A conceptual framework for mathematical ability analysis through the lens of cultural neuroscience

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Abstract

The conceptual framework presented in this paper will be used for analyzing variance in mathematical thinking, skills, abilities, processes and achievements in mathematics assessment among students in different ethnic national schools in Malaysia through the lens of cultural neuroscience. Cultural neuroscience is the study of cultural influence on cognition due to shared values, goals, daily life practices and beliefs; working of brain in various work settings and culture oriented relationships between cognition and brain activities. The bidirectional interface between mathematical thinking and cultural neuroscience is used in this research to explore different learning styles, cognition patterns and neural activities of mathematical thinking influenced by culture. Research questions are emerged by exploring the contribution of human's innate mathematical abilities, plasticity of the young brains and the cultural mathematics environment to uncover mathematical thinking. The cultural impact on mathematics achievement are intended to be explored to find the underneath myth for performance divergence. The embedded effect of culture with in mathematical thinking is also needed to be exposed to differentiate among mathematical thinking and learning trajectories resulting in distinct neural activation patterns.

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 is a big concern and becomes a hot polemic in 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 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. Although the performance gap decreased from 1991 to 2001, still Chinese are dominant in the percentage passes. The above stated situation leads to several questions and potential research themes. The major concern is to identify the factors affecting mathematics achievement and the question "can we manipulate these identified factors for improved mathematical skills" arises. 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" has already been explored (Lim, 2002, 2003) and the findings are quite helpful to visualize the problem dimensions. Our research is focused on "variations in the activation patterns in brain during mathematical thinking" that emerge due to the interweaving of mathematical thinking and cultural neuroscience concepts and it is still unexplored within Malaysian context. We want to identify the difference in mathematical learning trajectories at one or more grade level(s) 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, there is firstly the need to explore them separately to build up an overarching exemplar for our future research. After

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captivating the working regularities of these inter-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 as the research progresses.

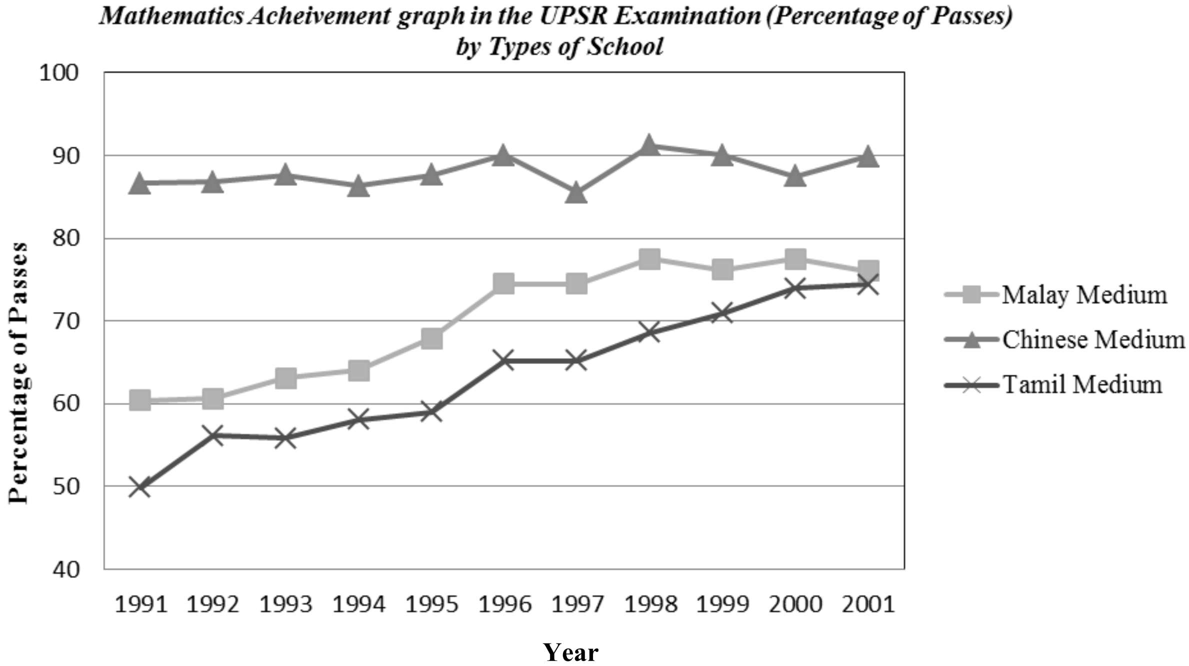

Figure1. Graph prepared from the data of Malaysian Examination Board Yearly Report for the year 1991-2001.

