MATHEMATICS, PRIOR KNOWLEDGE, AND THE AUSTRALIAN ABORIGINE

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This paper reviews research related to mathematics achievement of Aboriginal students, studies of cognition, including a cross-cultural comparison studies and within culture studies, and aspects of culture and language pertinent to mathematics learning. The term ethnomathematics *and its significance is discussed, and research in this vein is reviewed. The paper concludes that an understanding of the nature of an individual's prior knowledge is critical for successful learning. For the Australian Aborigine there is evidence that sophisticated intellectual functions have been developed for dealing with quantitative and spatial problems arising in traditional environments which teachers should take account of when planning instruction. Some attention is given to the question of using card game skills as platforms of teaching elementary mathematics knowledge.*

MATHEMATICS ACHIEVEMENT

By conventional yardsticks, achievement levels of Aboriginal children in mathematics have been shown to be poor. Bourke and Parkin (1977) analysed numeracy data from Aboriginal children aged ten and fourteen years. Within each age level children were allocated to either one of two groups. Group One consisted of Aboriginal children attending remote schools on missions, stations and settlements in the Northern Territory. Because of their location these schools were mainly attended by only Aboriginal students. Group Two consisted of Aboriginal children attending other schools, both in the Northern Territory and other parts of Australia. Metropolitan and non-metropolitan schools were included in the Group Two sample. Aboriginal children formed a small proportion of the numbers enrolled in any school - - the majority of students being of European origin. The test items used were considered to represent a minimum standard necessary for normal functioning in everyday Australian society. Table 1 summarises information contained in the report.

Aboriginal children did not or could not attempt selected items on the tests either because they failed to respond within the required time limit or the test was considered beyond the child's capacity and was withdrawn by the teacher supervisor. The results show quite clearly that a majority of Aboriginal children performed poorly on tests of basic arithmetic, with Group One children worse performers than Group Two children.

De Lemos (1979) investigated school achievement of Aboriginal children attending Grades 2, 4 and 6 in Victorian primary schools. She included a comparison group of children attending the same school as well as a random sample of children attending suburban Melbourne schools. Two mathematics tests, selected from the AM series of the ACER (1970) mathematics tests, were a computation test (AM4), and a money test (AM5) which included items related to making change. A comparison of standard scores (De Lemos, 1979, p.48) showed the curves for the Aboriginal and non-Aboriginal group to be similar. Aboriginal scores on the computation test (AM4) indicated that this sample experienced greater difficulty relative to the non-Aboriginal groups, whose standard scores approached those of the Melbourne sample. The AM4 test is non-verbal. All items are presented in the form of questions, using only numerals and conventional mathematical symbols. Other tests given by De Lemos included measures of non-verbal ability, reading skills, basic numerical and quantitative concepts, social studies knowledge, and listening skill. In addition, a rating was made of socio-economic status based on the father's occupation. Correlations between test scores and socio-economic status showed that at the Grade 2 level all test scores correlated significantly with occupational ranking for non–Aboriginal children. The Aboriginal group showed a significant correlation between mathematics performance and father's occu-

In Research in Mathematics Education in Australia, 1983, 1, 13-24

TABLE 1: NUMBER PERFORMANCE OF ABORIGINAL STUDENTS
(Bourke & Parkin, 1977)

Tests		10 year old			14 year old		
		Group One	*Group Two*	*Aust. Overall*	*Group One*	*Group Two*	*Aust. Overall*
Recall of number facts: (4 items)	Av. % correct	24	63	84	52	90	96
Using the four operations: +, −, x, ÷. (4 items)	Av. % correct	7	45	69	23	79	89
Tasks involving money: (5 items)	Av. % correct	12	74	93	7	52	79
Telling the time: (1 item)	Av. % correct	2	25	71	3	73	89
Children not attempting selected items:	%	77	16	3	38	7	1
Has received remedial instruction:	%	22	20	8	29	2	4
Needs and has not received instruction:	%	48	23	12	36	29	12

pation. De Lemos suggested that family contact with the Australian economic system may result in more successful mathematics achievement.

