DIFFiculties and Misconceptions in the learning of
fractions by primary school children:
a case of hemispheric mismatch

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A thesis submitted
in full fulfillment of the requirements for the degree of
Doctorate of Philosophy

Faculty of Cognitive Sciences and Human Development
Universiti Malaysia Sarawak
June 2001
ABSTRACT

Every human being, through nature and nurture, exhibits a propensity to employ different brain substrates for different thoughts, actions and reactions to the environment. The left hemisphere is said to be responsible for processing verbal stimuli and the right hemisphere for visual-spatial processing. Hence, pupils with different brain laterality patterns will demonstrate different capacities in learning a particular topic or subject. This study aimed to identify the brain laterality patterns of pupils and to investigate its associations with visual-spatial ability, mathematics and fraction scores.

Paper-and-pencil tests of brain laterality, visual-spatial and fractions were conducted among a random sample of 512 Primary 5 children. 28 high achievers and 28 low achievers in the fraction diagnostic tests were randomly selected for clinical interview sessions. An attempt to understand the nature and specificity of the learning difficulties experienced by children in fractions was made by identifying the cerebral substrates used in fraction processing. This was done by comparing task-related EEG changes between 20 low and 19 high ability pupils during fraction tasks. These pupils, randomly selected from the clinical interview group, were all right-handed and had no previous history of neurological dysfunctions.

It was found that pupils of whole-brained dominance scored statistically highest in fraction conceptual knowledge test. High fraction achievers were also high visual-spatial scorers and vice versa. The results suggested that there was an involvement of both whole brain and visual-spatial processing in the learning of fractions. The significant differences in task-related EEG activation patterns and asymmetry indices between these high and low achievers were interpreted in terms of their differential cognitive and information processing strategies. Whilst the low achievers presented a tonic bias for a more active right hemisphere during resting conditions, they exhibited a tendency to employ more of their left hemispheres in working out fraction tasks. This contrasted with the high achievers who, while presenting a resting tonic bias for a more active left hemisphere, were able to utilize more of their right hemispheres during fraction tasks. As the right hemisphere has been widely postulated to be involved in visual-spatial strategies, the findings suggested that the low achievers employed less efficient neural substrates and hence, less efficient cognitive strategies whilst the high achievers were more likely to use more efficient visual-based strategies. This observation was discussed in relation to the learning difficulties and misconceptions of the low achievers identified through a verbal protocol of the cognitive task analysis.

A neurobiological model of fraction learning was developed to discuss the involvement of appropriate neural resources in the processing of fraction tasks. This model was then used to describe the breakdown in fraction learning through an apparent mismatch of neural substrates and task demands. The implications towards using audio-visual aids, non-symbolic manipulations and visual-based strategies in the teaching and learning of fractions were also discussed. Recommendations were made for instructional and curricular reforms towards the teaching and learning of fractions. This study also directed attention to a multidisciplinary approach of cognitive neuroscience in educational research.
ABSTRAK

Setiap manusia, secara semulajadi dan pengalaman, menunjukkan suatu kecenderungan untuk menggunakan substrat-substrat otak yang berlainan untuk pemikiran, tindakan dan gerakbalas kepada persekitaran. Hemisfera otak kiri dikatakan bertanggung jawab untuk pemprosesan stimuli lisan manakala hemisfera kanan pemprosesan visual-spatial. Oleh itu, murid-murid dengan corak lateraliti otak yang berbeza akan menunjukkan keupayaan yang berbeza untuk belajar sesuatu topik atau mata pelajaran. Kajian ini bertujuan untuk mengenalpasti corak lateraliti otak para murid serta menyelidiki perkaitannya dengan kebolehan visual-spatial, skor-skor matematik dan pecahan.

Ujian-ujian kertas-pensel mengenai lateraliti otak, visual-spatial dan pecahan ditadbirkan kepada satu sample rawak terdiri daripada 512 murid Tahun 5. 28 orang murid berkebolehan tinggi dan 28 orang murid berkebolehan rendah dalam ujian-ujian diagnostik pecahan dipilih secara rawak untuk sesi temubual klinik. Dari kumpulan ini, 20 orang murid berkebolehan tinggi dan 19 orang murid berkebolehan rendah dipilih untuk kajian EEG yang bertujuan untuk mengenalpasti substrat-substrat otak yang digunakan semasa pemprosesan pecahan. Ahli-ahli sub-sample ini bukan kidadan tidak mempunyai sebarang masalah neurologikal.


