

Emotions in Learning Mathematics and Its relationship to Memory: Insight from Neuroscience to Classroom findings

Las emociones en el aprendizaje de las matemáticas y su relación con la memoria: una visión desde la neurociencia hasta los hallazgos del aula

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ABSTRACT

Neuroscientific research has revealed that brain and emotion processing are closely intertwined. This is important because emotional response module and guide cognitive to enable adaptive responses to the classroom environment. This study aims to identify negative emotions in learning mathematics and its relationship to memory. The questionnaire was used to collect data to identify negative emotion consist of anger, anxiety, boredom and shame and students memory in learning mathematics. The sample of the study consisted of 644 secondary school students in learning mathematics. The statistical analysis of the data showed a negative correlation between students negative emotions and their memory in learning mathematics. This indicates that negative emotions can be negative attributed to the students' memory. We also demonstrate that integrating perspectives from education, psychology and neuroscience contributes to a greater understanding of negative emotions in learning mathematics. Research from neuroscience and psychology illustrates the effect of negative emotion in learning mathematics and memory can be used to conceptualise the negative emotions and its impact on avoidant behaviour and students wellbeing. Therefore, using this transdisciplinary framework to consider emotions make it possible to identify strategies to reduce negative emotions in mathematics learning. Implementation of these strategies among teachers and policy makers could be beneficial to improve learning environment that emphasizes positive emotions and minimizes negative emotions that can enhance students' memory.

Keywords: Emotions, Memory, Learning Mathematics, Neuroscience.

RESUMEN

La investigación neurocientífica ha revelado que el procesamiento del cerebro y las emociones están estrechamente entrelazados. Esto es importante porque el módulo de respuesta emocional y la guía cognitiva permiten respuestas adaptativas al entorno del aula. Este estudio tiene como objetivo identificar las emociones negativas en el aprendizaje de las matemáticas y su relación con la memoria. El cuestionario se usó para recopilar datos para identificar emociones negativas que consisten en ira, ansiedad, aburrimiento y vergüenza y memoria de los estudiantes en el aprendizaje de las matemáticas. La muestra del estudio consistió en 644 estudiantes de secundaria en el aprendizaje de las matemáticas. El análisis estadístico de los datos mostró una correlación negativa entre las emociones negativas de los estudiantes y su memoria en el aprendizaje de las matemáticas. Esto indica que las emociones negativas pueden atribuirse negativamente a la memoria de los estudiantes. También demostramos que la integración de las perspectivas de la educación, la psicología y la neurociencia contribuye a una mayor comprensión de las emociones negativas en el aprendizaje de las matemáticas. La investigación de la neurociencia y la psicología ilustra el efecto de las emociones negativas en el aprendizaje de las matemáticas y la memoria puede usarse para conceptualizar las emociones negativas y su impacto en el comportamiento evitativo y el bienestar de los estudiantes. Por lo tanto, el uso de este marco transdisciplinario para considerar las emociones hace posible identificar estrategias para reducir las emociones negativas en el aprendizaje de las matemáticas. La implementación de estas estrategias entre maestros y formuladores de políticas podría ser beneficiosa para mejorar el ambiente de aprendizaje que enfatiza las emociones positivas y minimiza las emociones negativas que pueden mejorar la memoria de los estudiantes.

Palabras clave: emociones, memoria, aprendizaje de las matemáticas, neurociencia.

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1. INTRODUCTION

Neuroscience and education is one of fields that are growing rapidly in dealing with teaching and learning issue especially in the classroom (Janet, 2015; Howard Jones, 2014). These developments have helped researchers particularly in education field to understand students from the biological perspective of brain function and students' psychology (Elsbeth Stern et al., 2016; Howard Jones, 2014). One of the main issues in teaching and learning is the student's emotional problem in teaching and learning process of mathematics (Puteh & Khalin, 2016; Gustavo Martínez-Sierra, 2016). Neuroscientists believe that understanding the role of emotions in the classroom can stimulate students' cognitive learning (Immardino- Yang 2015; Daniel Ansari, 2011). This is because, the emotional aspect of this student is very significant in affecting the function of the brain such as enhancing the prefrontal lobe function that serves to process and convey information (Susanne Vogel & Lars Schwabe, 2016; Howard Jones, 2010). This information portrays that inputs from neuroscience studies are one of the alternatives that can help in understanding students' emotional problems in mathematics learning (Daniel B Berch, 2016; Sarah Buckley et al. 2016).

