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## Brain Dominance, Learning Styles, and Mathematics Performance of Pre-Service Mathematics Teachers

**ABSTRACT:** Brain dominance has been a topic in various researches in brain-based research and neuro science. Some researches show that people typically favor the use of one side of their brain over the other. Discussions about brain hemispheres reveal the fact that there are differences between individual learning styles. Different models, approaches, and inventories have been developed depending on the result or findings of brain studies. The study described the brain dominance, learning styles, and mathematics performance of pre-service mathematics teachers. It aimed to identify right- and left-brain thinkers and certain styles of learning (specifically visual, auditory, or kinesthetic) of pre-service mathematics teachers in relation to mathematics performance. The HBDI (Hemisphere Brain Dominance Inventory), the LSI (Learning Style Inventory), and the MPT (Mathematics Performance Test) were used to identify the brain dominance, learning styles, and mathematics performance of the pre-service teachers respectively. The study employed the descriptive research design, specifically the survey method. Results revealed that pre-service mathematics teachers have varied brain dominance. Learning style and brain dominance were found to be significant factors associated to mathematics performance. Moreover, learning styles and brain dominance are also significantly associated. Research-based evidence from the study may be used to encourage teachers and curriculum planners to develop and use appropriate styles of teaching to enhance their student's mathematics performance.

**KEY WORD:** Brain Dominance; Learning Styles; Mathematics Performance.

**RINGKASAN:** "Dominasi Otak, Gaya Belajar, dan Kinerja Matematika dari Guru Matematika Pra-Jabatan". Dominasi otak telah menjadi topik dalam berbagai penelitian dalam kajian berbasis otak dan ilmu saraf. Beberapa penelitian menunjukkan bahwa orang biasanya lebih menyukai penggunaan satu sisi otak mereka daripada sisi lainnya. Diskusi tentang belahan otak mengungkapkan fakta bahwa ada perbedaan antara gaya belajar individu. Berbagai model, pendekatan, dan inventaris telah dikembangkan tergantung pada hasil atau temuan studi otak. Studi ini menggambarkan dominasi otak, gaya belajar, dan kinerja matematika dari guru matematika pra-jabatan. Ini bertujuan untuk mengidentifikasi pemikiran otak kanan dan kiri dan gaya belajar tertentu (khususnya visual, auditori, atau kinestetik) guru matematika pra-jabatan dalam kaitannya dengan kinerja matematika. HBDI (Inventarisasi Belahan Otak Dominan), LSI (Inventarisasi Gaya Belajar), dan MPT (Tes Kinerja Matematika) digunakan untuk mengidentifikasi dominasi otak, gaya belajar, dan kinerja matematika dari masing-masing guru pra-jabatan. Penelitian ini menggunakan desain penelitian deskriptif, khususnya metode survei. Hasil penelitian menunjukkan bahwa guru matematika pra-jabatan memiliki variasi dominasi otak. Gaya belajar dan dominasi otak ditemukan sebagai faktor signifikan yang terkait dengan kinerja matematika. Selain itu, gaya belajar dan dominasi otak juga berhubungan secara signifikan. Bukti berbasis penelitian dari kajian ini dapat digunakan untuk mendorong guru dan perencana kurikulum untuk mengembangkan dan menggunakan gaya pengajaran yang sesuai untuk meningkatkan kinerja matematika siswa mereka.

**KATA KUNCI:** Dominasi Otak; Gaya Belajar; Kinerja Matematika.

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## INTRODUCTION

Brain dominance has been a topic in various researches in brain-based research and neuro science. Some researches show that people typically favor the use of one side of their brain over the other. However, there are those who are more whole-brained and equally adept at utilizing both hemispheres. Traditional teachings tend to favor the left-brained modes of learning, focusing on logical thinking, analysis, and memorization rather than right-brained modes, such as feeling, intuition, and creativity (Bielefeldt, 2006; Jarret, 2012; and Papadatou-Pastou, Haliou & Vlachos, 2017).

The studies about split brain show that different types of information are processed in left and right brain hemispheres; and the functions of these two hemispheres are different (Jagt *et al.*, 2003; Funnell, Colvin & Gazzaniga, 2007; and Pinto *et al.*, 2017). According to studies, left hemisphere exhibits a more analytic approach; while right hemisphere displays holistic and spatial approach. Each hemisphere has special mental abilities. The left hemisphere is analytical, abstract, verbal, digital, logical, sequential, and rational; while the right hemisphere is holistic, concrete, non-verbal, visual-spatial, intuitive, simultaneous, and analogical (McCarthy, Germain & Lippitt, 2006; Ozgen, Tataroglu & Alkan, 2011; and Pinto *et al.*, 2017).