DECLARATION

No portion of the work referred to in this thesis has been submitted in support of an application for another degree of qualification of this or any other university or institution of higher learning.

PENGAKUAN

Tiada bahagian daripada tesis ini telah dikemukakan untuk menyokong sesuatu permohonan lain untuk mendapatkan ijazah di universiti ini atau institusi pengajian tinggi yang lain.

Signature: [Signature]

Name: Ong Puay Hoon

Date: 27 June 2001
To Kum Loy,

Kher Lee,

Kher Ching,

Khai Meng,

and

in sweet and everlasting memory of our first-born, Nq Khai Thit

Only a while you smiled at us,
Only too brief we held you close,
But forever, we treasure those moments.
Sweet child .....
till we meet again at heaven's door.
I would like to acknowledge the award of the scholarship and study leave from the Ministry of Education and Aminuddin Baki Institute, Malaysia to pursue a course that leads to the Degree of Doctorate of Philosophy at this university.

The pursuit of the study that culminates in this academic thesis will not be possible without the help of many people. It is with a grateful and humble heart that I acknowledge all the help extended to me.

My supervisors have been an unfailing source of valuable inputs, insights and guidance, both in the work and preparation of the manuscript. You have given me direction, shape the quest, guide the writing, and most of all, each of you have ungrudgingly given me your time to listen me out. Your constructive and sharp criticisms gave me confidence and encouragement. With admiration and humility, I thank you all, Prof. Dr. Syed Hassan bin Syed Ahmad Almashoor, Prof. Dr. Razali bin Arof, Prof. Madya Dr. Peter Songan and Dr. Wang Yin Chai, from the bottom of my heart. Only God can repay this deed and may He continues to shower his blessings on each one of you.

I thank Mr. Kamal D. E. Quadra, Director of Sabah Education Department, who as ex-principal of Maktab Perguruan Gaya, Kota Kinabalu, unceasingly encouraged and supported his staff to pursue further studies.

I acknowledged the insightful and tireless comments of Prof. Dr. Dietrich Lehmann, Director, The KEY Institute for Brain-Mind Research, University Hospital of Psychiatry, Zurich, Switzerland for analysis of the EEG data and to Dr. Abu Bakar Abd. Rahman, Consultant Neurologist, Pantai Medical Center, Melaka for his invaluable help in editing the EEG output.

The late Prof. Madya Dr. Jamali Ismail had helped to guide my first few attempts in shaping the research proposal. I owe him my grateful thanks and pray that his soul rest in peace among God's chosen people in heaven.

Despite her heavy work schedule, Madam Elaine Khoo Guat Lein (Faculty of Cognitive Sciences and Human Development, UNIMAS) still found time to read, edit, comment and critique my research proposal and the thesis draft. Thank you Elaine, I am truly indebted to you. I record my heartfelt thanks to Dr. Akhbar Ibrahim who as my Principal in Tun Abdul Razak Teacher-Training College found time among his tight schedule to read and offer constructive suggestions to the draft.

I take this opportunity to thank Cik Norazuna Norahim (Deputy Dean, Center of Language Studies, UNIMAS), Puan Muriatul Khusmah Musa (Center of Language Studies, UNIMAS), Puan Monica Lau (Tun Abdul Razak Teacher-Training College, Kota Samarahan) and Encik Md. Zin Mohd. Amin (Gaya Teacher-Training College, Kota Kinabalu) who helped to translate the research instruments.
My grateful thanks also to Mr. Hong Kian Sam (Faculty of Cognitive Sciences and Human Development, UNIMAS) whose observations, comments and suggestions to the statistical procedures and analyses allowed a greater sense of confidence in the reporting. I gratefully acknowledged the help and assistance of Dr. Spencer Empading (Faculty of Social Sciences, UNIMAS), Dr. Charlie Laman (Faculty of Resource Science and Technology); Mr. Nagarajah Lee (Universiti Teknologi MARA, Kota Samarahan) and Dr. Toh Wah Seng (Batu Lintang Teacher-Training College, Kuching) who have most willingly given up their time to sort out my statistical difficulties and loaned out useful references.