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 hard-wired 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. He separated three levels of mathematical thinking as hard-wired rudimentary arithmetic in the 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 learning processes using formal mathematical language, abstraction, de-contextualization and proof (Uri). Corte and Verschaffel (2007) reported four interlinked components of mathematical thinking and learning as competence, learning, intervention and assessment as depicted in Figure 2 along with their working regularities.

The collaboration of neuroscience and cultural psychology emerge 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 need to be explored and neural activity patterns 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 in understanding the cognitive processes of mathematical thinking. The above mentioned components combined together help to answer how variation in mathematical thinking is guided by culture (Rule et al., 2011). Gutchess et al., (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 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). The latest research finding in the field of cultural psychology provided sufficient evidence that different ethnic groups possess quite opposite thinking and processing styles. A comparison between people of Western and Asian cultures are carried out and results showed that the former possess analytical thinking style that is familiar to important central objects but less sensitive to contexts whereas the latter 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 ethnic groups in Malaysia.

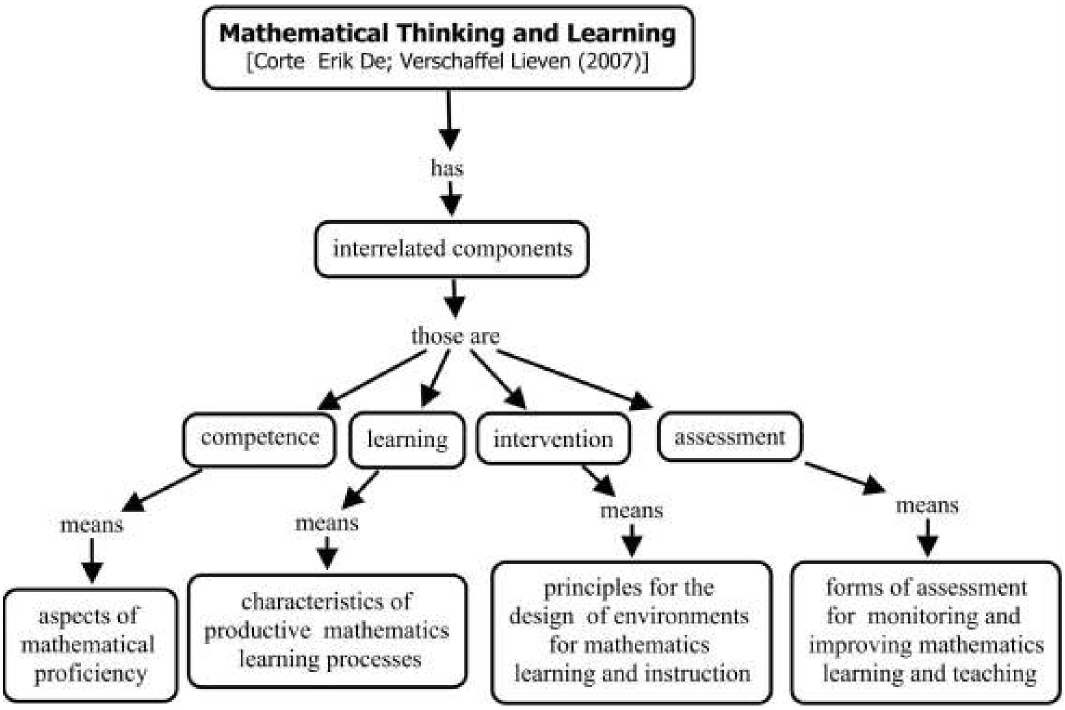

Figure2. Interrelated components of mathematical thinking and learning

Cultural influence on multi-level thinking processes and neural correlates primary thinking processes like perceptual or attention-based processing are also reported by the 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.

Ginsburg et al., 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 the 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 among different communities. 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).