Both hemispheres are in interaction with each other under normal circumstances. However, each has different basic functions. In this context, N. Herrmann (2000), and other scholars, stated that separating the human brain into two parts as left and right brain were insufficient in terms of identifying the differences. Thus, N. Herrmann (2000), and other scholars, used the term “brain dominance” in order to emphasize the fact that humans use a certain part of their brain more often than other parts (*cf* Herrmann, 2000; Ozgen, Tataroglu & Alkan, 2011; and Ozyel, 2016).

The concept of brain dominance is similar to the natural dominance concept between the double-structured parts of body, i.e. right-left hand. This is applied evenly to the brain and forms the fundamental point of dominant

brain theory. This model exhibits the mental preferences of the individuals, but it does not show their abilities or competence. It creates a strong connection between skills and preferences that affect each other (Herrmann, 2000; Ozgen, Tataroglu & Alkan, 2011; and Corballis, 2014).

On the other hand, two people who have exactly the same mental profile may not always have the same mental preferences. N. Herrmann (2000), and other scholars, again emphasized that humans were born with certain mental abilities, that everybody had strong and weak sides; and the tendency to use the dominant brain hemisphere. They also stated that the brain learns, as a whole and using brain hemisphere together, had a vital importance in learning (Herrmann, 2000; Jarret, 2012; and Corballis, 2014).

Discussions about brain hemispheres reveal the fact that there are differences between individual learning styles. Different models, approaches, and inventories have been developed depending on the result or findings of brain studies. For example, B. McCarthy, C.S. Germain & L. Lippitt (2006), and other scholars, identified the 4MAT (4 Mode Application Techniques) learning model by taking the brain hemispheres into account (*cf* Huitt, 2000; McCarthy, Germain & Lippitt, 2006; Aktas & Bilgin, 2015; and Seker & Ovez, 2018).

In some studies, the concepts of learning style, cognitive style, and modes of thinking are used interchangeably. However, researchers point out that these concepts are different and they cannot be used synonymously (Keefe, 1979; Campbell, 1991; Leng & Hoo, 1997; Cano-Garcia & Hughes, 2004; and Willingham, 2018).

Moreover, learning style is assumed to be a different concept from brain hemisphere preferences. In reality, learning style is the sum of all cognitive, affective, and psychological elements that determine how the individual perceives the learning environment, how they interact with the environment, and how they react to this environment (Keefe, 1979; Naserieh, 2009; and Grossmann, 2011).

Teachers should be familiar with the brain dominance and learning styles of students in

order to better address individualization and enhance students' mathematics performance. This knowledge may be helpful for teachers in facilitating learning in mathematics classes. Knowing the brain dominance and learning styles of pre-service mathematics teachers will help them to improve learning processes, which are appropriate for students' individual differences (Bielefeldt, 2006; Bhagat, Vyas & Singh, 2015; and Enomoto, 2015).

Traditional teaching techniques should be examined and new teaching techniques should be designed and developed based on research findings about how the brain operates. Thus, it is important to understand the concepts of brain dominance and preferred styles of learning. It is also important to understand the relationships of brain dominance and learning style to mathematics performance that will help teachers in developing teaching techniques needed to enhance students' learning. This knowledge can assist teachers in becoming more flexible and effective in teaching in the classroom (Bielefeldt, 2006; Duman, 2010; and Vermunt & Donche, 2017).

**Hemisphere Brain Dominance.** The concept of hemispheric dominance ascribes different information processing characteristics of to one or the other of the two brain hemispheres. It is concluded, therefore, that the dominant use of either the left or the right hemisphere determines a person's way of thinking and personality (Rowson & McGilchrist, 2013; Corballis, 2014; and Pinto *et al.*, 2017).

According to the ascribed characteristics, the left brain is the rational, intellectual, logical, analytical, and verbal hemisphere. It is the hemisphere that specialises in processing verbal and numerical information in a deductive or logical way. It is the hemisphere that specialises in processing verbal and numerical information based on a deductive or logical way of thinking. This means the left hemisphere dissects information by analysing and distinguishing the single parts of the whole. Thereby, it processes the information sequentially in a linear and ordered manner. Thus, it is asserted that the left hemisphere has a bias for detailed

information, is very capable of analysing and structuring information, and is best suited for tasks that comprise language, reading and writing, algebra, mathematical problems, logic operations, and the processing of serial sequences of information (Prado, Chadha & Booth, 2011; Rowson & McGilchrist, 2013; and Babcock & Vallesi, 2015).