I am indebted and grateful to the heads of schools, senior assistants and teachers of the schools involved in the pilot and research studies who have pleasantly and whole-heartedly rendered their approval, assistance and support. To the pupils involved in Sekolah Rendah St. Anthony, Penampang, Sabah; Sekolah Rendah Bantuan St. Theresa, Kuching; Sekolah Rendah Bantuan St. Thomas, Kuching; Sekolah Rendah Kebangsaan Encik Buyong, Kuching and Sekolah Rendah Merpati Jepang, Kuching and their parents/guardians, I thank you with all of my heart.

I am indebted to the Dr. Liding Jungian, Director of the Medical Services, Sarawak General Hospital for his approval to use the EEG machine and technician expertise. Very special thanks and gratitude to Mr. Berinoe Rojey, the EEG technician of Sarawak General Hospital, who has given so much of his time and sharing of expertise to do the EEG recordings and analysis. I acknowledged the free use of the Medelec’s Power Spectrum Analysis program from Mr. Choong K.K. of Delta Medisains Sdn. Bhd., Kuala Lumpur and the expert comments on EEG procedures of Mr. Thomas Yeoh, Medical Neurophysiology Technologist, Loh Guan Lai Specialist Hospital, Penang.

I thank Miss Angela Anthonysamy (Faculty of Cognitive Sciences and Human Development, UNIMAS) for her valuable support and help in sourcing out much-needed research articles. My grateful thanks to Mr. Lee Kim Chong, Maktab Perguruan Gaya, Kota Kinabalu for his help in opening my way to the pilot-study school and his most patient tutoring in AutoCAD.

I thank Prof. Dr. Ibrahim bin Mamat, Dean, Faculty of Cognitive Sciences and Human Development, UNIMAS for his support and help in facilitating my study. I acknowledge and thank Dr. Abang Ahmad Ridzuan bin Abang Awit (Faculty of Cognitive Sciences and Human Development, UNIMAS) for opening my way into the research schools. Grateful thanks to the lecturers, tutors, managers, administrative assistant and support staff of Faculty of Cognitive Sciences and Human Development and Center of Language Studies, UNIMAS for their help and words of encouragement. I thank the managers and support staff of Center of Graduate Studies and Research Support, Center of Academic Information Services, Chancellery and the telephone operators for their joyful countenance and support.
I acknowledge the help of Dr. Soe Soe New (resident doctor, UNIMAS), Madam Park Young Soon (Faculty of Information Technology, UNIMAS), Dr. Ang Whye Tong (Faculty of Information Technology, UNIMAS) and Mr. Tan Chong Eng (Faculty of Information Technology, UNIMAS) for their help in facilitating the EEG study. I thank the many graduate and undergraduate students of UNIMAS who have never failed to provide a smile, a pat on the shoulder or help with the computer whenever there was a need. To Fletcher Tan, Phang Khar Yeow, Donny Chan, Ng Giap Weng, Dunstan Goh, Crispin, Nelson, Rojin - my grateful thanks.

My heartfelt gratitude to my best friends, Miss Fong Lye Choo (Maktab Perguruan Persekutuan Pulau Pinang, Penang) and Miss Ewe Mee King (Tuanku Bainun Teacher-Training College, Bukit Mertajam for their constant encouragement, moral, physical and spiritual support to me and my family.

My sisters, Liu and Tee, have been a constant source of inspiration. When the going gets tough, they are always there to lend a helping hand. Their encouraging words lent some sense of sanity when hopelessness prevailed. Their attention and care to my children during these trying period when the matriarch seemed lost in her quest for a dream provided strength to the structure of the family framework. Thank you, girls, for the notebook, editing the draft and ....... everything!

Upon urgent summons, my mother has flown across the seas to come and look after what’s left of my family. Her unfailing support and love tug at my heart-strings and constantly reminded me not to quit. To both my parents who have stood by me and my family, I salute and love you. To my siblings and in-laws, thank you all for the unconditional support.

