piece of paper the word "sum" as the heading for the third column.

The children started to play the game of Boodeem with both children in each pair tossing the 10 stones separately. The child who caught the most stones on the top of his or her hands won the right to begin the game. The videotape data disclosed that the remainder of the game primarily consisted of striking one stone with another that had been propelled by the flick of a finger as in the game of "croquinot." A player could not attempt to capture a stone that was less than a finger width from the one that he or she was striking. Thus a custom of the game was for a child always to draw a finger between the two stones before attempting to flick one at the other. A round ended when all 10 stones had been collected by one or both of the children. It was at the end of a round that children recorded how many stones they had gathered and then added these numbers to get the sum which should have been always equal to 10.

The video-tape data revealed that all of the children enthusiastically played the game and displayed a high level of time-on-task. Further, the majority were successful at being able to record and calculate the sum of their scores. Sitting on the floor in a cross-legged position, the children tossed, flicked, counted, and added the stones for over 60 minutes.

Propositional Theme III

Complementarity: Movement and Bhutanese Children

Development of the Working Hypothesis. It seems most fitting and opportune that this research was conducted during the 1987 year when the United Nations Children's Fund (UNICEF), the world organization for the well-being of children and the founding organization of TTC/DS, had as its calendar

theme: "Learning to Grow." In the prologue of that calendar the following is stated:

> Children learn through their *senses and movement* [italics added]; each day is different and filled with new discoveries. Their first steps are as astounding as man's first steps on the moon. Their new experiences reawaken the child in the observing adult and recreate the sense of wonderment in learning and growing, for the world of children is an expanding spiral of consciousness of themselves, of each other, of adults, and of the natural environment around them. (UNICEF, 1987, p. i)

During the first five years of life, children learn predominantly through their senses and movement; thus, the kinesthetic sense, our sixth sense, plays a fundamental role in this learning and growing process (Balaskas, 1977; Blakeslee, 1980; Wittrock, 1977). Kinesthesis refers to the sense of movement and position of the limbs that depends upon sensory receptors in joints, muscles and tendons (Talbot, 1977).

The mathematics educator Donald Albers (1981) has claimed that children's bodies are the most powerful and richest source of mathematical knowledge that there ever was. He continued by asserting that their own body knowledge is a form of intuitive geometry and since they were born they have learned through their senses and movement that each day is different and filled with new discoveries.

The hemispheric brain research extends the importance of the complementary relationship between the two hemispheres by suggesting that the right hemisphere is superior to the left in the kinesthetic mode (Carmon, 1970; Corkin, 1965; Fincher, 1984; Levin, 1973). It is also known that the left hemisphere is superior to the right in the verbal, linear, and sequential processing of information, and thus mathematical calculation (Blakeslee, 1980; Ornstein, 1972; Restak, 1984; Springer & Deutsch, 1981). Therefore, it is hypothesized that the teaching of elementary school mathematics through movement with Bhutanese children will be an actualization of complementarity.

Demonstrative Account

Mr. T. N.'s Children, the Trainees, and the Concept of Measurement. On Wednesday, 20 May, in a mathematics methodology period, the trainees (XI batch) and the researcher discussed the concept of measurement and the best way to introduce linear measurement to Mr. T. N.'s children through the use of their bodies. The trainees suggested using traditional ways of measuring such as hand and arm spans, as well as strides, footsteps, and finger walks.

Children could be seen using their hands, feet, and arms to measure distances; for example, in the trainees' classroom, one trainee had his student using hand spans to measure the height of a chair while another had his student measuring the length of the blackboard with his forearms. One

student teacher's pupils measured the width of the trainees' classroom utilizing footsteps.

In all instructional areas, and as the videotape data revealed, the children made use of different body parts in the linear measurement of floors, walls, desks, chairs, windows, doors, blackboards, tables, books, and each other's height. Again, the children showed a high participation ratio because of working in small groups, which were scattered throughout four teaching locations.

Indicators of Student Achievement

Time-on-task

In an article entitled "*What School Factors Raise Achievement in the Third" World?"* Fuller (1987) reports findings from more than 60 third world investigations on what school characteristics do and do not appear to contribute to pupil achievement. These studies were categorized within five school factors, which were: (a) school expenditures, (b) specific material inputs, (c) teacher quality, (d) teaching practices and classroom organization, and (e) school management and structure.

After reviewing 14 third world studies which focused upon the school factor of "teaching practices and classroom organization," Fuller (1987) reached the following conclusion: The duration of instruction was consistently related to improved student performance. That is, within these 14 studies the length of the instructional program, expressed as hours per day or days per week, was consistently related to higher student achievement. Fuller concludes by stating that "the length of instruction was significantly related to achievement in 12 of 14 analyses" (p. 283).