Research undertaken in Western Australia by Courtney and Wood (n.d.) investigated whether Aboriginal children's understanding of number concepts followed the same development sequence as for European children. The children tested attended primary schools in several remote areas with large Aboriginal populations. Tasks given included: (a) counting and sorting activities; (b) a pegboard activity, which required children to complete a pattern; (c) manipulation of plastic counters in order to demonstrate conservation of number, solve addition and subtraction facts, share a set of objects, make groups of a given number, and reverse a relation; (d) solving a polyomino puzzle consisting of a grid of 100 squares and a supply of templates designed to assess the child's ability to solve a problem dependent on spatial relations and to associate number with geometrically structured objects.

The results indicated that development of number concepts for Aboriginal children followed the same sequence as for European children, although the pre-operational stage of cognitive development tended to be longer. Courtney and Wood suggested that this may be due to fewer opportunities for language development. However, the concept of space appeared to develop earlier in Aboriginal children. Results for the grid activity showed that a majority of Aboriginal children successfully completed the task, including those who performed poorly on other tasks. Children who had difficulty counting using round counters were able to identify the number of square regions covered on the polyomino puzzle board without hesitation.

The literature shows that Aboriginal children perform poorly on traditional paper and pencil mathematics tests compared with European children – – especially Aboriginal children living in remote areas. These data are consistent with studies of mathematics achievement of minorities conducted elsewhere (Anick, Carpenter, & Smith, 1981). Unfortunately, achievement studies fail to provide information about the reasons why Aboriginal children fail to succeed.

COGNITION

The inclusion of cognitive studies in the review is considered appropriate because they may offer one explanation why mathematics programs have been unsuccessful for Aboriginal children in the past. The studies are divided into two categories. Firstly, studies conducted between Aboriginal and European cultures and, secondly, studies conducted within Aboriginal culture.

Between cultures

McElwain and Kearney (1968) reported the results of tests which measured differences in cognitive ability between Aboriginal and European children using the Queensland test. The Queensland Test is administered individually and includes five item types. The material is non-verbal in both administration and response and all material is non-representational. The Aboriginal sample included over 1,000 children and adults from areas considered by the researchers to have differing amounts of European contact. The European sample included children attending Primary school as well as deaf children. The results suggested that Aboriginal groups are inferior to Europeans to the same degree as they lack contact with Europeans. McElwain and Kearney considered that there was no genetic limitation on the basic intelligence of Aboriginals, rather an inability to cope with problems encountered during testing. These included the verbal component of the tests, inability to use symmetry as easily as European children to solve problems, difficulty in handling flat surface representations, lack of quantitative components in their language systems, and difficulty in distinguishing between relevant and irrelevant stimuli.

Dasen (1970) assessed the influence of European contact and the relative development of logico-mathematical operations and spatial operations. Logico-mathematical operations included conservation of quantity, weight, volume, and height, and seriation of length. Spatial operations included linear, circular, and reverse order, horizontality and rotation of two landscape models.

Subjects studied were 55 low contact Aboriginal children and 90 high contact Aboriginal chiodren, aged between six and sixteen years, together with 20 adults, from two different locations in Central Australia. Eighty European children were also tested. The results indicated that both European and Aboriginal groups responded to the test according to Piaget's developmental sequence (Piaget & Inhelder, 1969). However, the rate at which the concepts developed in the Aboriginal children was slower than the European sample and a large proportion of these children did not show development of some concepts at all, even as adults.

Dasen suggested from his findings that the influence of European contact does not become important until after the age of 10–11 years and is more marked where tasks less relevant to the Aboriginal culture are used; that is, tasks involving certain logico-mathematical concepts. A follow-up study by Dasen sixteen months later using a modified test battery with 80 Aboriginal children, of whom 36 had been tested previously, produced similar results (Dasen, 1972).

De Lacey (1970) investigated the relationship between classificatory ability and environmental setting in the major ethnic groups in Australia, and attempted a comparison of performances of Aboriginal and white Australian children living in similar environments. Subjects were drawn from both European and full-blood Aboriginal populations, who were designated either high or low-contact according to de Lacey's (1970) index of contact. The four tests used to measure classificatory ability were based on the classification test of Inhelder and Piaget (1964). The results showed a relationship between setting and classificatory performance of the children in favour of high socio-economic Europeans. De Lacey claimed support for Inhelder and Piaget's (1964) notion that parallel development between additive and multiple classificatory ability may be influenced by environmental factors.