Kum Loy, my beloved, is a husband beyond compare. I am because you are! Your steadfastness and unconditional support allow me to be what I am and can do. Your love surrounds and gives me strength. Thank you, darling. To my children - Kher Lee, Kher Ching and Khai Meng who were initially mystified at their mother having to study and leave them, I thank you all for struggling with me.

To all of you who have provided moral support and, whether directly or indirectly, lent a hand to the successful completion of this work, I thank you.

And most importantly, thank you God, for your unfailing presence and blessings to me and my family.
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INTRODUCTION

All men by nature desireth to know.

Aristotle

1.1 Introduction

Mathematics being part of universal education appears in the curriculum of all schools. It has long been recognized that the basis of success of any society is predicated to a certain extent on its ability to use mathematical concepts as mathematical understanding facilitates a person’s participation and appreciation of many daily human activities. Further, mathematics achievement, in part, determines future education and employment prospects (Sammons, 1995). However, mathematics educators all over the world are expressing concern about the degree of mathematical understanding displayed by children in schools (Shohtoku, 1993). The declining levels of mathematics achievement in some countries have caused a serious deterioration in their industrial strength and handicap their progress in research and development. Needless to say, this decline has seriously constrained the countries’ efforts to compete internationally.

The level and extent of mathematical understanding and computational expertise by Malaysian children is also a national concern. Local research has shown that the level of achievement and attainment in mathematics in primary schools, especially qualitatively, has not been favorable (Jabatan Pendidikan Sabah, 1990). Although pupils were able to pass mathematics, the grade achievement in a scale of A to E of a significant majority hovered around C. A later study by the Ministry of Education showed that the standard of mathematics at primary school level in rural areas of the country was not satisfactory (Star, 1991). A survey by the Perak Education Office showed that at least 10% of Primary 2 and 9% of Primary 3 pupils were still unable to read, write and compute well (Utusan Malaysia, 1991). Abdul Wahab Hashim (Deputy Director-General of Education) reported an approximate 85,000 pupils in our primary schools as slow learners, that is, exhibiting serious learning difficulties in the 3Rs (Reading, ‘Riting and ‘Rithmetic) (Star, 24 August 1998). These slow learners were to be put through a new and intensive, and of course very costly, remedial programme beginning 1999. Very recently, we learnt that 70 percent of pupils in 1786 schools failed in the Primary School Evaluation Test (Ujian Penilaian Sekolah Rendah, UPSR), which was nationally-administered for all Primary 6 pupils (Vinesh, 2000). This ought to be viewed with deep concern as the core subjects being assessed in this national examination include Mathematics, Science, Malay Language and English Language.
The Primary School Evaluation Test is an evaluation of the achievement of pupils who are in their final year of primary school education. In the evaluation of 1994, the percentage of passes in Mathematics for pupils in the three types of primary schools were as follows:

1) National and National-Type schools (Sekolah Kebangsaan dan Sekolah Rendah Kebangsaan) .... 64.0%
2) National-Type (Chinese) schools (Sekolah Rendah Kebangsaan (Cina)) .... 86.36
3) National-Type (Indian) schools (Sekolah Rendah Kebangsaan (Tamil)) .... 58.1%

Average percentage of passes in Mathematics .... 69.5%


Schools with different medium of instruction displayed different performances. The Chinese language-medium schools performed best with 86% pass, followed by the Malay language-medium schools at 64% and lastly, the Tamil language-medium schools which fared the worst at 58%. An extensive doctoral study supported these findings and showed that not only pupils from Chinese language-medium schools scored higher in mathematics, they indicated more positive attitudes towards the subject than their counterparts (Nasir, 1997). This disparity of achievement in mathematics was also seen between the urban and rural schools and between pupils of different socio-economic groups and ethnicity. Pupils from urban schools, from upper socio-economic groups and of Chinese parentage performed better, both in mathematics scores and positive attitudes.