The implication of this finding is that if students display a high level of time-on-task during their instructional sessions then achievement will be enhanced. This implication is based on the fact that educational researchers frequently utilize time-on-task as an indicator that learning is taking place (Borg & Gall, 1983). Thompson (1988) concurs by stating: "Descriptive research has led to the importance of time-on-task as a process variable that relates to pupil learning" (p. 17).

For this research, the importance of this chain of reasoning lies with the audio-visual and written documentation of the high level of time-on-task exhibited by Mr. U. T.'s PP A children and Mr. T. N.'s II B children during the instructional lessons. Fuller (1987) suggests that student time-on-task is an extremely important educational variable. He states:

> Classrooms vary enormously in the amount of time actually spent on instructional tasks rather than keeping order, checking each student's homework, or arranging lessons. And efficient use of classroom time is [also] related to pupil performance in industrialized nations. . . . Considerable progress on this potential of school efficiency could be made in the third

world—by sharpening classroom management and teaching skills within constrained levels of material inputs. (pp. 283-284)

Self-reports

Fuller (1987) continues by disclosing that pedagogical practices have received only minor attention from researchers working in the third world. Out of the 60 studies reviewed, he reports only three studies that examined the effect of active learning through participation as compared to a chalk-and-talk pedagogical approach. One of these studies in rural Brazil discovered a consistent positive effect on pupil performance as a result of the number and variety of instructional activities reported by teachers. The teachers employed nine different activities, such as small work groups, dramatic reading, manual work, and storytelling. The results suggest that the variety and total number of activities helped to explain the high pupil achievement. Since this last study appears similar to this present investigation, more credibility can be given to the self-reports which follow.

Mr. T. N. In an article entitled "*New Approach to Primary Education,*" published in an educational document by the Department of Education, Bhutan (1988), Mr. T. N. made the following statement about the NAPE project and the children of this investigation:

> NAPE is the New Approach to Primary Education which deals with modern methods of teaching and learning in all subjects. . . . The NAPE program deals with relevant methodology and syllabus according to the situation of Bhutan. It emphasizes not only reading and writing but also other important roles in the development of children: physically, socially, emotionally, and intellectually . . . . The fruitful result of the NAPE program will not be seen in a year. When the children are brought up step by step, we can see the vast difference in learning. I see the example of my own children who are in their third year of a NAPE class. They have been in the NAPE program right from class one. After the third year of learning through NAPE, I can see lots of improvement in learning, understanding, reading and writing. I am proud to see their skills. When I was in standard V [class V], I didn't achieve the skills that they have now. I am sure that students of other NAPE schools who have been learning through the NAPE program for three years are more advanced and developed than other class III students of non-NAPE schools. (p. 5)

Further evidence in support of the NAPE project and this research is revealed by the fact that there has been a significant increase in attendance at NAPE schools, including the demonstration school of TTC/DS, not only by students (11%) but also by teachers (9%), since the implementation of the project in March of 1986 (Turner, 1988b). The reader may recall that one of the purposes of this research is to give support to the NAPE project. The former Director of Education stated at the first annual NAPE conference in August of 1986, that the challenge to the implementers and the teachers of this new pedagogical approach is to effectively integrate learning by rote with learning through active participation: a complementary task. Consequently, this research is in support of, and is an extension of, the overall NAPE philosophy.

Mr. U. T. and his PP A Class. On 18 May 1987, Mr. U. T. was requested to interview separately each child of his class and pose the following questions:

(1) Do you enjoy working with the trainees on Mondays? and (2) If yes, what do you like about working with the trainees? Mr. U. T. recorded on a checklist the children's responses and gave permission for this information to become part of the data for this research. Of the 34 children present, 28 (85.5%) said they liked working with the trainees while only four (12.5%) said they did not. Mr. U. T. stated that only eight students were able to verbalize why they liked the experience and of these eight, six students stated "songs" for their reason.

In a subsequent tape-recorded interview on 25 May 1987, Mr. U. T. and the researcher formally discussed the study thus far and the results of the children's responses to the above two questions. Mr. U. T. was asked why he believed that the majority of his class enjoyed the lessons with the trainees. He stated that small groups, varied activities, going outside, and attention from the trainees were reasons for his children's positive attitude towards the classes.

In response to the question: What are your thoughts on learning mathematics through these activities? Mr. U. T. stated that after graduating from TTC/DS, he has been teaching PP for five years at the demonstration school and has always made use of active learning. However, the variety and frequency of the activities this year had enabled his children to master being able to form their numerals and had solved a recurring problem involving the reversal of numerals such as three, six or nine.