Further research by de Lacey (1971) questioned the appropriateness of considering Aboriginal groups as homogenous, because of differences in living conditions among rural part-Aborigines, whose dwellings ranged from makeshift huts to European-style houses. He investigated differences in level of cognitive functioning, both in terms of verbal intelligence and operational thinking. Subjects were 11 part-Aboriginal children from a reserve, 13 part-Aboriginal children from town and 22 low socio-economic European children, all aged approximately five and a half years. The Peabody Picture Vocabulary

Test (Form B) which required a pointing rather than a verbal response was administered. De Lacey considered it to be appropriate for Aboriginal children because of their reluctance to respond verbally. The Nixon test, which is an individual test of classificatory ability, was employed as the test of operational thinking. This test did not require verbal responses either. The results showed progressively lower levels of verbal intelligence and operational thinking for the low-socio-economic European, town Aboriginal and reserve Aboriginal sample. Low correlations between PPVT and the Nixon Test generally, suggested, according to de Lacey, there is not a strong relationship between intelligence test scores and tests of operational thinking. However, de Lacey considered that the higher correlation found with the European children suggested that further investigation may be appropriate between children from more contrasting environments.

Kearins (1975) suggested that when testing cognitive functioning of various racial groups more consideration should be given to the environments in which the groups have developed, on the assumption that environmental pressures lead to the selection of characteristics which may be behavioural, cognitive and sensory. Her Aboriginal sample included forty-four children attending school in a Western Australian outback town whose ages ranged from 12 to 16 years. Her comparison group were white children of European descent attending a high school in an outer suburb of Perth. Kearins used a variation of Kim's game. Each subject viewed an array of objects on a grid-marked tray for thirty seconds, after which the tray was disarrayed. The subject was required to replace each object in its original position on the tray. Four arrays were used; unnatural/different, unnatural/same, natural/different and natural/same, with two array sizes; 12 objects and 20 objects. The results showed a significant difference on all tasks - - the Aboriginal children scoring better than the European children. Kearins suggested that the results support the argument for consideration of environmental history and ecological material when assessing the capability of different racial groups. The comparatively poor performance of the European children was thought to be due to their reliance on verbal coding strategies.

Drinkwater (1976) conducted a similar experiment between non-tribal Aboriginal children, who were considered to have a moderately high degree of European contact, and European children, in Queensland. She found no significant differences between Aboriginal children and European children on visual memory tasks. This result is consistent with Kearin's notion that milieu is an important influence on cognitive ability.

Kearins (1981) reported a series of studies on visual spatial memory on desert Aboriginal children. One study investigated the possibility that adolescents learned special habits of observation and/or memory from their semi-traditional parents. Her sample included three groups of children. The first group of 46 children were classified as non-traditional and included Aboriginal children who were fully or predominantly Aboriginal, aged between six and eleven years. The second group, of 46 children were also aged between six and eleven years, were white Australians who were attending a country school of approximately the same size as the one attended by the Aboriginal children. The third group were desert settlement (semi-traditional) children and included 37 children between six and eleven years who lived with their families at a desert settlement in Central Australia. This group spoke non-standard English as a second language at school and local language with their families and about the settlement. Three memory tasks were employed. The 20 item unnatural/different and natural/different arrays of the earlier study (Kearins, 1975) were used together with a further 20 item unnatural/same array which was constructed by adding a further 8 bottles to a 12 - array previously used. The results showed that the performance of both Aboriginal groups, non-traditional and semi-traditional, were significantly superior to the white Australian children. Kearins suggested that, as with her first experiment, the white Australian scores were influenced by the nature and familiarity of items. This did not appear to be the case for the Aboriginal sample. Questioning of the children concerning strategies used by the children confirmed, for Kearins, that Aboriginal children were utilizing visual strategies whereas white Australian children used verbal strategies.