Previous studies have shown that mathematics achievement problems are linked to students' emotions in learning (Arsaythamby Vello et al., 2011; Effandi Zakaria et al., 2012; Suppiah, Kanmani et al. 2016). Student's emotional issues in classroom can be seen when they are under pressure from learning mathematics because they are afraid of dealing with teachers who are too fierce and too serious when delivering lessons (Peixoto et al. 2017; Penkrun et al. 2011). This problem is further exacerbated when there are teachers who practice autocracy in teaching that cause students to fear of learning. Autocratic approaches used such as critiquing, cursing and speaking profane language with the aim of disciplining students in the classroom and ensuring teaching can be delivered has gave negative impact on students' emotions. This can trigger students' interest in learning mathematics in the classroom. Students with high negative emotions are difficult to provide and remember information they learned otherwise they remember negative events that occurred during the teaching process. (Suárez-Pellicioni et al., 2016; Elsbeth Stern et al., 2016)

Besides that, unattractive and boring teacher teaching practice has cause students to be uninterested in learning mathematics (Shaffe Daud et al. 2011). This problem has unable them to concentrate on understanding the lesson delivered instead will lead them to problematic behaviours such as disturbing peers, play truant and so on. Moreover, non-interactive teacher teaching and only using one-way approach has triggered student's negative emotional problems Arsaythamby Vello et al., 2011; Effandi Zakaria et al., 2012). This is because, students unable to express knowledge and understanding through their involvement in the classroom. In other words, students have no opportunity to express their emotion and knowledge of mathematics classes since teachers only focus on delivering content of the teaching. This problem causes teachers to lose access of the ability of remembering and procedural memory in solving mathematical problems.

Difficulty of students to remember the theory, formula, logic and facts about numbers cause them to have negative perceptions in learning mathematics. This is because; students cannot relate the importance of mathematics in their context of life. Abstract learning that is less associated with students' life influences the role of working memory to help them store information for long term and short term memory. Gustavo Martínez-Sierra (2016) and Puteh dan Khalin (2016) studies explained that students' perceptions have direct connection with working memory for thinking and solving mathematical problems. This poses a threat to the effectiveness of teaching process that affects student's academics achievement. This causes students to refrain themselves from learning mathematics, to enter science stream classes or even to further career that involves applying mathematics.

The above discussion shows that emotional issues in learning mathematics affect student's memory to learn the subject. From these discussions, students' emotions are the main aspect that must be concerned especially in teaching and learning process. Ignoring the emotional aspects in the classroom affects memory ability and students' achievement in learning mathematics. Thus, this study identifies students' emotional relationships in learning mathematics and memory. This study also utilises educational neuroscience research inputs that can explain and support the role of emotion and memory from a biological and psychological perspective. The findings of this research show that teachers play an important role in understanding student development from the perspective of neuroscience, psychology and education in learning mathematics.

2. LITERATURE REVIEW

Human's emotions play a vital role in influencing life development of individuals. Emotions are the result of external stimulation that interacts with subjective feelings, physiological reactions and behaviors (Dettweiler et al. 2017; Carmen Sandi dan József Haller 2015). Recent development of technologies have helped neuroscientists to clearly understand the role of emotions using neuroimaging techniques that work to detect and recognise human emotional states that can contribute to the cognitive, affective neuroscience and educational psychology that can optimize memory that influences learning outcomes Benno, Bruce and Sumantra, 2009; Baixauli 2017). There are several perspectives to understand mood and emotional change (Dettweiler et al. 2017; Baixauli 2017) (1) a subjective approach that can evaluate feelings and experiences that have been experienced (2) understanding through behaviour, facial expressions shown as well as voice expressions and gestural changes. In educational context, both approaches are widely used to measure students' emotions in understanding the role of emotion in the teaching and learning process. This is because many previous studies have revealed that emotions influence students' cognitive processing in learning mathematics (Suárez-Pellicioni et al., 2016; Elsbeth Stern et al., 2016)

Whereas in the context of neuroscience (3) the objective approach through physiological response consists of electrical and hemodynamic central nervous system (CNS) activities in addition to autonomic nervous system

(ANS) responses such as heart rate, body temperature, high blood pressure are used to understand the emotions and functions of the human brain (Susanne Vogel dan Lars Schwabe, 2016; Immordino-Yang, M. H. 2015). There are many neuroscientific studies that highlight the role of emotion in affecting the brain region of the amygdala and prefrontal cortex of students. These parts of the brain can influence students' cognitive processing in the classroom (Lyons and Beilock, 2012; Susanne Vogel dan Lars Schwabe, 2016; Immordino-Yang, M. H. 2015). The prefrontal cortex is the part of the brain that processes information for a high level of reasoning while the amygdala records emotions or situations in life. From the findings of the neuroscience research, the researchers will discuss in more detail the results of this study that can be applied in the context of learning.

