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Mathematics Engagement Clinic Grounded on Brain Dominance: Its Effect on Critical Thinking and Problem-Solving Skills, and Mathematics Achievement

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ABSTRACT

Contextualization, localization, and indigenization have touched the ground of the dominant cultural character of learners. The teaching and learning process in the K to 12 curricula has integrated its essence. However, in recent ages,s the border-crossing of digital culture among learners was prevalent in their attitudes and learning preferences. Cognitive preferences such as the students' brain dominance must be considered in the lesson planning as an additional option. With a transformative worldview through an action research design, the study evoked the effects of Mathematics Engagement Clinic (MEC) grounded on brain dominance or the whole brain theory to critical thinking and problem-solving skills, and mathematics achievement. MEC has different effects on the left and right brain dominant participants in terms of their thinking processes such as critical thinking and problem-solving skills. In particular, left brain dominant participants have a distinct behavioral cognition which the researcher called affirmation behavioral learning. The implication of affirmation behavioral learning to the whole brain theory was a notion that brain dominance groups might have specific behavioral cognition. As for this study, affirmation behavioral learning was evident and observed among left-brain dominant participants. As affirmed by the quantitative results, the enhancement program Mathematics Engagement Clinic (MEC) grounded on the whole brain theory or brain dominance can hone thinking processes such as critical thinking and problem-solving skills, and thereby, improve mathematics achievement. Despite the abnormality distribution of participants in the study MEC has managed to cater to the participants' preferences. With the positive effect of the enhancement program, MEC grounded on brain dominance on the thinking processes and mathematics achievement of the participants, the researcher has constructed a modular mathematics enhancement program framework as a guide to researchers, and other interested parties in the planning, designing, redesigning and implementing modular mathematics enhancement programs grounded on brain dominance to hone and enhance thinking processes such as critical thinking and problem-solving skills, and thereby, improve mathematics achievement.

1. INTRODUCTION

1.1. Research Background

Students' behaviors are often misinterpreted due to their diverse learning styles, thinking styles, and other visible and measurable indicators. For instance, two students were caught by the teacher chatting while answering their test during the periodical examination. Weighing the gravity of the situation the teacher called the attention of the two students and investigated if they cheated. The process was biased considering that the situation might have arising factors that delimit the teachers' judgment. One factor that a teacher must consider was the learners' brain dominance [1], it was the preference of an individual to learn, act and listen. Students have these specific indicators. In the new normal, such criteria left a wide vertical wall for teachers to view. Teachers must be good qualitative observers.

For instance, left-brain dominant learners would be likely to approach problem-solving in a logical manner and to take account

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of facts, figures, statistics, and other tangibles. They would prefer conclusions that are backed up by supporting data or by examples of precedent. Others like structure in a practical and procedural sense [2]. Currently, as mentioned in the Basic Education - Learning Continuity Plan (BE – LCP) schools have to adopt distance learning as means to deliver the teaching and learning process [3]. The river-wide gap in the teaching and learning process was dredged deeper by the pandemic.

If a given assessment does not consider such conditions most likely some would ask the evaluator or at least the examinee continuously. What is the implication of brain dominance to Mathematics and Mathematics teaching? Do they have connections? Can improving critical thinking and problem-solving skills enhance the students' mathematics achievement? Will an enhancement program grounded in brain dominance hone the thinking processes of the students?

Noting such critical issues in Mathematics teaching, an enhancement program Mathematics Engagement Clinic MEC was constructed. It would specifically aim to improve the thinking process, such as critical thinking and problem-solving skills, as mentioned in the Mathematics Theoretical Framework [4]. It was also mentioned as the focus of 21st-century skills [5].