Based on these thinking and problem solving attributes of the left hemisphere, the concept of hemispheric dominance asserts that people who predominantly use the left part of their brain are rational, intellectual, detail oriented, logical, and analytical. That means that these people do well in tasks that require these abilities, such as mathematics, engineering, or natural sciences (McCarthy, Germain & Lippitt, 2006; Rowson & McGilchrist, 2013; and Kumar & Sharma, 2016).

In contrast to the left brain's analytical way of thinking, the right brain has attributed to it an intuitive, emotional, holistic, synthesising, non-verbal, visual-spatial mode of processing, resulting in a creative or inductive way of thinking. Thus, the right hemisphere lumps together information and processes it as a whole and in parallel, i.e. it sees the forest rather than the trees. It is supposed to deal in three-dimensional forms and images with a focus on similarities rather than differences, and so is seen as being strong in tasks that require the understanding of complex configurations and patterns and the simultaneous processing of diverse information like pattern recognition, face recognition or spatial relationships (Jager, 2005; Babcock & Vallesi, 2015; and Oaksford, 2015).

Due to these characteristics, people who predominantly use their right brain are considered as being artistic, intuitive, emotional, imaginative, and visually oriented. These people are strong in tasks that require synthesising and conceptualising abilities; and, hence, are said to be good at gathering, assembling, comparing, and reshuffling ideas in order to come up with new concepts. Furthermore, it is asserted that they have a strongly developed emotional and aesthetic sensitivity; and often follow creative and artistic professions (Corballis, 2014; Philip, 2015; and Viskontas, 2017).

According to the concept of hemisphericity, information is processed in different ways in the two brain hemispheres. It, further, states that the dominant brain hemisphere determines the way of processing. On the basis of this notion, the idea developed that the learning and thinking process could be enhanced when both sides of the brain participated in a balanced manner. Consequently, teaching and education programs were developed in order to strengthen the less dominant hemisphere of the brain and to synchronise the two hemispheres (Tendero, 2000; Funnell, Colvin & Gazzaniga, 2007; and Kordjazi & Ghonsooly, 2015).

Since it is assumed that schools generally favour left-brained ways of thinking and learning, such as analysis, logic, and accuracy, many teaching instruction techniques seek to include more right-brained activities. One example of such a whole-brained instruction method is “show and tell”; instead of only reading a “left-brained” text, the teacher also shows pictures and graphics in order to activate the right hemisphere (Bielefeldt, 2006; Funnell, Colvin & Gazzaniga, 2007; and Sulistyowati, 2017).

Other methods include the use of music, metaphors, role plays, meditation, drawing, etc. in order to achieve the synchronisation of the two hemispheres. While such methods could be valuable in the educational setting, they are based on a shaky foundation. The reduction of the two sides of the brain to mere seats of certain skills or qualities, and the application of this to education, are based on oversimplifications of tendencies that the brain exhibits (McCarthy, Germain & Lippitt, 2006; Funnell, Colvin & Gazzaniga, 2007; and Whitehouse, 2016).

**Learning Style.** Learning style may be defined as the way people come to understand and remember information. W.B. James & D.L. Gardner (1995), and other scholars, defined learning style as the complex manner in which, and conditions under which, learners most efficiently and most effectively perceive, process, store, and recall what they are attempting to learn (James & Gardner, 1995; Awla, 2014; and Ghani, Jaafar & Fauzi, 2015).

By taking what we know about how people perceive and process information, instructors need to now focus on how to transfer information to the student and assist them in developing his or her intelligences in the most effective manner. Ideally, the classroom would be organized around experiences that stimulate all types of thinking. The auditory, visual, and kinesthetic senses form the major learning modalities, the primary pathways by which information is taken in (Silver, Strong & Perini, 1997; Bielefeldt, 2006; and Timperley *et al.*, 2007).

Auditory learners learn through listening. They pick up new ideas and concepts better, when they hear the information. These learners require verbal lectures and discussions, role-playing exercises, structured sessions, and reading aloud. Auditory learners can typically follow instructions very precisely after being told only once or twice what to do. In other words, written information may have little meaning until it is heard (Bielefeldt, 2006; Busan, 2014; and Hossain, 2015).

