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Procedia - Social and Behavioral Sciences 56 (2012) 175 – 182

Procedia
Social and Behavioral Sciences

International Conference on Teaching and Learning in Higher Education (ICTLHE 2012) in conjunction with RCEE & RHED 2012

A Conceptual Framework for Mathematical Ability Analysis through the Lens of Cultural Neuroscience

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Abstract

This paper present a conceptual framework that will be used for analyzing divergence in mathematical thinking, skills, abilities, processes and achievements in mathematics through the lens of cultural neuroscience. The bidirectional interface between mathematical thinking and cultural neuroscience is used to explore different learning styles, cognition patterns and neural activities in response of mathematical thinking influenced by culture. Research questions are emerged as how do innate mathematical abilities, plasticity of the young brains and the mathematical cultural environment contribute to mathematical thinking? Why do a group of students from one ethnicity tend to achieve higher scores in mathematics than a group of students from another ethnicity? How does cultural neuroscience report the differences in mathematical thinking and learning trajectories? How does culture accelerate the mathematical thinking?

Keywords: Mathematical Ability Analysis; Mathematical Thinking; Cultural Neuroscience; Interpretivism; Mixed Method Research;

1. Introduction

Strength in mathematics is a gauge of a nation’s scientific and technological standing. Therefore, mathematics education gets big concern and becomes a hot polemic by the government especially the Ministry of Education (MOE) Malaysia. Since 1992, some common themes that appeared in the local news media reflect this concern. For example, “Maths help from Chinese schools” (The star, 21 January 1992); “Ministry studying Chinese approach to mathematics” (New Strait Times, 21 January 1992); “Teaching Math the Chinese way” (The Star, 3

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doi:10.1016/j.sbspro.2012.09.644

September, 1999) and lately "Success of Chinese students in science and math to be studied" (Business Times, 2 September 2004). Malaysian Examination Board yearly report for the year 1991-2001 also showed a clear difference in mathematics achievement of three ethnic national type schools. From the newspaper headlines and graphical representation of the above report as shown in figure 1, we found that Chinese students are high achievers in mathematics examination. Since the performance gap is decreased from 1991 to 2001 but still Chinese are dominant in the percentage passes. The above stated situation leads to several questions and potential research themes. Major concern is to identify the factors affecting the mathematics achievement and question arises "can we manipulate these identified factors for improved mathematical skills". One research domain related to culture and math in Malaysia titled as "The culture of mathematics learning in two Chinese school: Drill and Practice" and "Cultural Differences and Mathematical Learning in Malaysia" is already been explored (Lim, 2002, 2003) and findings are quite helpful to visualize the problem dimensions.

Our research is focused on "variations in activation patterns in brain during mathematical thinking" that emerged due to the interweaving of mathematical thinking and cultural neuroscience and still it is unexplored within Malaysian context. We want to identify difference in mathematical learning trajectories at one particular grade level among students of Malay Medium, Chinese Medium, and Tamil Medium National Schools. Before presenting the conceptual framework as a result of collaboration of both the focused and interlinked concepts of mathematical thinking and cultural neuroscience, the utter need is to explore them separately to build up an overarching exemplar for our future research. After captivating the working regularities of these communicating concepts, we will try to discover the shared regularities to formulate a potential future research Problem. Combining the queries from both the areas would paint the same picture in a distinct way resulting in a set of new research questions. The suggested framework will be dynamic in nature starting from a crude form and morphing to improved shapes along with the research progress.