Besides unsatisfactory performance and achievement, mathematics learning in Malaysia is also plagued by other problems. Students, both in the primary and secondary school levels, demonstrate a high level of mathematical anxiety and phobia (Tham, 1998). Teacher-trainees in mathematics also exhibit anxiety in learning mathematics (Gan, 2000) and display difficulties and misconceptions on many basic topics in mathematics (Kaur, 1990; Koe, 1992; Ong, Muhamad, Walaiporn, Wilai & Wakidi, 1992). Teacher-prepared materials and published text/workbooks used in schools display misconceptions in many fundamental concepts of mathematics and demonstrate limited flexibility and diversity in its, forms of representations (Koh, 1991). Students’ enrolment in secondary mathematics and science is falling (Jabatan Pendidikan Sarawak, 1996; Lee, Ghani, Yoong, Khadijah, Loo, Lim, Munirah & Zin, 1996) despite being earlier warned by Omar (1993) that our country is facing a shortage of expert human resource to run and manage the national science and technology enterprise. Chong Kah Kiat, Minister of Tourism, Environment, Science and Technology Development of Sabah, even exhorted that science subjects were the least liked in schools among Sabah students (Borneo Post, 2000).

An extensive research by Lee et al. (1996) revealed that many secondary school students in Malaysia shy away from Science because of their poor foundations in Mathematics (58.0% of Form 4 and 59.0% of Form 6 students). They have no confidence in Mathematics (42.8% of Form 4 and 48.1% of Form 6 students) and
they do not want to take Additional Mathematics (34.5% of Form 4 students). Pupils in National Primary schools (Sekolah Kebangsaan), when interviewed, declared having mental blocks in Mathematics to explain their performance. The researchers conjectured that this could probably be due to self-fulfilling prophecy.

They also provided data that there were 38 681 Science students (or 22.31%) and 134 669 Non-Science students (or 77.69%) in 1993 for all Forms 4 and 5 classes in all states in Malaysia, thus giving a ratio of Science to Non-Science students at 22: 78. In our strife to increase the ratio of Science to Non-Science students to 60: 40 as in Vision 2020 by the turn of the century (Ahmad Sarji, 1993), it is timely to call for greater attention to research of children’s learning of primary mathematics especially in the way the brain is involved. Brain research has become the basis for decisions to improve education, especially in United States and as teaching is considered both an art and science, it becomes imperative to seriously look into the applications of brain research in the classrooms.

1.2 Background of the Study

The official mathematics curricula differ from country to country according to the cultural values placed on mathematical knowledge and the current needs and demands of society. In Malaysia, our earnest drive for technology-literate knowledge workers via the smart schools for the scientific-technological challenges of Vision 2020 calls for greater attention and emphasis as to why our students and those abroad are still under-achieving in Mathematics.

While much attention and financial resources have been directed at the level of competence and attainment in secondary mathematics by the central government, for example, through the ‘Gerak Gempur Sains dan Matematik’ (Science and Mathematics Crash Program) (Kementerian Pendidikan Malaysia, 1996), primary mathematics has remained largely a concern for the individual state, district or school authorities. Yet, primary mathematics lay the foundation towards further conceptions, perceptions and inclinations of the pupils, not only towards mathematics, science and technology especially computer technology in later education but also in the world of work, in adulthood and support and guidance towards their off-springs as parents. The ‘multiplier effect’ of parents who are weak or ‘fear’ mathematics influencing their children on vocational choices might be a major factor in turning off many students from the science stream in Forms 4, 5 and 6. This view supported Shohtoku’s (1993) belief that “the education of girls and boys in mathematics and science at an early stage has a strong impact upon their aptitude for and interest in their choice of engineering and technology-related subjects at higher stages of education.” (p. 302). As these conceptions and perceptions are of utmost importance in the nation’s strive towards being a global market player, pupils’ level of success in primary mathematics demands attention.
1.2.1 Why fractions?

Mohamad’s (1988) findings that the effective learning of mathematics is hindered by three main factors, that is, no interest in mathematics, a misconception that mathematics is difficult and a poor basic knowledge of mathematics provided support that the grounding of the basic concepts and skills of mathematics in primary schools will influence its interest and achievement during the secondary schools.