Another study reported by Kearins (1981) was designed to differentiate between recognition of items previously seen and memory for spatial location. Subjects included 14 children, aged between ten and twelve years, who had been members of the non-traditional group of the previous experiment. The comparison group included 14 white Australian children, aged ten and eleven years who were attending a suburban Perth primary school. This group was considered to be comparable to the eleven year old white Australian group of the previous experiment. The task consisted of two elements; a spatial replacement requirement and an item recognition requirement. Twenty man-made items were set out on a board in a rectangular array. Subjects were allowed 30 seconds viewing time. The items were then mixed haphazardly with twenty similar items on a clear perspex tray. The children were required to select the items they had seen previously and replace them in their original positions on the tray. Neither group had difficulty with the recognition task, and Kearins suggested that the relatively low scores of the white Australian children in previous experiments were representative of a specific difficulty in remembering location of items rather than difficulty in item recognition. Scores for both groups were similar to those found in the previous experiment and Kearins concluded no incidental gain in the experiment.

A third study sought to identify uses made of a readily available verbal strategy. The task consisted of an array of 20 items, arranged in five columns. Each column contained items of only one broad category: shells, nuts, beaten copper, leaves, rocks and sticks. Kearins conjectured that if children were able to memorize the column labels than all items should be replaced in the appropriate columns. The Australian group was expected to score higher than the Aboriginal group because of the suspected strategies being used. The Aboriginal score was not expected to change. However, the Aboriginal group improved their score, rather than the Australian group. Kearins attributed this to differential practice effects, and the possibility of interference of verbal rehearsal strategies. All children attempted this task immediately following the task described in the second study, and, given the different strategies of the two groups, the strategies employed by the Aboriginal children led to greater practice benefits than those employed by the Australian children.

A fourth study considered the effect of a task in which items differed in only one attribute - - colour. An array, consisting of 20 two-strand Turk's head knots of three main colours, green – four shades, pink/red – three shades, and brown – two shades was presented to the two groups. The Aboriginal group scored higher than the white Australian group although both groups experienced difficulty with the task. The response patterns showed a high number of confusions between items of the same colour but different hues by the white Australian children. Kearins suggested that reliance on verbal strategies would be consistent with such a result. She also suggested that the white children attempted a reading-related strategy. That is, they commenced attempting to remember shades from the top left-hand corner, in order to cope with location coding patterns. The Aboriginal children's responses were more evenly distributed. Difficult-to-name items were not ignored by the Aboriginal group. Kearins suggested that the Aboriginal group were not using verbal strategies. However, she suggested these results also showed that if the number of physical attributes of array objects are restricted, memory for spatial relationships is restricted also.

Kearins results appear to support an environmental hypothesis. Future mathematics programmes will need to take advantage of skills which have been acquired by Aboriginal children in their early formative years and utilize these to develop suitable transitional programmes.

Within Culture

De Lemos (1973) conducted an investigation between two groups of Aboriginal children. Subjects were 65 children, considered to be full-blood Aboriginals, and 80 children, considered to be half full-blood and half part-Aboriginal. The first group lived at Elcho Island, which has a high summer rainfall and the second group were from Hermannsberg, a semi-desert area. The ages of the children ranged from eight to fifteen years. Tasks included conservation of quantity, weight, volume, length, area and number. The results showed that fifty percent success on the tasks was not achieved before ten to twelve years of age. Some of the younger Hermannsberg children performed equal to or better than older age groups. The greatest number of correct conservations responses for both groups were, in order, weight, length (younger children performed better on this task than older children), quantity, volume and area. The Elcho group found the test on number to be one of the easiest, where it was presented at the end of the series. The Number test was found to be one of the most difficult tests in the Hermannsburg group where it was presented at the beginning of the series. De Lemos suggested that there may have been an effect of presentation order. Part-Aboriginals performed better on all tests.

Seagrim and Lendon (1980) conducted a longitudinal study of Aboriginal children living on a mission in Central Australia and compared the results with Aboriginal children from other locations. Tests consisted of two tests of conservation: quantity and weight, two tests of classification: a reclassification test and a matrix test, a test of seriation, and a test of horizontality. Seagrim and Lendon concluded that performance on the tests was directly effected by influences on the Aboriginal child's lifestyle of European contact. The more 'Westernized' the Aboriginal child's lifestyle the higher the test score.