A further indication of the overall achievement of Mr. U. T.'s children in the field of mathematics was that, by the end of the year, they were able to progress to the class one mathematics syllabus and began subtraction of single digit numerals. Mr. U. T. stated that this was the first time in his teaching career that almost all of his PP class had progressed to this level.

The Trainees. During the time period from 10 August - 8 October 1987, the XI batch of trainees took part in their major eight week practice teaching assignment. These 24 trainees were designated to various primary schools in Bhutan and upon returning to TTC/DS after their practice teaching assignment, many trainees remarked how advanced Mr. T. N.'s class II were in comparison to other class II's they had observed. However, it is important to note that all of the factors that Fuller (1987) delineates as being highly effective in boosting student achievement in third world schools are present at TTC/DS and, more than likely, are not present at most other primary schools in Bhutan. These factors are: text books and instructional materials, years of teacher training, school library activity, length of instructional program, and pupil feeding programs. This suggests that the pedagogical practice utilized in this research was probably a significant factor in contributing to the achievement of these pupils because of the instructional materials used, as well as the high time-on-task exhibited by the students during their instructional program.

In the opinion of several trainees, Mr. T. N.'s children were progressing exceptionally well because of the use of small groups and because of the

"playway method," which appeared to leave an imprint on the minds of these children.

Other Teachers. From 3 June to 3 July 1987, the stone games of "Apeygodo" and Boodeem were introduced to Mr. U. T.'s PP A class for the purpose of teaching addition of single digit numerals. These stone games were observed by two other PP teachers and by the two class one teachers. Consequently, the two PP teachers began to use these ethnomathematical games in the teaching of addition to their children. Further, the two class one teachers requested the researcher to conduct a one day workshop with their children utilizing these ethnomathematical games. This workshop was conducted on Saturday, 13 June 1987, and Apeygodo and Boodeem were subsequently used in the mathematics lessons of these classes for learning and practicing the fundamental operations of addition and subtraction.

The Researcher. In conclusion, Borg (1981) asserts that the significant advantage of direct observation is that it allows the researcher to collect direct data about human behavior that can be gathered only indirectly by such measurement techniques as a pen-and-paper test. For example, we can probably learn much more about children's attitudes toward a certain form of pedagogy by observing their interactions with one another while participating in the teaching medium, as compared to asking questions about the teaching strategy on a pen-and-paper test. Taking from Borg's ideas, the following questions are well suited for study by direct observation: (a) What specific teaching strategies are most effective to teach basic number facts to Bhutanese children? and (b) How do Bhutanese children respond to a form of pedagogy that involves their songs, games, and play activities.

Based upon direct observation, the sections of this paper focusing upon the case record and the propositional themes have reported that the children of this study were effectively taught elementary school mathematics through their songs, games, and play activities. Further, the above data as well as the audio-visual data disclosed that these children had a positive attitude towards this pedagogical process.

Conclusion

Inherent within the everyday life of Bhutanese children is the act of singing, of hearing, of reproducing sound. From the recitation of Buddhist prayers, to the chanting of mantras, to the singing that accompanies Bhutanese dance, Bhutanese children have developed a unique skill at being able to receive and reproduce sound. Further, it has been stated that a child's body is the most powerful and richest source of mathematical knowledge that there ever was. D'Ambrosio (1981; 1985) has emphasized that the teacher's role must be one of helping a child to reflect critically upon his or her reality in order to discover how mathematics is inherent within a child's everyday life. Hence, it has been a goal of this research to portray how children can be given an opportunity to

reflect critically on their perceived reality and discover how their bodies, and extensions of their bodies, can be a rich source of mathematical knowledge.

In conclusion, this chain of reasoning allows one to state that the teaching of elementary school mathematics through the songs, games, and play activities of Bhutanese children is an actualization of complementarity and an exemplification of ethnomathematics. Complementarity has been demonstrated through a pedagogical process that taps both hemispheres of the human brain. Complementarity has been demonstrated by integrating a child's world of play with a child's world of school. At a given moment in time, these worlds are mutually exclusive, but they are the worlds of the same unified child and because they are polar opposites, they do influence each other in a recursive and complementary manner (Sawada & Caley, 1986).

It has been this extension of the theoretical validity of complementarity and the use of complementarity in the explanation of human behavior that allows one to state that this investigation has made an original contribution to knowledge and a further expansion of complementarity as a theoretical framework for understanding how children learn mathematics. In short, this research has been a realization of Niels Bohr's belief that complementarity could one day become part of public education.