In the classroom context, emotional stress and tension affect the physiological and biological of the brain. There are two main parts, the Autonomic Nervous System (ANS) and the 'hypothalamus - pituitary - adrenal' that will stimulate biochemistry in response to physiological and biological human brain. Autonomic Nervous System' (ANS) plays a role in secreting the Catecholamine hormone. Catecholamine hormones that secreted from the brain regions of Locus Coeruleus and Adrenal Medulla act as 'Flight or Fight' or 'fight' or 'abandon' in determining an environmentally responsible response. In other words, these responses will impact the students' behaviour in learning such as skipping class, disturbing classes and so on. Stimulation of these hormones affects concentration, working memory and long-term memory (Susanne Vogel dan Lars Schwabe, 2016; Carmen Sandi dan József Haller 2015). Therefore, it can be understood that high levels of negative emotions produce catecholamine that disrupt human biology and physiology.

Moreover, stressful learning environments will stimulate the amygdala to record emotions such as fear and anxiety in the classroom. The amygdala's focus on negative emotions can distract students from learning mathematics. Stress in the classroom affects modulation of the hypothalamus-pituitary-adrenal that secretes the Corticotrophin hormone (ACTH). Breedlove, Watson dan Rosezweig (2010) and Vanesa Hidalgo et al. (2018) stated that hypothalamus stimulates the pituitary's anterior brain to secrete hormone Corticotrophin (ACTH). The secretion of this hormone produces cortisol to be released into the blood's vessels. The concentration of cortisol that lasts between 20 and 30 minutes will affect neurons that can reduce the plasticity of the brain, which is a change for forming cell and connecting with other cells. Besides that, this hormone can slow down the production of dendrites by receiving and transmitting stimuli to other body cells. Furthermore, it also affects the formation of myelin (myelination) which is an insulator that protects the flow of neurons and can affect memory. This can inhibit the development of specific neurons in the prefrontal cortex and amygdala in the brain to function effectively.

Meanwhile, in the classroom context, when students are not interested in paying attention to understand and concentrate on teacher's teaching, it will give an impact on the prefrontal cortex especially involving aspects of reasoning, decision making and so on in mathematics. Susanne Vogel dan Lars Schwabe (2016) argued that emotional stress would prevent students from processing the information presented but recording negative emotions while learning mathematics. As a result, the negative emotions recorded by students in the classroom will give students a negative experience in learning mathematics. In other words, such experiences influence students' perceptions, interests and motivations for learning (Swanson, 2011; Storm, 2011). This problem will have an impact on students' academic achievement in mathematics. Researchers have found that learning environment is related to memory performance in learning mathematics. Thus, negative emotional problems affect the students' teaching and learning processes in learning mathematics.

The results of neuroscience studies on emotion and brain can be used to understand and support the results of this study. These inputs can close the gap between teachers' knowledge related to the brain aspect and emotions as well as students' cognitive. This is because most teachers have no background in neuroscience or courses related to neuroscience in education. In other words, teachers cannot understand how emotions affect the biological functioning of the brain and bio-chemistry, terms related to it including data from significant neuroscience studies. These constraints make most teachers misunderstand the contribution of neuroscience studies in teaching that can improve student learning in the classroom (Immordino-Yang, M. H. 2015; Janet, 2015; Howard Jones, 2014).

Additionally, neuroscientific studies connecting the role of emotion in teaching have implications for biological brain functioning, physiological functioning and cognitive processing (Amran, M et al. 2019; Vanesa Hidalgo et al. 2018; ; Storm, 2011; Carmen Sandi dan József Haller 2015). However, lack of previous research that interprets neuroscience perspectives in addressing students' emotional problems is discussed and described from an educational perspective (Immordino-Yang, M. H. 2015; Janet Zanida, 2015). This is because; most of the previous studies linked to neuroscience and education are discussed separately. These separate discussions have left teachers unable to relate the results of neuroscience studies to be translated into teaching and learning contexts. This study is an attempt to show the importance of emotion in learning mathematics and its relationship to learning memory. The findings of this study use neuroscience perspectives to support and highlight the importance of emotion in learning mathematics and its relationship to memory.