The cognitive studies reviewed indicate that European contact is a major factor for success with tests of cognitive ability, suggesting that European-type enrichment of the Aboriginal child's environment will lead to measurable gains in cognitive functioning and in mathematics achievement. However, the present thrust of Aboriginal communities as a whole to recapture their 'Aboriginality' may counter efforts in this regard. A more fruitful course of action may be to identify methods used by Aboriginal communities for dealing with situations which, by necessity, they have to adopt from Western Society - - for instance, sharing of available commodities, the household budget, etc. These strategies can then be used to form the basis for contemporary mathematics programmes.

LANGUAGE AND CULTURE

If the language of a culture is determined by the environment of that culture, then the number of Aboriginal terms which can be related directly to concepts underlying Western mathematics may be small due to vast environmental differences between cultures. Similarly, if the way that a culture perceives and interprets its environment determines the kinds of questions it asks, and the type of problems to be solved, the commonality of problems and questions deemed important by both Aboriginal and Western societies may be small also. For example, Sayers (1983) showed that Wikmunkan people at Aurukun have different classification systems and different modes of generalising concepts when compared with white Australians. Instead of classifying in terms of number, colour, or shape, the Wikmunkan classify according to edibility of protein food. For example, what we might see as a yellow banana, would be seen by an Aboriginal as a ripe banana. Development of a numeration system to account for quantities of mass-produced articles can be contrasted with a handcraft society in which every tool or weapon is seen to possess its own individuality. The white man learns the general concept of 'green' via instances of green leaves, green grass and green paint. The Aborigine learns the concept of 'kangaroo' in the animal kangaroo, the man of kangaroo totem, and the totem place (Sayers, 1983). Just as the Aborigine does not understand the significance of 'green', the white man fails to understand the significance of killing the totem animal (i.e. a brother) at a particular locality.

Several cultural and language differences appear to be relevant for learning mathematics. In general, it has been noted (Bishop, 1973; Harris, 1977; Sayers, 1983; Wilson, 1979) that Aboriginal students from isolated communities are less familiar with numbers, measurement, and other mathematical and scientific concepts than are students in urban Australia. In the absence of a developed numeration system it makes little sense to ask "How long is that?" since such a question implies that a conceptual system of units is available having certain relative and absolute properties. Indeed attributes of quantities such as height, length and breadth, are features which seem not be abstracted (Sayers, 1983). Comparison of two quantities which differ grossly can be effected by saying either x is tall; y is short, or x is tall; y is not tall. The latter expression exemplifies a difference in logical argument between the cultures. Sayers (1976, 1981) describes the form as Negated Antonym Paraphrase in which logical connectives are not used. Bishop (1973) identified causal thinking in Aboriginal culture as being fundamentally different to that of Western society. Aboriginals place emphasis on "personal" spiritistic and magical causes, whether they be seen or unseen, nearby or at a distance (p.14)".

Harris (1981) has noted that appeal to authority is used to explain much phenomena in traditional life, where emphasis is placed on memory and rote learning for teaching tribal traditions. Children in a tribal setting are not encouraged to ask how or why, although Harris has observed a high degree of perceptual curiosity, or a strong interest in the familiar. Associated with importance placed in authority is a high degree of cultural conservatism. Harris (1981) has observed in the Yolngu people of Milingimbi that there is a distinction made between what a person actually knows, and the right of that person to communicate that knowledge, according to their seniority in a clan. Traditional learning and problem solving traits are persistence and repetition, observation and imitation, personal trial and error and real-life performance rather than a practice in contrived situations. Skills learned are context specific, and are acquired through successive approximation to the efficient end product rather than through an ordered sequence of subparts (Harris, 1977).

Because a traditional lifestyle dictates that food cannot be stored for long periods, and crops are not planted, Aboriginal people might be expected to have less of a "future-time" orientation than white Australians (Harris, 1981). Ceremonial lore which stresses the significance of the past for life in the present could also be expected to work against a future orientation. However, Holm and McConnochie (1976) found the community with least contact with white Australian culture showed the greatest future orientation, and that contrary to expectation, boys were found to have a significantly greater future extension than girls across all age levels and communities studied, despite the psychological impact of initiation rituals. It is an open question whether absence of mathematics for predicting and anticipating solutions to problems can be explained by a "present-time" orientation.