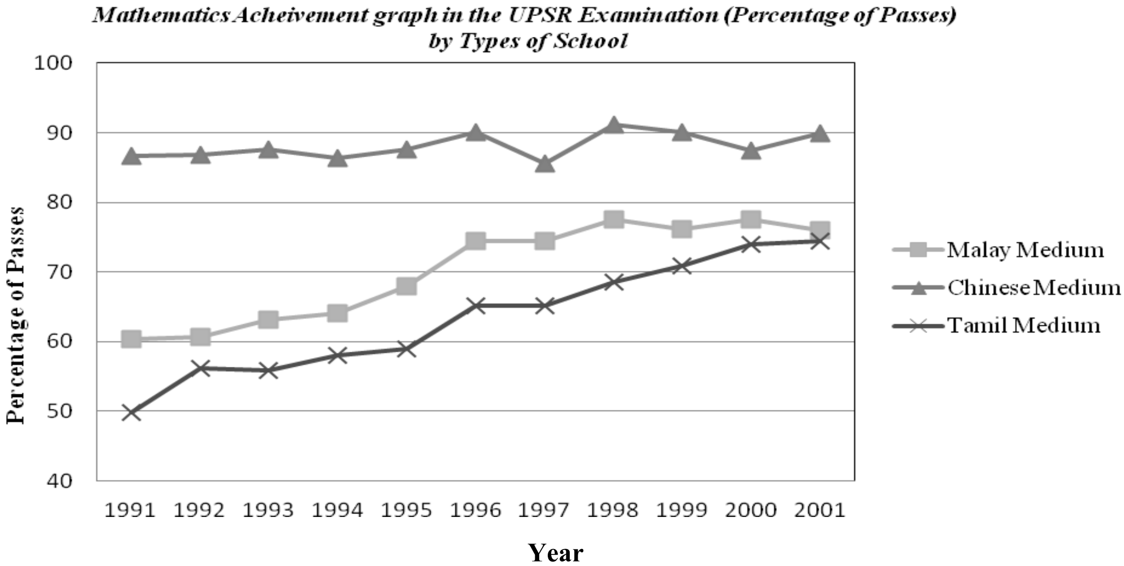


Fig. 1. Graph prepared from data of Malaysian Examination Board Yearly Report for the year 1991-2001.

To understand the shared regularities of mathematical thinking and cultural neuroscience concepts, we need to explore the joint research in mathematical thinking and cultural neuroscience.

1.1. Bi-directional relationship between mathematical thinking and cultural neuroscience

Mathematical ability involves effective thinking with conceptual learning; students need to be taught to think logically along with practicing the numerical problems but on the contrary they do practice a problem, and then repeatedly do the same kind of problems until that is hardwired in their brains (Pearse & Walton, 2011). According to Sfard (2008) mathematical thinking is a communication tool and is used in languages unintentionally whereas Uri Leron synthesizes the social, cognitive and biological roots of latest research in mathematical thinking (Uri, 2003). He separated three levels of mathematical thinking as hard-wired rudimentary arithmetic in brain supporting the existence of innate abilities , informal mathematics based on daily cognitive mechanisms easily learned by experiencing the world around and formal mathematics learnt through formal mathematical learning processes using formal mathematical language, abstraction, de-contextualization and proof (Uri, 2003). Corte and Verschaffel (2007) reported four interlinked components of mathematical thinking and learning as competence, learning, intervention and assessment as shown in Figure 2 along with their working regularities.