3. METHODOLOGY

This study uses a quantitative design which is survey method to collect data. The sample in this study involved 644 students that are 16 years. The selection of these respondents is important to provide feedback on the aspect of the study that will be conducted. The research instrument used was a questionnaire to measure

students' emotions when learning mathematics. The instruments of this study are adapted and modified from *Achievement Emotions Questionnaire (AEQ)*, Penkrun, Goetz and Perry (2005) and *Questionnaire of Memory' (Q-MEM)* Guerten et al. (2016). In this study negative emotions were consist of components of anger, anxiety, shame and boredom. The questionnaire was a Likert scale. A pilot study showed that the Cronbach's alpha for negative emotions and memory exceeds 0.70. This value indicates that the instrument of this study has high reliability.

Table 1 Reliability Cronbach Alpha

EMOTIONS	Construct	Cronbach Alpha
	Shame	0.877
	Anger	0.840
	Boredom	0.817
	Anxiety	0.876
	TOTAL	0.852
COGNITIVE	Memory	0.878
	Total	0.878

4. RESULT AND DISCUSSION

Emotions in learning mathematics and its relations to memory. Table 2 shows the relation of shame component ($r = -.513$, $N = 644$, $p = .000$), anger ($r = -.466$, $p = .000$), boredom ($r = -.488$, $N = 644$, $p = .000$) and anxiety ($r = -.493$, $p = .000$) with memory. Relationship gradients were negative and this indicated that correlations were inversely proportional. Meanwhile significant value of (p) obtained is 0.000^{**} . This value was smaller than the alpha value (0.01). Therefore, the results indicated that there was a significant negative relationship between anger, shame, anxiety and boredom with students' memory in learning mathematics. This means that students who have negative emotions in learning mathematics can reduce memory performance.

The result showed that there was a strong negative correlation between shame and memory in learning mathematics ($r = -.513$, $p < 0.05$) and anxiety ($r = -.523$, $p < .005$) compared to angry and boredom. These shy and anxious emotions affect students' psychological well-being because they are afraid of a scary learning environment, panic to answer questions and shy to respond and engage in teacher's teaching. Gustavo Martinez –Sierra (2016) and Penkrun et al (2011) Susanne Vogel and Lars Schawabe (2016) supports the results of this study which explaining that anxiety and shame provide negative experiences for students to learn. These negative experiences influence students' memory of the teaching delivered by teachers and affect students' ability to solve mathematical problems. Therefore, those results strongly support our hypothesis that there is correlation between negative emotion and memory in learning mathematics. Besides that, this result also supported by literature from neuroscience research based on Vanesa Hidalgo et al. (2018) Storm, 2011, Carmen Sandi dan József Haller (2015) that negative emotions can influence memory in learning process.

Table 2 Pearson Correlation Of Negative Emotional Components With Memory

COMPONENT	SHAME	ANGRY	BOREDOM	ANXIETY
SHAME	1.00			
ANGER	.485*	1.00		
BOREDOM	.454*	.760*	1.00	
ANXIETY	.429	.662*	.375*	1.00
MEMORY	-.513	-.466	-.488	-.523

*Significant Values $p < 0.05$

Emotions play a significant role in determining memory in learning. In this study, researchers have to identify the components of negative emotions and their relationship to memory in learning mathematics. The negative emotional components consists of angry, shame, bored and anxious. Correlation analysis showed that there was a significant negative relationship between the components of negative emotions and memory in learning mathematics. The findings also showed that students with high negative emotions will have a negative relationship with learning memory. From a psychological perspective, students with negative emotional states indicate that students are not interested in learning and have a negative perception of learning mathematics.

The results of this study showed that students who were bored with teacher teaching lack of concentration in the

classroom. If boredom is not addressed properly, students will react angrily to the teaching process of the teacher. This view is in line with another findings Penkrun et al., (2011) that explaining about this anger reaction was the result of students' suppressed feelings towards uninteresting way of teachers' teaching. In addition the teaching is not student-centered causing them to express emotions in the classroom during the lesson. This can lead to problematic behaviours such as absent in mathematics classes and neglects of learning mathematics. Moreover, this study also showed that students with anxiety in the classroom utilise less memory while learning mathematics. In fact, the anxiety problems that students face in the classroom are aspects that teachers need to pay attention too.