ETHNOMATHEMATICS

It is of interest to ask: What problems arise in traditional environments which require application of mathematical processes for their solution? What mathematical processes are used to solve those problems? How does the mathematics of a culture change in response to changes brought about by contact with a different culture? A suitable term to describe data arising from such avenues of enquiry is *ethnomathematics* -- mathematics used by a defined cultural group in the course of solving problems related to control of their environment. Gay and Cole (1967) called it indigenous mathematics. Serious enquiry of this kind requires collaboration between mathematics educators, psychologists, sociologists, linguists, and anthropologists; in short interdisciplinary effort.

It is not obvious why one should become interested in these kinds of questions. After all, if the mathematics necessary to launch a reusable space shuttle, and much more, already exists, then the problem surely reduces to choosing the appropriate mathematics, then teaching it using sound pedagogical principles. But the crucial questions are these: For *whom* does the mathematics necessary to launch a reusable space shuttle exist? By what processes does mathematics come to exist for an individual? If certain mathematics knowledge, with all its significance and meaning, exists for one individual, how can that individual make it exist for another? In other words, how does one person come to know the same mathematics that another person knows? Acquisition of mathematics knowledge is a personal constructive process. Language plays a vital role, but it is only a courier for the expression of ideas. A sensible strategy for the teacher, who decides that it is desirable for a pupil to know certain mathematics, is to discover mathematics that pupil already knows, or what problems the pupil can already solve. Having identified what the pupil already knows the teacher must decide how to take advantage of this knowledge to develop new mathematics knowledge. Such a strategy assumes that an individual's mental apparatus for solving mathematical problems develops by means of progressive restructuring and reorganisation. As the individual's mental systems mature, so grows the capacity for solving more complex problems. As the individual is confronted by more difficult problems, so the individual's mental systems progressively adapt and if necessary, restructure. A fundamental attitude shift is associated with ethnomathematical studies: away from demonstrating what the individual can't do, to what the individual can do.

Traditional environments studied to answer questions about the role played by mathematics include those of African peoples (Gay & Cole, 1976? Zaslavsky, 1973), the Oksapmin of Papua New Guinea (Saxe, 1981, 1982), purchasing foodstuffs in the Western suburban supermarket (Lave, Murtaugh & de la Rocha, 1982), and informal, out-of-school worlds of young children (Ginsberg, 1977; Streefland, 1978). Harris (1977) has provided a survey of literature dealing in part with mathematics observed in tribal Aboriginal societies. She cited reports of direction-finding skills of Western Desert Aborigines (Lewis, 1976), counting ability of an Aboriginal messenger (Howitt, 1904), who used body parts to address numbers, reminiscent of the Oksapmin (Saxe, 1982), quinary numeration systems of eastern Arnhem Land (Wurm, 1972), rapid mastery of the English counting system by Walbiris in Central Australia (Hale, n.d.), vocabulary specialisation for small numbers by Anindilyakwa of eastern Arnhem Land (Stokes, 1976), and card playing skills of Aboriginals in the Kimberley (Robinson & Yu, 1975), and in the Northern Territory (Berndt & Berndt, 1947; Holm & Japanangka, 1976).

Because certain card games played by Aborigines appear to demand knowledge with potential for learning and teaching mathematics, some discussion of Aboriginal card playing skills may be useful here. Other studies of card playing behaviour can be found in the literature (Brandewie, 1967; Laycock, 1966, 1967), including a detailed analysis of the game called *bayb-kad* played at Bamyili (Davidson, 1979).

In *bayb-kad* court cards and jokers are removed leaving 10 cards numbered from 1 (ace) to 10 in each of the four suits. Each player is dealt five cards, which are examined with the aim of combining the numerical values of any three of the cards so that the sum will be an even ten, i.e. 10, 20, or 30. The possession of three such cards allows the player to register a score. The score is then calculated by summing the value of the remaining two cards, discarding multiples of 10, and taking the unit value of the sum as the score. The player with the largest "number" wins.