In addition, research support has been systematically documented for the pedagogical recommendation within the new curriculum of the two teacher training institutions of Bhutan, that children can successfully be taught mathematics through such activities as sandplay, mudplay, stoneplay, circle games, throw and target games, as well as indigenous games. This research was used to support the above pedagogical recommendation which, thus, remained within the mathematics methodology section of the revised primary teacher education curriculum. This revised curriculum was implemented at NIE and TTC/DS in July of 1988 (Turner, 1988a, 1988b). In a statement by Thornley (1985), contained within the Canadian International Development Agency (CIDA) publication of *Development (Education),* he concurred with the international contribution of research such as this by affirming that "platoons of classroom teachers have given way (a sign of progress) to smaller numbers of specialists responding to precise requests for help in crucial areas, such as curriculum development or teacher training" (p. 1).

Implications

For the Education of the Whole Child

Hemispheric brain research suggests, as does the t'ai chi symbol of yin and yang, that there are two ways of knowing. One is rational and analytic, the other intuitive and synthetic. The scientist is known for rigorous logic, the artist for spontaneous intuition.

This research suggests that children can learn mathematical literacy and problem solving skills through a pedagogical approach that taps both hemispheres of the human brain, that taps the two major ways of knowing, thinking, and responding. The functions of each hemisphere are complementary and, thus, create a singular, whole personality and intellect. Therefore, an education, which includes dance, drama, music, and art as well as physical education must be given equal status to that of the 3Rs in curriculums throughout the world, if development of the whole child is to be realized (Bogen, 1975; Sperry, 1983).

For Future Research

In the article entitled, "*Third World School Quality: Current Collapse, Future Potential,*" Fuller and Heyneman (1989) state that:

> Research in developing countries should however, provide more textured portraits of life in classrooms . . . . Anecdotes abound regarding the chalk-and-talk pedagogical method employed by many third world teachers. But we have few concrete descriptions of how teachers interact with pupils, how student exercises are structured and evaluated, and what forms of knowledge are communicated. (p. 17)

Thus, the value of this research is extended by having provided the first comprehensive, textured, and longitudinal description of the "lived experience" of two Bhutanese primary classrooms at TTC/DS. Moreover, longitudinal studies of this nature are needed in other primary schools of Bhutan as well as other elementary schools throughout the third world. In addition, supplementary research is required concerning the complementary relationship between active learning and learning by rote in elementary school mathematics as well as other subject areas. Research of this nature could further investigate the principle of complementarity as a basis for epistemology. Lastly, research focusing upon the complementary relationship between math in the environment and math in the classroom could strengthen the concept of ethnomathematics and further extend the principle of complementarity as a theoretical structure for ethnomathematics.

For the NAPE Project

The international educationalists, Fuller and Heyneman (1989) also report a study conducted in Nigeria and Thailand in 1987 where it was found that teachers spent 66% of their time lecturing to children and when they did ask questions, a choral, factual response was expected. In contrast, the concrete descriptions in this research of the interactions between teacher and student, as well as between student-teacher and student, suggest that children have a positive attitude towards participation in instructional activities that involve their songs, games, and play, which fosters a high level of time-on-task. An important educational implication for Bhutan is that this pedagogical approach can be effective in creating a positive learning environment by synthesizing

learning by rote with learning by activity. Therefore, this research intimates that the NAPE approach can be effective in the primary schools of Bhutan.

For the Survival of Children

Most importantly, the educational implication of this research for Bhutanese children is that they can learn fundamental mathematical skills through an ethnomathematical medium that involves the study of their songs, games, and play. Consequently, it is possible for the three in four children that begin primary school in Bhutan, and subsequently return to their farming village before completing class six, to see how the mathematics that they have learned in school is a part of and relates to their culture.

The vital significance of this final implication for Bhutan may be seen by focusing upon UNICEF's "GOBI" project. The acronym GOBI represents the growth monitoring, oral rehydration, breast feeding, and immunization of children in the third world.

The educational implication of this research is that children can learn through their play the basic numeracy and literacy skills necessary to efficiently and independently administer the GOBI techniques. As D'Ambrosio (1981, 1985) has stated, if teachers can guide children to reflect critically upon their perceived reality, then these children can see how the mathematics that they study in school relates to the world in which they live. For the children of the third world this can be the difference between life and death.

It seems fitting to conclude this paper with a paradoxical and, yes, complementary message from UNICEF's 1987 calendar: *Learning to Grow.*

> The colour photographs selected for this edition represent many of the ways by which children learn — through everyday activities, imitation, practice and instruction. *They are shown both in spontaneous activities which largely determine how they acquire knowledge, as well as in more formal learning situations.* [italics added] (p. i)

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