Since hearing and speaking are so closely related; hence, auditory learners tend to use their voice as well as their ears. They will often repeat what is said or rephrase the information into a question for discussion. This helps them process the information. Another instructional method can include background music to facilitate and accelerate the learning. Music is one of the principle tools for inducing a relaxed mental state, in which material is more easily absorbed and retained (Bielefeldt, 2006; Nombre, 2012; and Busan, 2014).

Auditory learners work in quiet areas to reduce distractions, avoiding areas with conversation, music, and television. They sit away from doors or windows where noises may enter the classroom, rehearse information orally, attend lectures and tutorials regularly, and discuss topics with other students. Moreover, they use mnemonics, rhymes, jingles, and auditory repetition through tape recording to improve memory, use tape recorders to document lectures and for reading materials, remember to examine illustrations in textbooks and

convert them into verbal description, and read the directions for tests or assignments aloud especially if the directions are long and complicated (Fry, Ketteridge & Marshall eds., 2009; Nombre, 2012; and Busan, 2014).

Visual learners learn predominately with their eyes, they learn through seeing. These learners prefer to see how to do things rather than just talk about them. They prefer to watch demonstrations and will typically get more out of video-taped instruction rather than a lecture. These learners not only require visual displays, such as diagrams, powerpoint presentations, overhead transparencies, videos, flipcharts, handouts, field trips, and so on, but they also require seeing the instructors body language and facial expressions (Bielefeldt, 2006; Busan, 2014; and Louis, 2017).

Visual learners organize work and living space to avoid distractions. They usually sit in the front of the room to avoid distraction and away from doors or windows, where action takes place. They sit away from wall maps or bulletin boards; use neatly organized or typed material; and use visual association, visual imagery, written repetition, flash cards, and clustering strategies for improved memory. They reconstruct images in different ways try different spatial arrangements and take advantage of blank spaces on the page, use note pads, post its, to do lists, and other forms of reminders. They use organizational format outlining for recording notes, use underlining, highlighting in different colors, symbols, flow charts, graphs, or pictures in their notes (Hansen, 1997; Awla, 2014; and Louis, 2017).

Kinesthetic learners learn through moving and touching. They tend to get their body into action and move around. They are “hands-on” learners, who prefer doing rather than talking. These learners require active-learning exercises. To “quarantine” them to a classroom would probably spell failure in the student’s efforts. Because moving and action are so fundamental to kinesthetic learners, they often fidget if they are not involved. Fidgeting helps these learners concentrate better (Evans-DelCiappo, 2008; Bielefeldt, 2006; and Viskontas, 2017).

Kinesthetic learners keep verbal discourse short and to the point. They actively participate in discussions and use all senses – sight, touch, taste, smell, and hearing. They use direct involvement, physical manipulation, imagery, and “hands-on” activities to improve motivation, interest, and memory. They organize information into the steps that were used to physically complete a task. They seek out courses that have laboratories, field trips, etc., and lecturers who give real life examples. They use case studies and applications (example) to help with principles and abstract concepts. They allow for physical action in solving problems, read or summarize directions, especially if they are lengthy and complicated, to discourage starting a task without instructions. They use taped reading materials, practice, play acting, and modelling to prepare for tests. They allow for physical movement and periodic breaks during tests, while reading, or while composing written assignments, role play the exam situation (Bielefeldt, 2006; Boneva & Mihova, 2014; and Viskontas, 2017).

Visual learners want to see how something is done. Auditory learners prefer to hear explanations and like to talk their way through things. Kinesthetic oriented people want to have a hands-on experience, so they can “experience” how something is done. Research shows that people remember 90 percent of what they “do” as opposed to 30 percent of what they “see and hear”. Although kinesthetic learners retain best, they make up only approximately 10 percent of the population, whereas visual learners make up around 60 percent and auditory learners around 30 percent. When assessing individuals or groups, it is apparent from the literature that learning styles differ (Willingham, 2005; Bielefeldt, 2006; and Fatimah, 2017).

This study is anchored on the assumption that students’ problem solving performance varies across brain dominance and learning style. The conceptual paradigm shows that the study investigated how brain dominance and learning style relate to students’ mathematics performance. Moreover, the

study also investigated the relationship between brain dominance and learning style. See figure 1.