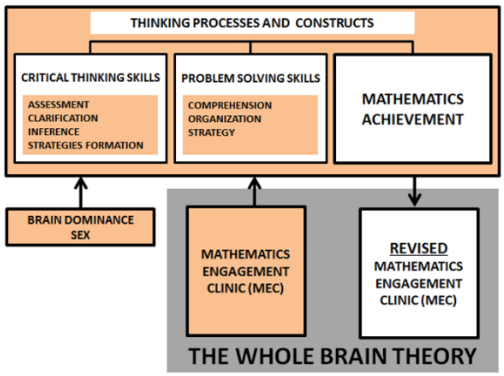

Figure 1. Brain dominance conceptual framework

The constructed Mathematics Engagement Clinic MEC is grounded in the Whole Brain Theory [1] [2]. In particular, brain dominance was considered in the construction as well as the procedure for the implementation of the MEC enhancement program.

The brain dominance conceptual framework above shows the graphical representation of the interrelationships of thinking processes and constructs in this research. The thinking processes and constructs were the three dependent variables, critical thinking, problem-solving skills, and mathematics achievement. Problem-solving skills have three sub-constructs: (1) comprehension, (2) organization, and (3) Strategy. Critical thinking skills have four sub-constructs: (1) assessment, (2) clarification, (3) Inference, and (4) strategy formation. Mathematics achievement was measured through the problem-solving and critical thinking skills of participants using the adapted rubrics. As an entire group and classified according to brain dominance and sex, the enhancement program MEC grounded on brain dominance was evaluated and assessed through the thinking processes and constructs to produce a better MEC program.

1.2. Literature Review

In a discussion paper on the "Enhanced K to 12 Basic Education Program" of [6] prepared by the Department of Education in the last quarter of 2010, it was pointed out that 'K to 12 is an effective cure to the deteriorating quality of the Philippine education system' relative to the global standard. Based on its Mathematics Curriculum Framework [4], critical thinking and problem solving were the main focus of learning propelled by discovery and inquiry-based learning, experiential and situated learning, cooperative learning, reflective learning, and constructivism.

Critical thinking was the most important skill for problem solving, inquiry, and discovery [7]. It is a systematic approach to making connections from the given facts or information to create the most measurable and observable solution to any type of problem, routine or non-routine, and abstract or concrete [8] [9] [7] [10]. Teaching does not always lead to this outcome. Teaching for critical thinking competence necessitates a philosophical shift in focus from learning to thinking [11], drill and practice to problem-based learning [12], subject isolation to subject integration, output to process, what is convenient to what is needed, and now to the future [7].

Difficulty in problem-solving may occur during one of the following phases; reading, comprehension, strategy know-how, transformation, process skill, and solution. Problem-solving is an essential part of Mathematics, yet many students spend much of their Mathematics career copying and reproducing algorithms [13]. According to Ref. [14], many students lack the ability, interest, and motivation to solve authentic and involved problems. Could this be related to brain hemisphere dominance or thinking preference?

Moreover, [15] revealed that (Filipino) students excel in knowledge acquisition but fare considerably low in lessons acquiring higher order thinking skills. This disappointing condition was evident in the performance of (Filipino) students in national and international surveys on Mathematics and Science competencies [16][17]. The Third International Mathematical Science Study [18] examined patterns of students' achievement in mathematics and found out that school effectiveness and teachers' competency impact learning and promotes a higher level of achievement [17]. The quality of instruction and effective instructional design is necessary to alleviate problems related to teaching and learning mathematics [19]. How would we deliver these cognitive factors while amending the learners' differences?

In the study of Thinking Styles and Cognitive Development, [20] recommended that "educators may enhance students' cognitive development by encouraging students to engage in a variety of thinking styles in their task performance. These tasks can be both of an educational and interpersonal nature. In particular, tasks that required students to think critically and to work with others can promote relativistic reasoning and counteract dualistic reasoning." In this sense, Mathematics Engagement Clinic (MEC) was formulated. Brain dominance (Hermann, 2000) of students was used as a guide for the teacher/researcher to adjust activities based on their thinking style. This study was grounded in the Whole Brain Theory [1]. It was believed that students' thinking processes also have preferences.

