Title	The cognition-ethnicity connection in mathematics learning
Author(s)	Yeap Lay Leng , Chong Tian Hoo and Low Guat Tin
Source	*The Mathematics Educator, 1*(2), 111-123
Published by	Association of Mathematics Educators

The Mathematics Educator
1996, Vol. 1 , No. 2, 111-123

The Cognition-Ethnicity Connection In Mathematics Learning

Yeap Lay Leng
Chong Tian Hoo
Low Guat Tin

Abstract

This study† looked into the cognitive profiles of mathematics achievers among the Chinese, Indians, and Malays in terms of the psychological dimensions of learning, namely perception, processing, and cerebral dominance (hemisphericity).

The purpose of this article is to introduce the background of the study, state the objectives, provide the rationale, indicate the sample, identify the instrumentation, provide the design and statistical analysis, and discuss the potential applications of the research findings.

Background of the Study

'Cognition-ethnicity' connection relates how learners of different ethnic groups, namely Chinese, Indians, and Malays in Singapore process and transform information, categorise new knowledge, and integrate the new knowledge within their memory structure in the learning of mathematics. A search for local studies on 'ethnicity-learning' connection was very disappointing. Foreign studies focused on American Indians, Asian, Arabs, and the Maoris (Farquharson, 1989; Algee & Bowers 1993; Rhodes, 1990; Dunn & Griggs, 1995). However these studies found that possible differences in academic achievement could be attributed to cultural factors, values, and learning styles among the different ethnic groups.

So, '*multiculturalism* has been defined as the fourth force in psychology one which complements the psychodynamic, behavioral, and humanistic explanations of human behavior' (Locke, 1993). One of the greatest concerns of human

---

† *This study is granted a 3 year funding by the Ministry of Education and the Nanyang Technological University in November 1994 through the National Institute of Education Centre for Educational Research (NIECER).*

behaviour is learning. Learning outcomes have been found to be related to learners' cognitive styles which are stable indicators of how individuals perceive, process, and manipulate information. Cognition also includes the newest element of the psychological domain of learning, that of hemisphericity which is defined as the tendency of a person to use one side of the brain to perceive and function more than the other.

Studies are emerging to investigate the 'Mathematics-cognition' connection (Dreyfus, 1990; Mayer 1991; Lee & Yeap, 1995). The 'cognition-learning' connection has been extended to 'culture/ethnicity and learning' connection which is an explosive issue in multiculturalism.

Objectives of the Study

The objectives of the study are as follows:

1. To investigate how mathematics achievers among the Chinese, Indians, and Malays perceive and process mathematical concepts.
2. To identify the mental processes that distinguish among the three ethnic groups, namely Chinese, Indians, and Malays in their learning of mathematics.
3. To identify mental processes which can possibly act as good predictors of learning success in mathematics.
4. To utilise learning characteristics observed among high mathematics achievers to assist the low mathematics achievers.
5. To cultivate an attitudinal shift about 'culture-proclivities' connection.

Specific Objectives

The specific objectives of the study are as follows:

1. To plot a stylistic profile of the Chinese, Indians, and Malays in terms of their cerebral dominance (right or left brain dominance) and the perception (concrete versus abstract) and processing dimensions (reflective versus active).
2. To provide a learning style profile categorised as diverger, converger, accommodator, assimilator among the Chinese, Indians, and Malays.

3. To compare the 'mental qualities' of mathematics achievers among the Chinese, Indians, and Malays so as to distinguish the characteristics that could have attributed to their varying performances in mathematics.
4. To find out if there is interaction between the left and right brain tasks, the perception, and processing dimensions among the ethnic groups.
5. To correlate the perception, processing, and hemisphericity profiles with the ethnic groups.
6. To provide an explanatory relationship between mathematics achievers and their cerebral dominance, perception, and processing of information.