From a Western perspective, mathematical demands of the game would appear to include (a) numeral recognition, to establish the face value of each card; (b) logical addition, to calculate the sum of three cards to 10, 20, or 30; and (c) ordering, to determine which player has the highest score. However, Davidson found that players of the game at Bamyili used little, if any, of the information conveyed by the numerical symbols printed on the cards. Sets of complex procedures involving pattern recognition were used instead. For example, in one strategy known as *rib*, a player examines the arrangements of motifs visible in a systematic way when one card is covered partially by another card, leaving exposed part of the motifs found at one or more of the four extremities of the card (Davidson, 1979). When the numerical symbol was used, Davidson concluded that the numbers were not summed in the expected way. Alternative strategies to logical addition involved memorised combinations of cards. There are twenty-two possible combinations of three cards using the *rib* method of card value identification. It is not clear that all Aboriginal communities use such strategies to play the game. Davidson (1979) agreed that Aborigines who visited Bamyili from Darwin may have played *bayb-kad* using numerical procedures. He certainly felt that younger generation players may have been capable of using a Western style of play. But one outcome of the Davidson study was that an important ingredient of the game was excitement and suspense, which the pattern recognition procedures provided, but which an arithmetical method would not. Another ingredient of Bamyili strategies not matched by a Western approach was the complexity afforded through perceptual analysis of information which differed in only very minor (to the Western eye) detail. Davidson concluded that procedures used at Baymili were consistent with other findings which suggested that Aborigines prefered strategies governed by simultaneous processing rather than sequential processing. the Bamyili card players had apparently assimilated a game of Chinese origin into their cultural framework and modes of problem solving. *Bayb-kad* played the Bamyili way appears to bear no resemblance to any content in elementary arithmetic.

But what do Western-type strategies for playing *bayb-kad*, or its equivalent, mean for the acquisition of elementary mathematics knowledge of Aboriginal children -- specifically knowledge of the whole number system of numeration? Concerns have been expressed by Holm and Japanangka (1976) and Sayers (1983). Principle problems appear to be (a) in the game, 3 + 4 = 7 and 7 + 5 = 2 (discarding the 10), so that 3 + 4 has a greater value than 7 + 5; and (b) 10 is equivalent in value to 20, which is equivalent in value to 30. Players of this game are in fact using a different arithmetic to the common arithmetic of whole numbers.

They are using an arithmetic modulo 10 -- a kind of metricated 'clock' arithmetic, in which the set of possible values, operationally speaking, is finite. The mathematical system supporting *bayb-kad* obeys a set of rules, but they are different rules, in part, to the rules of elementary arithmetic. If card games such as *bayb-kad*, *kuns*, or *lucky* are to provide a basis for developing children's whole number knowledge one must ask what meaning supports the mathematical objects that players use in such a context? Do the players understand the connection between the numerical symbol and the number of motifs on each card? If they do, what limitations could such knowledge have for a generalised conception of number? Sayers (1981a) has observed the ease with which children associate a number name with a particular perceptual array of objects, and the difficulty of breaking that perspective. The concept of ten as a unit is fundamental in an individual's construction of the whole number system of numeration. Ten is an important ingredient in the card game. Do children at play understand the significance of ten as a unit integrating 10 sub-units? if they do not, is there some aspect of the game which could be drawn upon to reinforce such a conception? What about the preliminary search for sums of 10, 20 or 30 using combinations of three cards? In what sense does a sequence adding to 20 or 30 suggest the notion of "two tens" or "three tens?" The operation of addition can be used to sum the cards. What meaningful basis for whole number addition is inherent in the cards, or imposed by the players? Do children find the sums using counting processes? Do they count all the motifs on each of the cards to be summed? Do they 'count-on', using cardinal information conveyed by the numerical symbol of one card to begin the count of motifs displayed on another card? Answers to such questions can be found by observing children in the act of playing, teaching other children to play, as well as some analysis and reflection on the game by the enquirer. The efficacy of using games such as *bayb-kad* for teaching and learning school mathematics depends ultimately on answers to questions like these.