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1.3. Research Objective

The study aimed to determine the effect of **the** Mathematics Engagement Clinic (MEC) grounded on brain dominance on critical thinking and problem-solving skills, and the mathematics achievement of grade 11 Science, Technology, Engineering and Mathematics (STEM) senior high school students of a National Comprehensive High School in Iloilo. Specifically, the study sought to answer the following questions; (1) *What is the level of critical thinking and problem-solving skills, and mathematics achievement of the participants taken as an entire group and classified according to brain dominance and sex before and after their exposure to MEC?* (2) *How do participants in each group of dominant brain hemisphere**s** solve mathematical problems and construct critical inquiries and assumptions?* And, (3) *Will Mathematics Engagement Clinic grounded on brain dominance improve **the** critical thinking and problem-solving skills, and mathematics achievement of the participants?*

2. MATERIALS AND METHODS

The researcher has adapted Cresswell's [21] Discourse on worldview and research approaches congruent to epistemological and theoretical perspectives [22], paradigms [23], and broadly conceived research methodologies [24].

Table 1.
Worldview and research approaches

Worldview	Design	Methods
Transformative	Participatory Action Research Design	1) Purposive Sampling 2) Journaling 3) Thematic Analysis Process

This Transformative worldview followed participatory action research design [21]. Action research can be defined as the process of studying a real school or classroom situation to understand and improve the quality of actions or instruction [25]. The quantitative and qualitative data are analyzed and the results were compared. In the study, the effect of brain dominance through the Mathematics Engagement Clinic (MEC) was analyzed through descriptive analysis, thematic analysis process [30], and inferential analysis.

To surmise the methods of the study: (1) Sampling technique employed was purposive sampling following an inclusion criterion; (2) Pre-test – Post-test one sample Quasi-Experimental Procedure (Quantitative data) through RMT and Thematic Analysis Process (Qualitative data) through Individual Journals, Researchers' Notes, Interviews, Pictures, and Videos was used to collect the data; (3) Descriptive and Inferential Statistical Analysis (Quantitative data) and Thematic Analysis (Qualitative Data) was used to analyze the data.

2.1 Participants of the study

The respondents of the study were Grade 11 senior high school students on the Academic track in STEM strand section A of a National Comprehensive High School in Iloilo. Using the brain dominance instruments, a total of 38 Grade 11 students were initially considered participants in phase I. Purposively the most dominant 9 participants were chosen from each brain dominance group, left and right dominance group, a total of 18 participants. The chosen initial participants were interviewed before testing of researchers' made test to determine availability and confirmation of their participation. The participants were informed of the content and purpose of the study and asked to sign a consent letter. Later, the parents of the participants were sent a consent letter to ask for permission to permit their child to participate in the study. In cases of non-minor participants with the unavailability of a guardian, their adviser signed their consent form. In connection, the inclusion criteria in determining the participants were; (1) the participant was a grade 11 senior high school student of National Comprehensive High School in Iloilo; (2) the participant was in section A of STEM Academics strand; (3) using Brain Dominance Questionnaire (BDQ) and Brain Dominance Checklist (BDC), the participant was in the top nine most dominant from each group (Right and Left Brain dominance); and, (4) the form served as consent and assent were signed by the participants and their parent/guardian.

Only eleven out of eighteen confirmed their participation and inclusively satisfied the criteria as a participant. Three of the participants were right brain dominant and eight were left brain dominant. Nine of the participants were females and two males. During data analysis, ten out of eleven participants completed the sessions of MEC. One participant missed attending two sessions, hence, the data of the said participant was not included in the analysis.

2.2 Instruments

In the study, the researcher used the following instruments; (1) Brain Dominance Questionnaire BDQ, (2) Brain Dominance Checklist (BDC), (3) Researcher Made Test (RMT), (4) Problem Solving Skill Rubric, (5) Critical Thinking Rubric, (6) LRMDS Soundness General Evaluation Checklist and Evaluation Rating Sheet for print Materials adopted from LRMDS Education Soundness Specification of DEPED, and (7) the MEC Module.