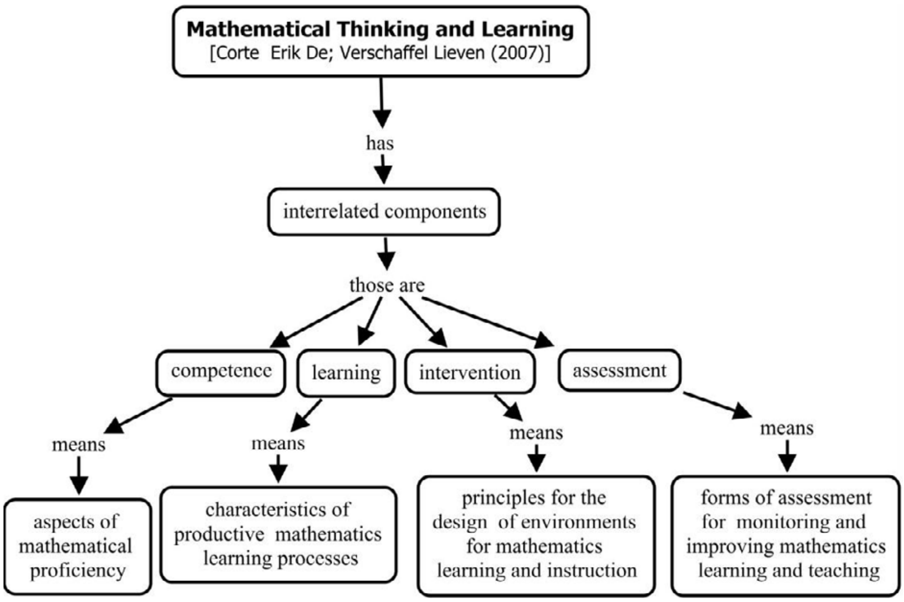


Fig. 2. Interrelated components of mathematical thinking and learning

The collaboration of neuroscience and cultural psychology is emerged as cultural neuroscience. Cultural variations in perception and thinking give rise to variations in mathematical thinking by showing the link between culture and cognition. Directive and self-consciousness of thoughts, feelings and actions are needed to be explored and neural activity pattern are required to be recorded to know the myth of mathematical thinking (Ames & Fiske, 2010). Cognition of problems, perception of objects and scenes, and emotions of cultural practices are considered to be the basic components to understand the cognitive processes of mathematical thinking. The above mentioned components combined together aid to answer how variation in mathematical thinking is guided by culture (Rule, Freeman, & Ambady, 2011). Gutchess, Schwartz, & Boduroğlu (2011) reported the influence of culture on memory by studying the cognitive processes across cultures. Pros and cons in information processing due to cultural norms are identified and culture based schemes are suggested to eliminate the mathematical thinking discrepancies. Distinct neural activities in distinct sequential manner are recorded to identify different information processing mechanisms and thus propose ways to implement the improved cognition required for different human brains (Gutchess et al., 2011).

Recent research findings in the field of Cultural psychology provided sufficient evidence that different ethnic groups possess quite opposite thinking processing styles. A comparison between people of Western and Asian cultures are carried out and results showed that former possess analytical thinking style that is familiar to important central objects but less sensitive to contexts whereas later are trained for holistic thinking style that is accustomed to background and contextual information. (Han, 2010). Our research will further explore the variations in mathematical thinking of different Asian practicing cultures in Malaysia.

Cultural influence on multi-level thinking processes and neural correlates primary thinking processes like perceptual or attention-based processing are also reported by latest brain imaging research. Cultural specific thinking styles thus emerged through understanding of thinking processes and their related neural activity patterns (Han, 2010). The bidirectional relationship between cultural neuroscience and mathematical thinking is shown in Figure 3. The self-explanatory concept map shows the three basic contributors i.e. innate mathematical abilities, informal educational culture and formal educational culture developing mathematical thinking and recorded by cultural neuroscience.

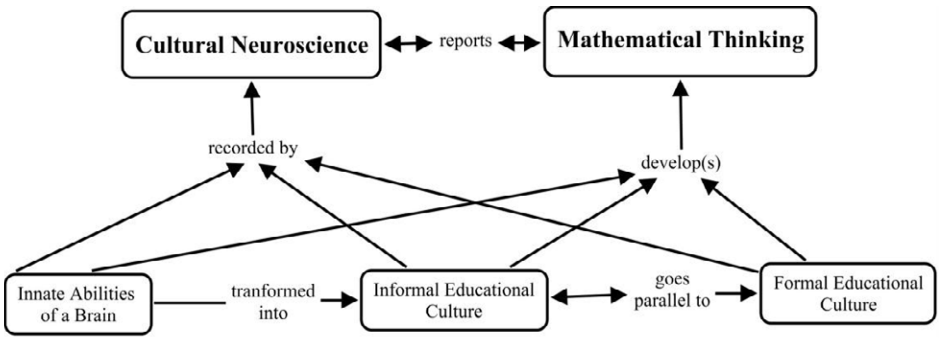


Fig. 3. Bidirectional relationship of cultural neuroscience and mathematical thinking

Ginsburg, Cannon, Eisenband and Pappas (2008) described several contributing factors in mathematical thinking such as instinct learning abilities, biological basis for prime concepts , physical environment, contribution of social environment in multiple ways and concluded that all young learners have ability, chance and drive to learn basic mathematical skills. They also reported that most of the research has been focused on numbers than other mathematical features and concluded that number based thinking is extremely difficult. Young brains have in-built ability to rote learn, use counting rules, work with concrete as well as abstract concepts, employ different strategies for addition, work with complex procedures (Ginsburg et al., 2008).

We want to investigate the developmental changes of innate abilities to higher level of mathematical thinking and will predict culture based mathematical learning trajectories to interpret the neural activities for specially designed problem set to carry out an fMRI experiment. An urgent need to understand the divergence in mathematical learning trajectories is required (Daniel, 2008) and will help to recognize the cultural influence on these abilities.