Finally, to conclude this paper, aspects of Harris's (1980) study of the Anindilyakwa of eastern Arnhem Land, Northern Territory, will be reviewed briefly. Harris found the Anindilyakwa people to possess a rich store of mathematics knowledge. Their vocabulary contains counting words making it possible theoretically to extend a count indefinitely upwards. In contrast to other eastern Arnhem Land languages the Anindilyawka system is not based on fingers and hands. Harris found evidence of words developed for number names pre-dating the earliest days of Macassan bartering. Due partly to the cumbersome nature of Anindilyakwa number words (e.g., 26 = wurrakiri yabalangawa awilyaba) English loanwords are used almost exclusively for numbers greater than five, except 10. Another reason that ~~but~~ ethnic higher number words are not used is due to the system of counting by fives - - 1, 2, 3, 4, *5*: 1, 2, 3, 4, *15*: 1, 2, 3, 4, *20* etc. The main use of counting was for the activity of sharing. The precise total of a quantity of turtle eggs was not as important as ensuring that each person received an equal pile of eggs. Although no concept of zero was found, since there are no number symbols in Anindilyakwa, the concept of 'nothing' was well defined and expressible linguistically. There are no special words for expressing position in a sequence, but clear ways for making position precise were found. One way was to use a cardinal name: for example, "when I hear two bell" = when I hear the second bell. Another way was to use the ethnic equivalent for 'times' with a cardinal number. For example, "after five time" – sixth.

Sorting and grouping, the basis in action for several arithmetic operations, were observed in numerous daily activities such as sorting berries, fish, or fibres for weaving. Words were found to express equality meaning similar and quality meaning identical. Linguistic mechanisms were found for group counting by twos, threes, fives, and so on. Countable objects too fiddly to count such as small berries, were shared in handfuls, thus providing examples of units consisting of pluralities in a natural setting. The fraction concept exists informally in the concept of sharing. Other activities of subdividing large game into portions provided instances of fractioning actions.

Do the Anindilyakwa possess a richer mathematical heritage, compared with other Aboriginal communities, because of environmental peculiarities and opportunity for contact with a trading culture? Or are other Aboriginal communities are at least as well endowed mathematically, albeit in different ways? We can't begin to answer these questions until we do some careful looking.

CONCLUSION

Aboriginal peoples of Australia have adapted to complex environments, and have sophisticated intellectual functions for controlling those environments which are not well understood by the Australian community at large, let alone mathematics teachers. Some reference has been made to the degree of fine tuning evidenced in contexts requiring spatial and directional skills. Explanatory models are required to account for behaviour in such contexts. Data has been reported showing that certain Aboriginal communities engage in sequential action strategies to sort out and distribute their food. If sharing and sorting behaviours have potential as meaningful bases for teaching whole numbers, fractions and decimals, to what extent are these behaviours widespread across other traditional communities? If, as Davidson (1979) suggests, Aboriginal people may employ synchronous processing in preference to serial processing when solving problems, and such processes are specialised functions of the cerebral cortex (Luria, 1973), how does this effect our efforts at teaching mathematics, or indeed language arts, to Aboriginal students? In general, much careful study of traditional Aboriginal culture is required to inform decisions concerning suitable mathematics curricula for these people. Current work by Harris (1982) is exemplary in this regard.

Studies reported and issues raised in this paper in respect of mathematical competency of Aborigines as a particular sub-group highlight fundamental weaknesses in mathematics education programs for all Australians. While the gap in mathematics achievement between Aboriginal and white Australian students grows wider as age and years of schooling increase, it is true that high proportions of white Australian students choose not to continue their mathematical education at the earliest opportunity. Reasons for such choices, in the face of overwhelming evidence of the benefits mathematics knowledge has for expanding the individual's life options cannot be dealt with here. What has been demonstrated, here, and in other research (Hendrickson, 1979; Houlihan & Ginsberg, 1981; Hunting, in press; Siegel, Goldsmith & Madson, 1982) is that the nature of prior knowledge, and awareness of the nature of prior knowledge by teachers and curriculum planners, are essential ingredients for achieving that crucial goal we call successful learning.

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The author gratefully acknowledges assistance given by Neil Holm, Judith Kearing and Ernie Stringer in the preparation of this report.