In this research, we want to investigate the developmental changes of innate abilities to a 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.

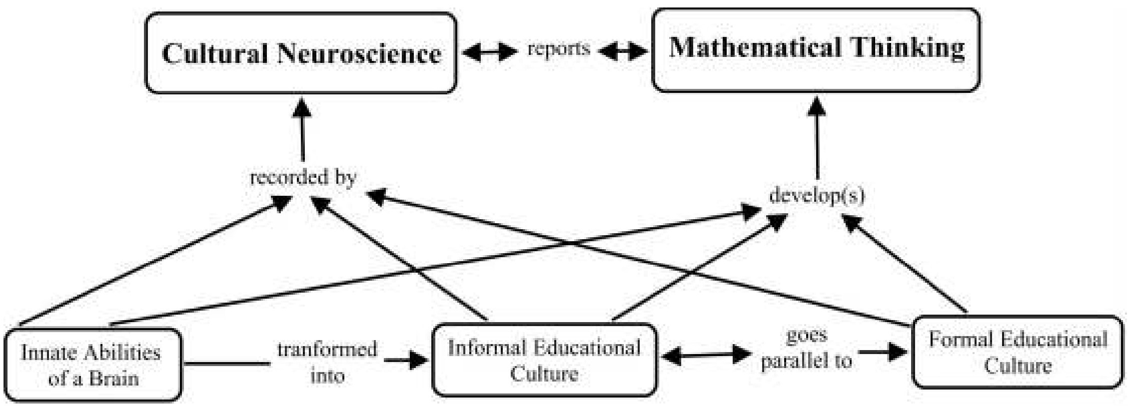

Figure3. Bidirectional relationship of cultural neuroscience and mathematical thinking

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. Mathematical ability analysis throught the lens of cultural neuroscience

The interpretivist epistemological perspective is selected for the development of conceptual framework shown in Figure 4. This perspective will enable us to view multiple subjective realities based on cultural variations and to describe a situation, experience or phenomenon dealing with mathematics ability within the cultural context. Due to diversity in processing styles of human brain, the methods and approaches of the above analysis would emerge and have to be adjusted during the study. This requires us to work on a 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 interpretivism in this mixed method research is likely to consider the situation, participants and researcher based contextual truth. Our research will try to reveal the individual stories of the participants from different cultural environments and to identify the underlying 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 strategies will be finalized from a pool of phenomenoloy, grounded theory, ethnography or by designing a collective case study with a combination of the above three. The last but most important stage of our research will be to develop an effective stimulus in the form of a problem set 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 to cultural impact.

Three active input streams, namely the innate ability to learn mathematics of the young brains, home and social culture contributing as informal development and educational culture as formal development to activate mathematical thinking processes are shown in Figure 4. The variation in mathematical thinking among individuals; among social and culture communities would result in variations of activation patterns of brain and the final results will be interpreted through mixed method research. The contributing variables for social and home culture are ethnicity, language, instruments, games, stories, legends, songs, poems and cultural methods of mathematical teaching and learning and all these participate as informal development of mathematical thinking whereas the first contributing factor for formal educational culture is the pedagogical approach for mathematical teaching that includes teaching and learning processes e.g. representation, visualization, mental images, abstraction, reasoning etc.

in the classroom, instructional methods, and coaching styles ; second contributing factor is assessment method. The quantitative or qualitative way of inquiry about each listed factor is still to be decided.