2. Proposed Conceptual Framework

The interpretivist epistemological perspective is selected for the development of conceptual framework shown in the figure 3. This perspective will enable us to view multiple subjective realities based on cultural variations and to describe a situation, experience or phenomenon dealing with mathematic ability within the cultural context. Due to diversity in processing styles of human brain, the methods and approaches of above analysis would emerge and have to be adjusted during the study. This requires us to work on partnership basis with the respondents to explore their brain processing activities based on a validated stimulus. The findings will lead us to record situated descriptions about variations in mathematical thinking trajectories based on cultural neuroscience. In this research we bracketed the contextual boundaries around the geographical region of Malaysia, specific mathematical learning abilities, primary and secondary schools goers and major cultural practices in Malaysia.

The overarching perspective of interpreticism in this mixed method research is likely to consider the situation, participants and researcher based contextual truth (Nancy, Elliot, & Wayne, 2008). Our research will try to tell the individual stories of the participants from diffent cultural environment and to identify the underlieing truth embedded in their mathematical thinking (Nancy et al., 2008). To get additional focus, we will finally select one or a combination of phenomenology, constructivism and social constructivism and symbolic interactionism. The research stretegies will be finalized from a pool of phenomenoloy, grounded theory, ethnography or by designing a collective case study with a combination of above three. The last but most important stage of our research will be to develop an effective stimulus for an fMRI experiment and to interpret the basis of different activation patterns during the mathematical thinking and a performance matrix to compare their neural responses due cultural impact.

Three active input streams named innate ability to learn mathematics of the young brains, home and social culture contributing as informal development and educational culture as formal development of mathematical thinking processes are shown in Figure 4. The variation in mathematical thinking among individuals and social and culture communities would result in variations of activation patterns of brain and final results are interpreted though quantitative as we as qualitative research methods. The contributing variables for social and home culture are ethnicity, language, attitudes and beliefs, parents' perception about mathematical thinking, importance of examination results, importance of active learning, importance of extra coaching and emotional directives and participate as informal development of mathematical thinking whereas contributing variables for formal educational culture are type of national school, vision and mission of school, attitudes and beliefs of teachers, teachers' perception about mathematical thinking, teaching and learning processes e.g. representation, visualization, metal images, abstraction, reasoning etc. in the classroom, importance of examination results, pedagogical approach for mathematical thinking, importance of extra coaching and emotional directives. The quantitative or qualitative way of inquiry about the each listed factors is still to be decided. Preliminary Study will help to decide about the proper investigation strategies for different potential factors causing mathematical thinking, the areas of mathematics to be focused depicting cultural influence and type of data to be collected.

The underlying theories will be selected by exploring the How People Learn (HPL) model known as meta-framework for instructional design defined by Bransford, Brown and Cocking (1999) and related theories will be meant for a chosen combination of student-centered, knowledge-centered, assessment- centered and community centered instruction intervention frameworks (Marilla, 2008) as shown in the figure 5. We need to be selective in choosing related theories serving the best to meet our research objectives. The preliminary study will also help us to carry on the selection regarding theories. For Cultural Neuroscience theory of Neural Correlates of Consciousness will be considered as potential candidate but there is an utter need to explore this area more specifically related to the our research goals and then utilized to find out the minimal set of neural activities and patterns adequate for a given conscious mathematical stimulus.