There are various number of factors that influence students' concerns in the classroom, such as mastery of mathematics knowledge, autocratic teacher attitudes and negative perceptions of mathematics teacher teaching. If the problem is not addressed, it can affect the motivation of the student to learn and thus contribute to the percentage of failure in learning mathematics. Furthermore, the results of this study showed that the relationship between students' emotions with their concentration had a significant impact on students' behavioural problems in the classroom. Students with high levels of negative emotions in the classroom can lead to behavioural problems during learning such as students skipping classes, bothering their peers or interrupting teacher in teaching. This can further affect students' involvement in the classroom as they do not respond to teacher's teaching, do not complete assignments, and so on. Student engagement in the classroom is very important because it shows one of the indicators of teacher success in delivering a lesson.

On top of that, negative emotions can also create a gap between teachers and students (Mistima et al. (2009). Peixoto et al. 2017; Penkrun et al. 2011). These interactions will help students to easily ask questions about what they do not understand during or after the teaching and learning process. This process is one of the methods that can help to improve students' memory. This is because students can interact with teachers about mathematics lessons and check their understanding and internalize the information they have learned. As a result, students are able to compile the information learned and thus stimulate working memory to store information in both long and short term memory.

From a neuroscience perspective, negative emotions also have a direct connection to memory. The resulting negative emotions such as fear, anxiety and worry will secrete the cortisol hormone in the blood. Activated cortisol hormone in the body that can destroy the dendrites in the brain of the prefrontal lobe consequently causes mental blocking to process information in the brain. The prefrontal lobe is the part that processes higher order thinking skills and it is very important for an organism to plan and make decisions (Vanessa Hidalgo et al. 2018; Storm, 2011). If mental block occurs in the mind then all information will not be processed in the prefrontal lobe. Therefore, high negative emotions influence the concentration of cortisol hormone in the body to reduce the plasticity of the brain, slow down the production of dendrites and the formation of myelin (myelination). The secretion of these cortisol hormones can affect memory to store information and improve functionality working memory (Breedlove, Watson dan Rosezweig, 2010; Baixauli E (2017).

In fact, the secretion of this cortisol hormone also affects the physiological reaction of the students' body. In the classroom context, teachers who practice autocratic teaching cause students to feel anxious and afraid to learn. Students who are too scared and worried about the teacher not only affecting the secretion of cortisol hormone but also influencing physiological reactions such as sweating, muscle tension, trembling and so on. This would be worst if the student already had previous negative experiences or perceptions.

In general, the combination of neuroscience research and education is one of the efforts used to improve delivery sytem in education thus enhancing students' emotions for learning. Although the network of disciplines between neuroscience and education is very complex, a comprehensive effort is required as the results of this channel of knowledge can have a significant impact on improving teaching and learning practices in the classroom especially in developing student's emotions. Research showed that emotions play a vital role in influencing students' memory in learning mathematics. In other words, this study emphasised that negative emotions when learning mathematics can affect students' low levels of memory performance. Therefore, teachers play an important role in emphasizing students' emotional aspects in order to enhance their memory performance.

5. CONCLUSION

In conclusion, this study reveals that emotions in learning mathematics must be taken into account in order to enhance students' memory in learning mathematics. This study supports the study of Neuroscientific research that has revealed that brain and emotion processing are closely intertwined. This is important because emotional response modulete and guide cognitive to enable adaptive responses to the classroom enviroment. Discussion of the findings from a neuroscience and psychology perspective definitely can benefit teachers in improving their teaching. This is because this study provides input to teachers, especially mathematicians whereby emotional roles should be given attention so that the lessons learned and the classroom environment can generate positive emotions among students thus improving their achievement in mathematics. The boring, worrying and unpleasant learning atmosphere should be avoided in order for students to be happy to learn and engage in teacher teaching. It can be concluded that emotion to mathematics is one of the factors that play a role in determining the level of mathematical achievement of students whether they are excellent, satisfying or failing. This understanding can encourage teachers to create an attractive environment that is compatible with the biological functioning of the students' brain. Thus, a fun learning environment reduces students' negative emotions and improves students' memory performance.

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