BDQ and BDC were validated through triangulation using an interview schedule in a Barangay High School in Alimodian. Participants affirmed their results in BDC and BDQ through an Interview Schedule. The MEC module was conceptualized through a seminar conducted by the researcher. It was attended by a poll of experts and panel members. The content and structure of the MEC module were discussed in the seminar.

Later, the content and face validity of the constructed RMT (10 open words problem test), Problem Solving Skill Rubric, Critical Thinking Rubric, and MEC module were evaluated by three experts in Measurement and Evaluation, Module Structure, and Mathematics Teaching using the LRMDS Soundness General Evaluation Checklist and Evaluation Rating Sheet for print Materials adopted from LRMDS Education Soundness Specification of DepEd.

After integration of suggestions and comments in RMT, Problem Solving Skill Rubric, and Critical Thinking Rubric, it was then evaluated and assessed by three DepEd Senior High School Mathematics Teaching experts using the LRMDS Soundness General Evaluation Checklist and Evaluation Rating Sheet for print Materials adopted from LRMDS Education Soundness Specification of DepEd. It was done to ensure the appropriateness of the content and structure for a Senior High School student at the same time validate the integration of the suggestion given by the three experts in Measurement and

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Evaluation, Module Structure, and Mathematics Teaching using the LRMDS Soundness General Evaluation Checklist and Evaluation Rating Sheet for print Materials adopted from LRMDS Education Soundness Specification of DepEd. Appropriateness and validation of the integration of suggestions to the MEC module were done by Panel of members during the second session of the MEC enhancement program.

The Scorability of the RMT was administered to a National High School in Iloilo and assessed through Problem Solving Ability Rubric and Critical Thinking Rubric. The subjectivity of the RMT was considered by having three raters scoring the collected RMT data. The average of three raters' scores to each RMT result of participants was primarily coded.

2.3 *Intervention – Enhancement Program Mathematics Engagement Clinic (MEC)*

Interventions and activities included in the MEC were assessed and determined through Seminar Workshop. The workshop has helped the researcher to determine more activities suited to thinking styles based on Brain Dominance or the whole brain theory [1] as suggested by the participants in the seminar workshop. Later, enhanced by integrating the suggestions of three experts in different fields. During the implementation, the panel members visited the second session of the MEC enhancement program. Panel members include the research adviser, an outside expert, a curriculum and development expert, a Mathematics Teaching Expert, and a research design specialist. They also assessed and validated visually the printed MEC module. They observe the whole session and make clarification, critique and give further recommendations.

The chosen topics included in the enhancement program were Making Judgment and Inference, Number Theory: Check Digit, Rewriting Word Problems, Distances, and Angles, and Solving Linear Picture Problems. The specific mathematical skills identified to enhance our comprehension skills (for Rewriting Word Problems), inference (for Making Judgement and Inferences), estimation (Distances and Angles), mathematical representation and ease anxiety on mathematical symbols (Solving Linear Picture problems), and accuracy (Number Theory: Check Digit).

2.4 *Data Collection Procedure*

The data collection procedure of the study involves two phases, phase I and phase II. Phase I has three levels. It discusses the process of determining the participants, and instruments used as bases for identifying the participants. Phase II was the implementation of the enhancement program with which the chosen interventions were given to the participants. Also, in this phase, the pre-test and post-test were given to the participants (Figure 2).