This study is an extension of local studies on cognition and student achievement (Yeap, 1989), cognitive matching (Yeo, 1993), and cognitive diversity among Singapore students (Yeap & Wong, 1991; Chan, 1994; Lee & Yeap, 1995). The study is unique and timely as it investigates a new dimension of learning that moves away from the traditional measurement of IQ scores. The study focuses on a horizontal dimension which compares learners' relative performances of information tasks in terms of their strengths and weaknesses, learning preferences, and cerebral dominance. Cognitive profiling can provide some crucial explanation for 'cognition-ethnicity' connection in mathematics learning among the ethnic groups.

Rationale of the Study

1. How to grapple with mathematics has been discussed tirelessly. Mathematics is perhaps the only discipline where individuals can suffer severely from anxiety, helplessness, and 'mathophobia.' The Ministry of Education Review Committee Report (1991) on 'Improving Primary School Education' laid down the importance of Mathematics:

> *... that all children should have a firm foundation in Mathematics which is the key to mastering technological skills. In a world dominated by technology, a person who is mathematically illiterate is at a grave disadvantage. Our children must never be put in a position where, because of a lack of competence in Mathematics, they are unable to acquire the skills needed to cope with modern technology which will be part of their daily lives. (preliminary page)*

The nature of the discipline and the foundations of mathematics education is more than just manipulating symbols. They contribute to the development

and growth of mental abilities essential for problem solving, thinking, logical reasoning, and analysing across disciplines like engineering, military, finance, technology, and daily living.

2. Recent local and international media reported with some concern mathematics issues ranging from the importance of mathematics and language in a technological society, the varying achievement levels of mathematics performance among the ethnic groups, and the positive strategies to improve mathematics performance.

3. There is a need to shift from using the traditional vertical dimension of IQ scores to measure the complexities of learning. An invariant IQ score is inadequate to explain why individuals are not performing. Cognitive profiling gives a qualitative picture of students' learning styles in terms of their learning preferences and dominance which can explain why certain groups are performing or not performing. This moves away from the traditional 'better or worse' type of measurement to the fact that there are other equally valid methods of processing, perceiving, and storing information.

4. Mathematics curriculum is pointing to learning processes rather than merely content. The most common errors found in mathematics are usually errors in process skills. The study may explain the existence of certain process skills that might account for why some individuals are not making the grades in mathematics.

Sample

A total number of 1320 pupils from the three ethnic groups, namely Chinese, Indians, and Malays were surveyed. They were 16 to 17 years old students studying in secondary 3 and 4 from 10 secondary schools in Singapore. A careful selection of schools ensured a fair distribution of students by mathematics achievement according to the ethnic groups.

1. The sample was categorised by academic achievement, namely Normal, Express and Special/Gifted as determined by their Primary School Leaving Certificate (PSLE) results (Tables 1 & 2).

Table 1: % distribution by achievement levels, Normal, Express, Special/Gifted among the ethnic groups from the total sample (n=1320)

Achievement Level / Ethnic Group	Normal (Low)		Express (Average)		Special/Gifted (High)	
	n	%	n	%	n	%
Chinese (n=623)	146	11.06	178	13.48	299	22.65
Indian (n=308)	135	10.23	116	8.79	57	4.32
Malay (n=336)	139	10.53	148	11.21	49	3.71
Others (n=53)	24	1.82	19	1.44	10	0.76

Table 2: % distribution by achievement levels, Normal, Express, Special/Gifted within each ethnic group

Achievement Level / Ethnic Group	Normal (Low)		Express (Average)		Special/Gifted (High)	
	n	%	n	%	n	%
Chinese (n=623)	146	23.43	178	28.57	299	48.00
Indian (n=308)	135	43.83	116	37.66	57	18.51
Malay (n=336)	139	41.37	148	44.05	49	14.58
Others (n=53)	24	45.28	19	35.85	10	18.87

2. The sample was also categorised by mathematics achievement, namely high, average, and low by the PSLE (Tables 3 & 4). Since the PSLE Mathematics results were obtained three years ago, the students' mathematics

performances were checked by the individual schools' end-of-year Mathematics examination results. The investigators were fully aware that the non-standardised Mathematics tests had varying levels of difficulty. A comparative check on the PSLE and school examination data showed that poor mathematics performers in PSLE were also poor mathematics performers in the end-of-year school Mathematics examination.