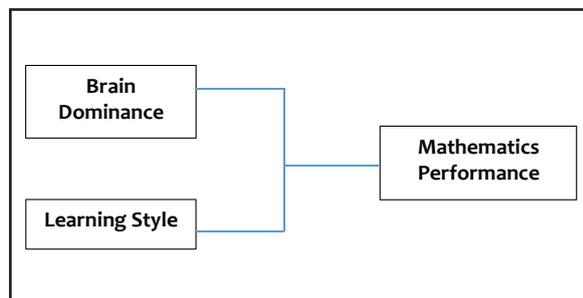


Figure 1:  
Conceptual Paradigm

**Statement of the Problem.** The study attempted to describe the brain dominance, learning styles, and mathematics performance of pre-service mathematics teachers. Specifically, it sought answers to the following questions:

Firstly, what is the profile of pre-service mathematics teachers in terms of the following variables: brain dominance, learning style, and mathematics performance?

Secondly, is there a significant relationship among the following variables: brain dominance, learning style, and mathematics performance?

## METHODS

**Research Design.** The study employed the descriptive research design, specifically the survey method (Williams, 2007; Cresswell, 2008; and Lau, 2017). The HDI (Hemisphere Dominance Inventory) was used to identify the students' brain dominance. The LSI (Learning Style Inventory) was also given to the students to identify their learning styles. Lastly, a PSPT (Problem Solving Performance Test) was developed to measure students' problem solving performance (Soyoof *et al.*, 2014; Bhagat, Vyas & Singh, 2015; and Molnar & Csapo, 2018).

**Participants of the Study.** The study involved 62 pre-service mathematics teachers in a state university in Manila, Philippines. Specifically, they were second year and third year students of BEMSE (Bachelor of Elementary Mathematics and

Science Education) and BME (Bachelor of Mathematics Education) in the School Year 2017 – 2018. These students were selected randomly (Williams, 2007; Cresswell, 2008; and Lau, 2017).

**Research Instruments.** The following research instruments were utilized in this study: LSI (Learning Styles Inventory), HBDI (Hemisphere Brain Dominance Inventory), and MPT (Mathematics Performance Test).

About the LSI (Learning Styles Inventory). This instrument was adapted from J.A. Beatrice (2009). This was used to determine the students' learning styles. The instrument consists of 14 items involving learning situations. Each item consists of three options that determine whether the student is a visual, auditory, or kinesthetic learner (cf Beatrice, 2009; Bhagat, Vyas & Singh, 2015; and Inal, Buyukyavuz & Tekin, 2015).

About the HBDI (Hemisphere Brain Dominance Inventory). This was adapted from N. Herrmann (2000), and other scholars, who developed the Brain Dominance Theory. This instrument measures the dominant side of the brain that the student utilized. It determines whether the student is left-hemisphere dominant, right-hemisphere dominant, or balanced hemisphere. The inventory consists of 16 items, each item has two options which determine the brain dominance of the students (Herrmann, 2000; Jarret, 2012; and Bunderson, 2017).

About the MPT (Mathematics Performance Test). This instrument measures students' performance in Advanced Algebra. The test consists of 12 items, which are open-ended type. Each item of the test is worth 5 points. A scoring rubric was used to assess the students' responses or answers to the items of the test (Cai, Jakabcsin & Lane, 2010; Yachina, Gorev & Nurgaliyeva, 2015; and Tejeda & Gallardo, 2017).

**Procedure.** To gather the needed data, the Learning Styles Inventory was administered to the pre-service mathematics teachers in June 2017; the HDI (Hemisphere Dominance Inventory) was administered in July 2017; and the MPT (Mathematics Performance Test) was administered in September 2017.

**Table 1:**  
Pre-Service Teachers' Hemisphere Brain Dominance Profile

Brain Dominance	Frequency	Percent
Balanced Hemisphere	20	32.3
Left Hemisphere	20	32.3
Right Hemisphere	22	35.5
<b>Total</b>	<b>62</b>	<b>100.0</b>

**Table 2:**  
Pre-Service Teachers' Learning Style Profile

Learning Style	Frequency	Percent
Auditory	16	25.8
Kinesthetic	12	19.4
Visual	34	54.8
<b>Total</b>	<b>62</b>	<b>100.0</b>

**Table 3:**  
Pre-Service Teachers' Mathematics Performance Profile

Learning Style	Frequency	Percent
Low	22	35.5
Average	24	38.7
High	16	25.8
<b>Total</b>	<b>62</b>	<b>100.0</b>

The data were, then, organized and analysed statistically to answer the specific research questions (Williams, 2007; Cresswell, 2008; and Lau, 2017).