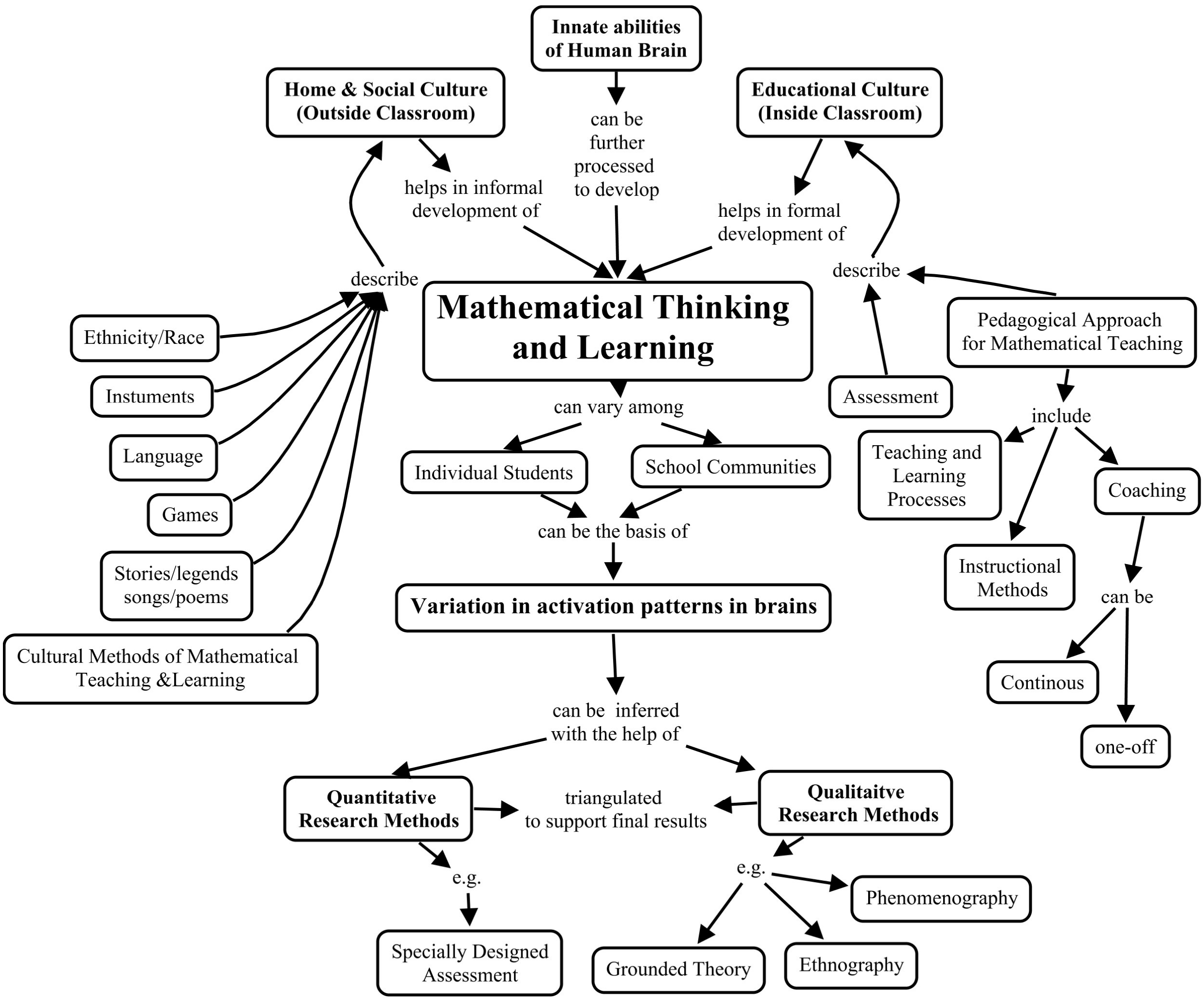

Figure4. Conceptual Framework of Mathematical Ability Analysis through cultural Neuroscience

The Preliminary Study will help to decide the proper investigation strategies for different potential factors that contribute to mathematical thinking, the areas of mathematics to be focused depicting cultural influence and the 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 et al., (1999) and its four main components are shown in Figure 5. The theories related to student-centered, knowledge-centered, assessment-centered and community-centered frameworks (Marilla, 2008) are shown in Figure 6 to 8.

We need to be selective in choosing the related theories that best serve our research objectives. The preliminary study will also help us to carry out the selection regarding theories. For Cultural Neuroscience, the theory of Neural Correlates of Consciousness will be considered as the potential candidate but there is an utter need to explore this area more specifically related to our research goals and then utilized to find out the minimal set of neural activities and patterns adequate for a given conscious mathematical stimulus.