Table 3: Mathematics achievers in ethnic groups from PSLE & school exam results out of total sample (n=1320)

Maths Score / Ethnic Group	D/E/F		B/C		A		A*	
	n	%	n	%	n	%	n	%
Chinese (n=623)	51	3.86	116	8.79	82	6.21	374	28.33
Indian (n=308)	105	7.95	92	6.97	35	2.65	76	5.76
Malay (n=336)	101	7.65	75	5.68	75	5.68	85	6.44
Others (n=53)	13	0.98	17	1.29	3	0.23	20	1.52

Maths Score / Ethnic Group	Below 50%		50-59%		60-79%		80-90+%	
	n	%	n	%	n	%	n	%
Chinese (n=623)	62	4.70	69	5.23	235	17.8	257	19.47
Indian (n=308)	92	6.97	68	5.15	113	8.56	35	2.65
Malay (n=336)	89	6.74	78	5.91	138	10.45	31	2.35
Others (n=53)	13	0.98	11	0.83	21	1.59	8	0.61

Key: Grades = PSLE Maths results.
% = end-of -year examination Mathematics results

Table 4: % distribution of Mathematics achievers within each ethnic group from PSLE & end-of-year examination Mathematics results

Maths Score / Ethnic Group	D/E/F		B/C		A		A*	
	n	%	n	%	n	%	n	%
Chinese (n=623)	51	8.19	116	18.62	82	13.16	374	60.03
Indian (n=308)	105	34.09	92	29.87	35	11.36	76	24.68
Malay (n=336)	101	30.06	75	22.32	75	22.32	85	25.30
Others (n=53)	13	24.53	17	32.08	3	5.66	20	37.74

Maths Score / Ethnic Group	Below 50%		50-59%		60-79%		80-90+%	
	n	%	n	%	n	%	n	%
Chinese (n=623)	62	9.95	69	11.08	235	37.72	257	41.25
Indian (n=308)	92	29.87	68	22.08	113	36.69	35	11.36
Malay (n=336)	89	26.49	78	23.21	138	41.08	31	9.22
Others (n=53)	13	24.53	11	20.75	21	39.62	8	15.09

Key: Grades = PSLE Maths results
%= end-of-year examination Mathematics results

Instrumentation

Three instruments were carefully evaluated and selected, namely The Learning Style Inventory (Kolb, 1986), Cognitive Laterality Battery (Gordon, 1986), and the Demographic Data Inventory (Yeap, Chong, & Low, 1994).

1. <u>The Learning Style Inventory (LSI) (Kolb, 1986)</u>

The LSI was a 12 item self-descriptive instrument designed to measure a person's preferred way of perceiving and processing information. The instrument provided a profile of how information is processed, the strengths and weaknesses in coping with tasks and problems, and the interaction with ideas and concepts. Each of the 12 items had four options to be ranked in order of preference. A

scoring process summed the rankings of the four options into four scores to determine the individuals' dominant learning modes, namely concrete experience, abstract conceptualisation, reflective observation, and active experimentation. The learning modes' scores were further reduced to two scores to obtain a one-word descriptor of the individual's most preferred style of learning, namely diverger, converger, assimilator, and accommodator.

Criticisms of Kolb's LSI included brevity, possibility of different interpretations of individual words, suitability for English speaking audience only, possibility of response set, and the difficulty in making choices because they are within the same dimension (Kirby, 1979). However, the advantages of the LSI included the following:

- it was developed based on research findings
- it had appropriate reliability and validity
- it provided for stylistic differentiation along a continuum
- it was simple and quick to administer and analyse
- it allowed for quick self-scoring
- it was relatively inexpensive and suitable for large group administration
- it was easily and readily available

2. The Cognitive Laterality Battery (CLB) (Gordon, 1986)

The hemispheric element (cerebral dominance) was measured by the CLB, a performance test of eight subtests. Four of them were associated with the left hemispheric functions and the other four were associated with the right hemispheric functions. The CLB was taken directly or adapted from tests demonstrating left and right hemispheric superiority in brain divided patients and normal subjects. It was a performance test unlike other tests which were preferential inventories. These inventories tend to depend on individuals' interpretation of a student's preferences. Factors like culture, social and environmental considerations, gender, self-image, truthfulness, modes, and perception could affect a person's response that would in turn affect his/her preferences.