## RESULTS AND DISCUSSION

This section presents the answers to the specific research questions stated previously, particularly related to: (1) *Brain Dominance Profile of Pre-Service Mathematics Teachers*; (2) *Relationship between Brain Dominance and Mathematics Performance*; (3) *Relationship between Learning Styles and Mathematics Performance*; and (4) *Relationship between Brain Dominance and Learning Styles*.

Firstly, **Brain Dominance Profile of Pre-Service Mathematics Teachers**. Table 1 shows the brain dominance profile of the pre-service mathematics teachers. It can be viewed from the table that pre-service teachers have varied hemisphere brain dominance. It is also evident from the table that they are almost equally distributed across different brain dominance.

The result obtained from this study does support many previous research findings that

most people who are inclined in mathematics like mathematicians, or people successful in mathematics, are left brain dominant (cf Leng *et al.*, 1998; Herrmann, 2000; Steyn & Maree, 2002; Ali & Kor, 2007; and Singer *et al.*, 2016). This implies that mathematically inclined person does not necessarily left brain dominant. He/she may be left brain dominant, right brain dominant, or whole brained. People naturally carry out mental activities in different ways and have learning preferences accordingly (Rowson & McGilchrist, 2013; Corballis, 2014; and Sulistyowati, 2017).

Table 2 shows the learning style profile of the pre-service mathematics teachers. It can be seen from the table that most of them are visual learners. This implies that most pre-service teachers prefer to see how to do things rather than just talk about them. They prefer to watch demonstrations and will typically get more out of videotaped instruction rather than a lecture (cf Timperley *et al.*, 2007; Mohamad & Rajuddin, 2013; and Cuevas & Dawson, 2018). See again table 2.

Meanwhile, table 3 shows the pre-service

**Table 4:**  
Pre-Service Teachers' Mathematics Performance Profile When Grouped According to Brain Dominance

Brain Dominance	Mathematics Performance			Total
	Average	High	Low	
Balanced Hemisphere	6	12	2	20
Left Hemisphere	8	0	12	20
Right Hemisphere	8	12	2	22
<b>Total</b>	<b>22</b>	<b>24</b>	<b>16</b>	<b>62</b>

**Table 5:**  
Chi-Square Test of Association for Mathematics Performance and Brain Dominance

Chi-Square Value	Df	p-Value
25.178	4	p < 0.05

**Table 6:**  
Pre-Service Teachers' Mathematics Performance Profile When Grouped According to Learning Styles

Learning Styles	Mathematics Performance			Total
	Average	High	Low	
Auditory	0	16	0	16
Kinesthetic	8	4	0	12
Visual	14	4	16	34
<b>Total</b>	<b>22</b>	<b>24</b>	<b>16</b>	<b>62</b>

teachers' mathematics performance. It can be viewed most of them have low and average mathematics performance. Only 25.8% of the pre-service teachers have high mathematics performance (cf Cai, Jakabcsin & Lane, 2010; Veldhuis & Heuvel-Panhuizen, 2014; and Yachina, Gorev & Nurgaliyeva, 2015). See again table 3.

**Secondly, Relationship between Brain Dominance and Mathematics Performance.**

Table 4 shows the pre-service teachers' mathematics performance profile, when grouped according to brain dominance. It is evident in the table 4 that majority of the pre-service teachers with balanced brain dominance and right brain dominance have high mathematics performance. On the other hand, most students who are left brain dominance have low mathematics performance.

This confirms the previous result that left brain dominant learners do not necessarily perform well in mathematics. It cannot be said that people, whose left brain preference is dominant, are more successful in the process of mathematics learning. For instance, solving mathematics problems require exhibition not

only of logical approaches, but also of intuitive approaches (Kitchens, Barber & Barber, 1991; Leng et al., 1998; and Yazgan & Sahin, 2018). Being intuitive is a characteristic of a right-brain dominant person. See again table 4.

Table 5 provides the Chi-Square Test of Association result, which reveals that there is a relationship between brain dominance and mathematics performance. This means that brain dominance is a factor that is associated to mathematics performance. The data suggest that those with balanced and right brain dominance tend to have high mathematics performance (cf Beck et al., 2016; Bunderson, 2017; and Yazgan & Sahin, 2018).