The Malaysian primary mathematics curriculum, Integrated Curriculum for Primary Schools (Kurikulum Bersepadu Sekolah Rendah, KBSR), consists of eight topics, of which one of them is fractions (Curriculum Development Center, 1994) (Appendix A). Fractions is taught beginning Primary 3 until Primary 6 (Appendix B). There are a number of reasons why the topic fractions has been chosen to be the primary focus in this study.

Firstly, fractions is a compulsory topic in all primary school mathematics curricula of South-East Asia’s Ministers of Education Organization (SEAMEO) countries and generally taught in the schools’ mathematics curricula of other countries. Hence, pupils in these countries might encounter similar learning problems in fractions.

Secondly, fractions appear to be an inherently difficult abstraction right from early times. People in early civilizations went to great lengths to avoid them. One common method used by the early people to deal with fractional parts without having to resort to fractions was to create sub-units of a measure. For example, the merchants of Rome would speak of “uncias” (1/12 of the ‘as’), “sextans” (2/12 of the ‘as’), “semuncia” (1/24 of the ‘as’) and so on, the ‘as’ being a pound of copper (Smith, 1958).

Thirdly, it has been ranked as one of the three most difficult topics to learn by pupils and to teach by teachers in Malaysian schools (Ferrer, Leong & Liau, 1989; Seth & Menon, 1990; Ong et al., 1992). Seth (1990) identified decimals, fractions and division in word problems as the first three most difficult topics to teach in order of decreasing difficulty. Teachers perceived the difficulty was brought about by children’s misconceptions and lack of instructional materials. There was a slight mismatch between teachers and students preferences in the teaching-learning process as students ranked fractions as the most difficult topic to learn before decimals. Elsewhere, Suydam (1978) after reviewing data from a variety of assessments, wrote, “the topics with which difficulty (or weakness) were reported can be ranked in this order of frequency: first, fractions, ...” (p. 212).

Fourthly, fractions is introduced early in the curriculum, that is, in Primary 3 (Appendix B) and extends until Form 5 in the secondary schools. The existence of any gaps in learning or misconceptions in this early stage if not systematically diagnosed and remediated might prevail during the learner’s entire schooling experience.
Fifthly, knowledge and skills in common fractions are important bases for subsequent topics in mathematics – decimal fractions, percentages, ratio, proportion, multiplication, division, measurement (e.g. length, weight, volume, area, time), algebra and graphs. Not only will any initial ‘minor’ difficulty in early fraction work get exacerbated as the cumulative fraction syllabus gets spirally wider, the difficulty might ‘over-spill’ into these related areas in mathematics and even other subjects.

Sixthly, experienced (Fuller, 1997) and prospective (Kaur, 1990; Ong et al., 1992) mathematics teachers have been shown to exhibit significant areas of weaknesses in basic concepts and computational procedures of fractions. There were teachers who view fractions as consisting of two separate numbers, each number denoting different quantities (Ong et al., 1992).

Seventhly, fractions has proved important for life outside school – at home, playground and at work. The process of sharing or dividing something between two and more people could involve fractions. For example, dividing a pizza between the six members in a family or distributing a pack of cards among four players. Measurements are often expressed as fractional parts of main units, for example at the supermarket, there are goods sold by the half kilogram (sugar, salt, butter, margarine) and the half liter (milk, lemonade, cooking oil). Material might be bought to the nearest half or the nearest quarter meter, for example 1¾ meters for a skirt, or 10 ¼ meters for curtains. Time is often expressed as quarter past, half past and quarter to the hour.

1.2.2 Why are fractions difficult to learn?

There are a number of features inherent in the structure of fractions that lead to it being difficult to learn, teach and use. The following list describes these features:

1) There are diverse interpretations and possible sub-constructs for rational numbers (of which fraction is a subset) – as part-whole relationship, a measure, quotient, ratio, operator/mapping number and probability (Keiren, 1976). Fractions, itself, has several different conceptual meanings:

(a) a number (either the same as rational number or a subset of the rational numbers);
(b) a numeral (symbol, expression);
(c) a part of a regional whole;
(d) a portion of a discrete set of objects;
(e) a measurement point on a number line;
(f) one number divided by another; or
(g) an ordered pair (does not matter whether written as (a, b) or a: b or \( \frac{a}{b} \)).