The CLB, a battery of performance tests, assessed a subject's performance on specialised cognitive functions through the use of 35mm slides synchronised with prerecorded audio cassettes. It had four subtests to measure visuospatial abilities, and another four to measure verbal abilities. It provided for the cognitive profiles of the individual student. The profile was to assess the relative level of functioning of the right and left hemispheres.

3. The Demographic Data Inventory (Yeap, Chong, & Low, 1994)

This was a paper and pencil questionaire used to identify the commonalities and differences of the students in terms of the achievement levels, types of mathematics achievers, gender, proficiency in languages, and subject performances in schools. The commonalities and differences would enable the results to be generalisable through logical inference to a larger population having similar characteristics.

Design

The independent/predictor variables were variables that were to be manipulated. They included the following:

1. The three mathematics achievement groups, namely the low, average, and high achievers between the sixteen and seventeen years old secondary 3 and 4 students.
2. The brain lateralisation tests in the CLB instrument consisting of two values, namely the performance of the left brain dominant tasks (Propositional), and the performance of the right brain dominant tasks (Appositional).
3. The perception and processing dimensions in the Learning Style Inventory with its four learning mode values, namely concrete, abstract (both in perception dimension), reflective, active (both in processing dimension); and the four learning style values, namely diverger, converger, assimilator, and accommodator.

The dependent/criterion variables were variations the investigators wanted to explain or predict. They consisted of three domains namely,

1. The learning modes, namely concrete versus abstract, reflective versus active.
2. The learning styles categorised as accommodator, assimilator, diverger, converger.
3. The three values measured by the Cognitive Laterality Battery, namely the students' overall performance termed the Cognitive Performance Quotient (CPQ), the students' cognitive profiles termed the Cognitive Laterality Quotient (CLQ), the students' performances of the left brain dominant tasks (Propositional) and the right brain dominant tasks (Appositional).

Statistical Analysis

The statistical package, Statistical Analysis System (SAS) was used to analyse the data. The statistical methods used were frequency and percentages to show distribution, ANOVA to indicate significant differences among the ethnic groups, multiple regression analysis to examine the predictive or explanatory relationship among variables, and correlational analysis to provide information concerning the degree of relationship between variables.

Potential Applications of Research Findings

The study may have findings that answer specific questions of national concern regarding mathematics performance among the Chinese, Indians, and Malays. The findings may reveal workings of the minds on how mathematical concepts are perceived and processed within and across the ethnic and achievement group to explain why certain students achieve in mathematics.

Cognitive profiling research also has great potential applications to different aspects of life, the most recent being matching teaching and learning styles, whole brain learning, management, critical thinking, and problem solving. Research has shown that such a relationship affects academic achievement (Yeo, 1993), and management styles (Hermann, 1990). Adequate profiling may act as good indicators to certain learning and career successes. Given the consistent way people of different dominances perform, the analyses will hopefully provide insights to explain why certain students achieve highly in mathematics and others have cognitive obstacles. The findings can lead to the formulation of educational approaches to match teaching styles with students' learning preferences and cognitive dominance. The findings may provide useful insights to the preferences among the ethnic and achievement groups to improve response to questions about learning and working preferences. It is not surprising to find that 'occupational norms' exist and that certain profiles do show up more in some occupations than in others.

Good teaching is adapting instruction to individual differences among the learners. Instruction can revolve around students' learning processes appropriate to the disciplines. This means consciously incorporating process skills like observing, direct learning, listening, and thinking into the teaching of content areas. With process skills awareness, students are in possession of lifelong tools applicable to situations beyond the school.

References

Algee, A. & Bowers, W. (1993). *A comparison of learning styles between Asian and American seminary students.* ERIC ED 360887

Chan, Y. M. (1994). *Interrelationships of cognitive style, formal reasoning ability, sex and Chemistry achievement among junior college students.* Master of Education Dissertaion, National University of Singapore, Singapore.