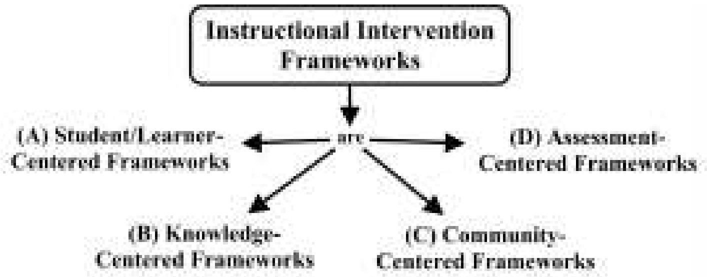

Figure5. Meta Framework of HPL showing the related theories used for all types of instruction intervention frameworks

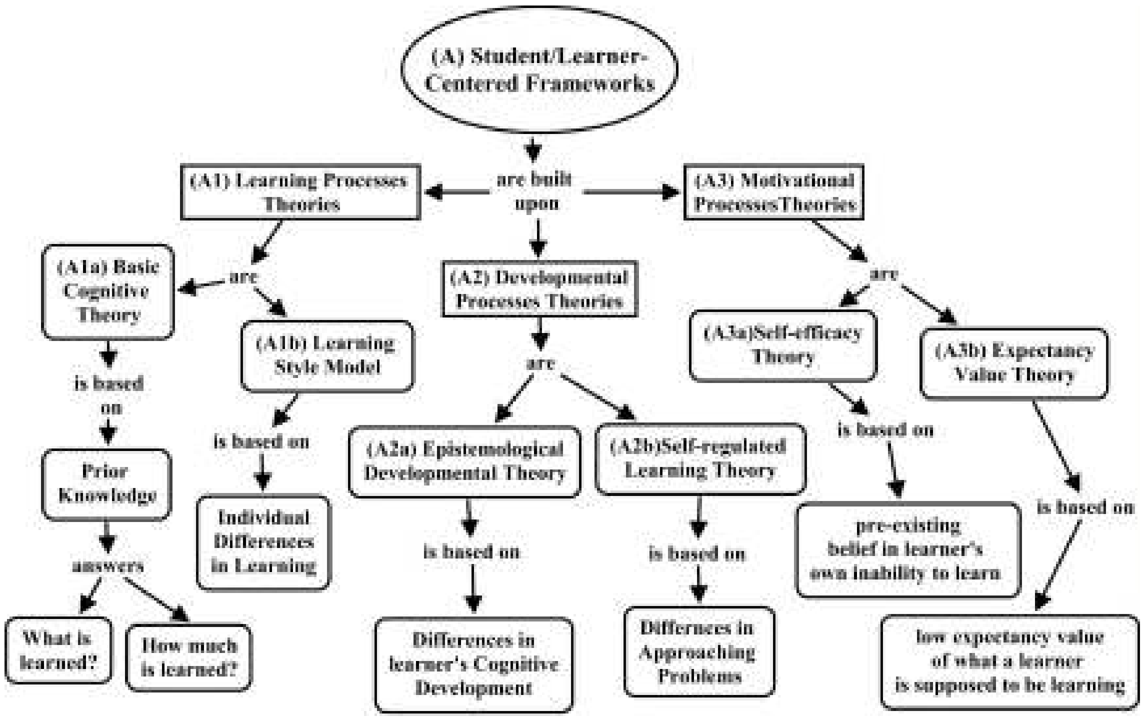

Figure6. Student/Learner Centered Frameworks and related theories

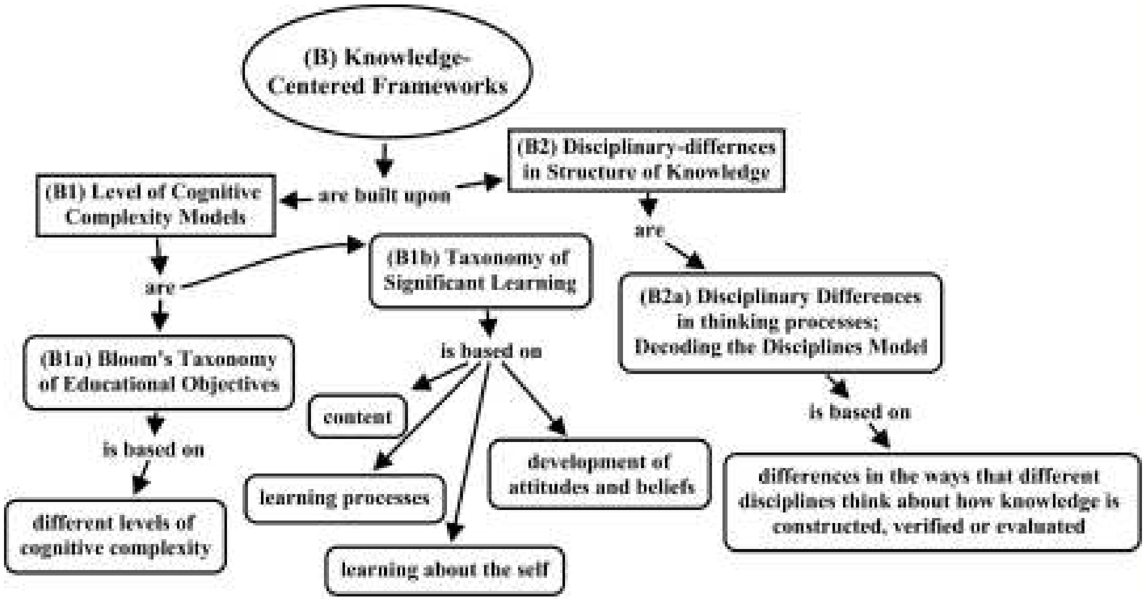

Figure7. Knowledge Centered Frameworks and related theories

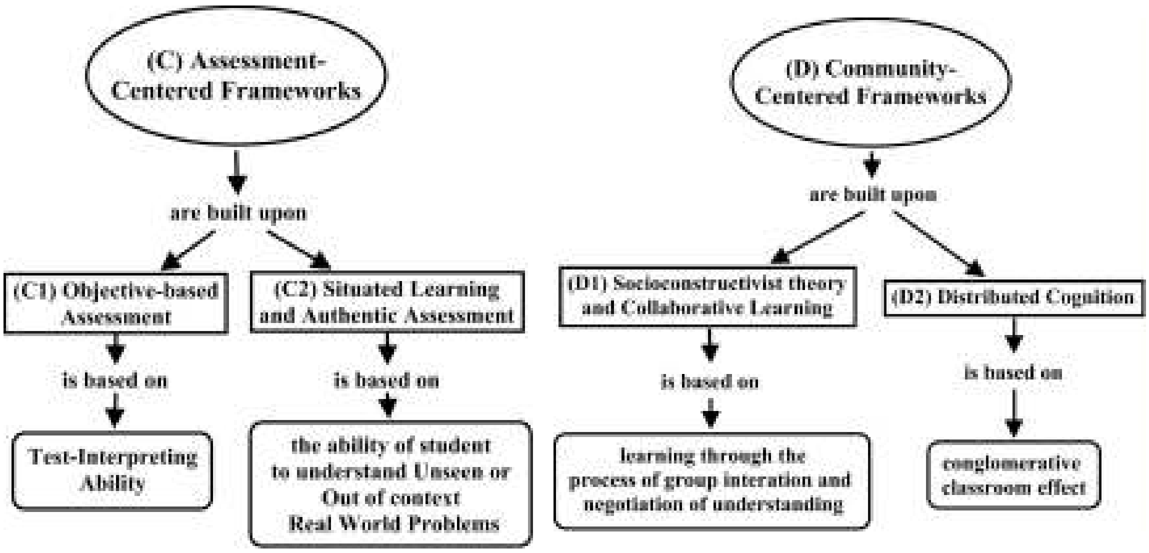

Figure8. Assessment Centered and Community Centered Frameworks and related theories

3. Conclusions

The conceptual framework presented in this paper will help us to investigate the progressive changes of inborn abilities of a student to an advanced level of mathematical thinking; to identify culture based mathematical learning trajectories that will be used to interpret the neural activities in response of a specially designed problem set for fMRI experiment. The inferences from this research would help to replicate the same practice for the investigation of similar problems in a multicultural society specifically in Asian and generally in any country. This research will be extended to a higher level to devise the improvement strategies and sustainability of mathematical thinking that would lead a nation to a higher tendency to opt for science and engineering professional careers.

Acknowledgements

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