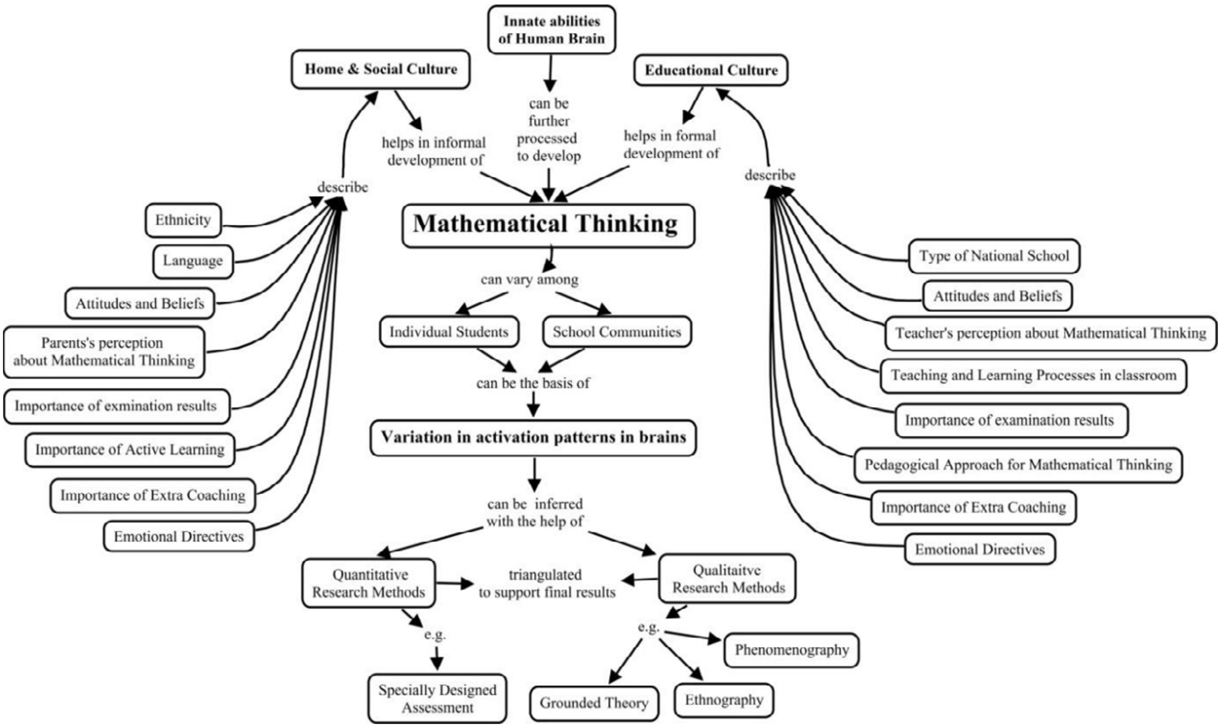
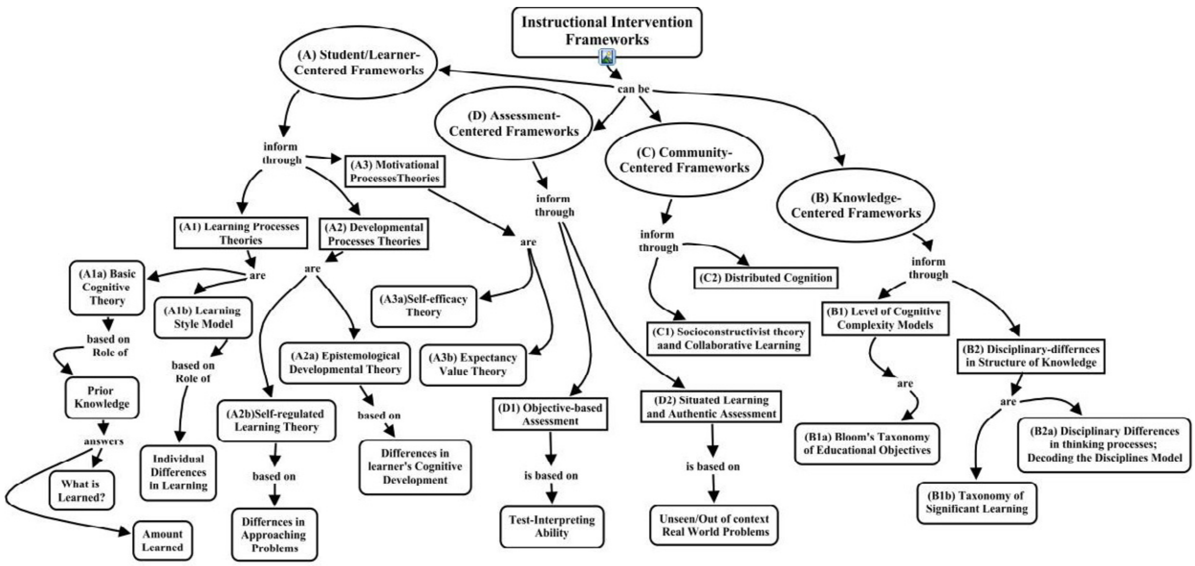


Fig. 4. Conceptual Framework of Mathematical Ability Analysis through cultural Neuroscience



Adapted From: Marilla D. Svinicki (University of Texas) "A Guidebook On Conceptual Frameworks For Research in Engineering Education", 2008

Fig. 5. Meta Framework of HPL showing the related theories used for all types of instruction intervention frameworks

Acknowledgements

The authors acknowledge the Malaysian Japan International Institute of Technology (MJIIT) and the Center for Artificial Intelligence and Robotics (CAIRO), Universiti Teknologi Malaysia Kuala Lumpur for the financial support given in this work.

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