Dreyfus, T. (1990). Advanced mathematical thinking. In Nesher, P. & Kilpatrick, J. (Eds.), *Mathematics and cognition: A research synthesis by the international group for the psychology of mathematics education* (pp. 113-134). Cambridge: Cambridge University Press.

Dunn, R. & Griggs, S. (1995). Multiculturalism and learning style. *Teaching and counselling adolescents.* ERIC ED 386526

Farquharson, M. (1989). *Learning styles of Arab students in EFL classrooms.* ERIC ED 311741.

Gordon, W. (1986). The Cognitive Laterality Battery: Tests of specialised cognitive function. *International Journal of Neuroscience, 6*, 79-92.

Hermann, N. (1990). *The creative brain.* North Carolina: Brain Books.

Hudak, M. A. & Anderson, D. E. (1990). Formal operations and learning styles predict success in statistics and computer science courses. *Teaching of Psychology, 17*(4), 231-234.

Jen, C. I. (1991), The relationship between selected educational cognitive style elements and mathematics achievement among sixth and seventh graders. *Dissertation Abstracts International, 52*(5), 1627A (University Microfilm No. 91-21, 264).

Kirby, P. (1979). *Cognitive style, learning style and transfer skill acquisition.* Columbus, Ohio: National Centre for Research in Vocational Education, The Ohio State University.

Kolb, D. A. (1986). *Learning Style Inventory: Self scoring inventory and interpretation booklet.* Boston, MA: McBer.

Lavach, J. F. (1991). Cerebral hemisphericity, college major and occupational choices. *Journal of Creative Behavior, 25*(3), 218-222.

Lee, S.C. & Yeap, L. L. (1995). Cognitive style preferences among adolescent mathematics achievers: Perception, processing, and hemisphericity. *SCIENTAS, 9,* 2-14.

Lim, S. D. (1987). An investigation of the relationships of brain dominance, spatial-visualisation ability, attitude toward mathematics, gender, and geometry proficiency test results in high school. *Dissertation Abstracts International, 48*(8), 2011A.

Locke, D. C. (1993). *Multicultural counselling.* ERIC, ED 357316.

Mayer, R.E. (1991). *Thinking, problem solving, and cognition* (2nd ed.) N.Y.: W.H. Freeman.

Ministry of Education (1991). *Improving primary school education.* Report of Review Committee. Singapore.

Parker, C. J. (1989). Computer-assisted instruction, Mathematics achievement, and learning style. *Dissertation Abstracts International, 50*(10), 3144A.

Rhodes, R. W. (1990). Measurements of Navajo and Hopi brain dominance and learning styles. *Journal of American Indian Education, 29* (3), 29-40.

Smith, D.M. & Kolb, D. A. (1986). *User's guide for the Learning Style Inventory: A manual for teachers and trainers.* Boston: McBer.

Yeap, L. L. (1989). Hemisphericity and student achievement. *International Journal of Neuroscience, 48*(3-4), 225-232.

Yeap, L. L., Chong T. H., & Low, G. T. (1994). *Demographic Data Inventory.* Singapore.

Yeap, L. L., Chong, T. H., & Wong, P. (1993). *Cognitive profiles of mathematics achievers.* Paper presented at the International Seminar on Mathematical Science, Kuching, Sarawak, Malaysia.

Yeap, L. L., Chong, T. H., & Wong, P. Cognitive diversity among adolescent mathematics achievers. In *Growing up in Singapore: The adolescent years.* Singapore. *(in press)*

Yeap, L. L. & Wong, P. (1991). Self perceived and measured cognitive styles among trainee teachers. In W.K. Ho & R. Y. L.Wong (Eds.), *Improving the quality of the teaching profession: An international perspective.* Singapore: Institute of Education with the permission of the International Council on Education for Teaching.

Yeo, K. C. (1993). *The learning of Shakespearean drama: The effects of visual-auditory and audio-and-print modalities.* Master of Education Dissertation, National University of Singapore, Singapore.