Thirdly, **Relationship between Learning Styles and Mathematics Performance.** Table 6 displays the mathematics performance of the pre-service mathematics teachers, when grouped according to learning styles. It can be viewed from the table 6 that all auditory learners have high mathematics performance. On the other hand, most kinesthetic learners have average mathematics performance, while most visual learners have either average or low mathematics performance.

The data suggest that auditory learners

**Table 7:**  
Chi-Square Test of Association for Mathematics Performance and Learning Styles

Chi-Square Value	Df	p-Value
44.446	4	p < 0.05

**Table 8:**  
Pre-Service Teachers' Brain Dominance Profile When Grouped According to Learning Styles

Learning Styles	Brain Dominance			Total
	Balanced Hemisphere	Left Hemisphere	Right Hemisphere	
Auditory	8	0	8	16
Kinesthetic	0	0	12	12
Visual	12	20	2	34
<b>Total</b>	<b>20</b>	<b>20</b>	<b>22</b>	<b>62</b>

**Table 9:**  
Chi-Square Test of Association for Brain Dominance and Learning Styles

Chi-Square Value	Df	p-Value
45.422	4	p < 0.05

tend to perform high in mathematics. Auditory learners pick up new ideas and concepts better, when they hear the information. These learners require verbal lectures and discussions, role-playing exercises, structured sessions, and reading aloud. Auditory learners can typically follow instructions very precisely after being told only once or twice what to do. In other words, written information may have little meaning until it is heard (cf Bielefeldt, 2006; Busan, 2014; and Pinto *et al.*, 2017). See again table 6.

Table 7 reveals that the Chi-Square Test of Association yielded a significant relationship between mathematics performance and learning styles. This implies that learning style is a significant factor on mathematics performance (cf Bunderson, 2017; Bosman & Schulze, 2018; and Yazgan & Sahin, 2018).

Fourthly, **Relationship between Brain Dominance and Learning Styles.** Table 8 gives the pre-service mathematics teachers brain dominance, when grouped according to learning styles. It can be seen from the table 8 that most auditory learners have either balanced or right brain dominance. It can be noted from the previous analysis that right brain dominant learners, whole brain learners, and auditory learners have high mathematics performance. On the other hand, it is evident

in table 8 that all kinesthetic learners are right brain dominant while most visual learners are left-brain dominant (cf Singer *et al.*, 2016; Papadatou-Pastou, Haliou & Vlachos, 2017; and Yazgan & Sahin, 2018). See again table 8.

Table 9 gives the result of the Chi-Square Test of Association for brain dominance and learning styles. It is evident from the table that there is a significant relationship between brain dominance and learning styles. This means that brain dominance is a significant factor associated to learning styles (cf Awla, 2014; Kordjazi & Ghonsooly, 2015; and Yachina, Gorev & Nurgaliyeva, 2015).

## CONCLUSION

Based on the findings of this study, the following conclusions are drawn. Pre-service mathematics teachers have varied brain dominance. Most pre-service mathematics teachers are visual learners. Most pre-service mathematics teachers have low and average mathematics performance.

Auditory learners tend to have high mathematics performance. Right brain dominant and whole brain learners tend to have high mathematics performance. Brain dominance and learning styles are significant factors associated to mathematics performance. There is a significant association

between brain dominance and learning styles.

The following are hereby recommended. Firstly, brain dominance and learning styles of learners should be considered when planning and designing learning activities that aim to develop student's mathematics performance. This is especially true for left-brain dominant learners and visual learners, because most of them have low mathematics performance.

Secondly, a larger size of sample of pre-service mathematics teachers should be used to see if similar results will be obtained and to determine if the findings of this study can be generalized.

Thirdly, similar studies on brain dominance and learning styles may be done to other subject areas to confirm their associations to academic performance.<sup>1</sup>

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- Statement:** This is to certify that the manuscript is an original work by us based on the research. We have duly acknowledged the work(s) of others we used in writing this article/manuscript. We have duly cited all such work(s) in the text as well in the list of the References, and that we have presented within quotes all the original sentences and phrases, etc. taken from the sources, which we have consulted in writing this article/manuscript. We, further, declare that the paper has not been previously published, it is not currently submitted for reviews to any other journal/magazine or periodicals, and it will not be submitted elsewhere.
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