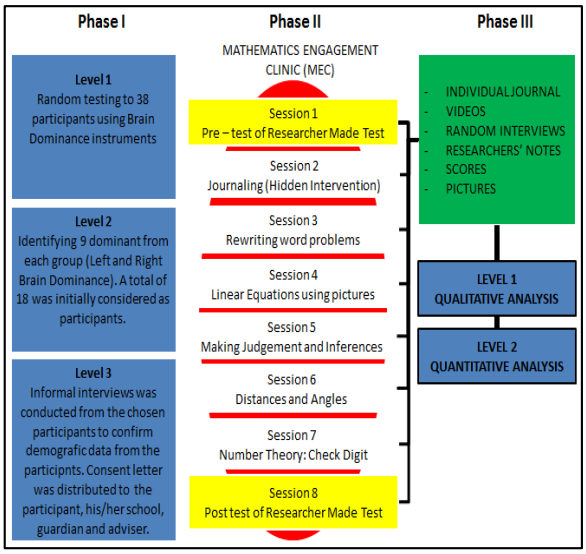

Figure 2. The procedure of data collection and analysis

2.5 *Data Analysis Procedure*

Phase III was the data analysis procedure of the study composed of quantitative and qualitative analysis. It represented the data analysis of the collected facts. As dictated by participatory action research design in a transformative worldview, the researcher ran the collected data through thematic, descriptive, and inferential analyses.

For qualitative analysis, the researcher used thematic analysis [26]. With 10 participants, thematic analysis was used to find repeated patterns of meaning across a set of data. In the study, the data used for thematic analysis were the journals of each participant specifically their reflection on every session, and the researchers' notes based on observation and videos. For quantitative analysis, the researcher used descriptive analysis and inferential analysis to describe and quantify the collected raw data. The data used for quantitative analysis were the results of the average percentage scores of participants on critical thinking and problem solving skills, and its sub-constructs, and mathematics achievement as a whole (Figure 3). A non-parametric statistical tool was considered during inferential analysis through SPSS.

In the study, thematic analysis was appropriate for the following situations: (1) Data interpretation [27] [28] [29]; (2) Deductive and inductive approaches [30] [31] [29]; (3) Analysis of two different phased data [26] [32] [29]; (4) Coding and categorising [26] [27] [33] [32] [29].

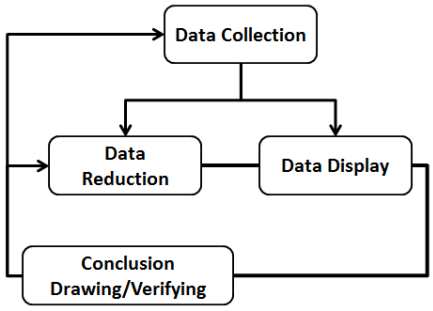

Figure 3.
Adapted Thematic process

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The researcher adapted the Miles and Huberman [26] model cited by Alhojailan [29] for the thematic analysis process. It is composed of three link stages, i.e. data reduction, data display and data conclusion – drawing/verifying. See the researchers' revised model above.

3 RESULT AND DISCUSSION

The essential question that embodies this research was; what is the effect of the Mathematics Engagement Clinic (MEC) grounded on brain dominance on critical thinking and problem-solving skills, and mathematics achievement to the participants?

3.1 Descriptive Analysis Result

According to the study of Alcantara [34], the mathematics performance of the students is significantly related to their level of critical thinking skills. It shows a positive weak correlation between the mathematics performance of the students and their level of critical thinking skills. Their study claimed that students with better critical thinking skills are more likely to have better mathematics performance. In addition, competencies considered moderately difficult for high school students was interpreting accurately and concluding graphic and tabular presentations of statistical data.

Table 2.
Level of Critical Thinking and Problem Solving Skills, and Mathematics Achievement as an entire group and classified according to Brain Dominance and Sex before and after their exposure to MEC

Constructs	Before			After		
	SD Standard Deviation	*M (%)* Mean Percentage	Qualitative Description	*SD* Standard Deviation	*M (%)* Mean Percentage	Qualitative Description
Critical Thinking Skills	6.12	19.15	Low	9.75	39.86	Average
(1) Male	0.59	19.57	Low	16.82	36.27	Average
(2) Female	6.93	19.05	Low	8.74	40.76	Above Average
(1) Leftt Brain Dominant	7.19	18.20	Low	10.01	39.28	Average
(2) Right Brain Dominant	1.74	21.38	Average	10.97	41.21	Above Average
Problem Solving Skills	7.01	20.02	Average	9.99	41.52	Above Average
(1) Male	0.98	20.12	Average	17.51	37.10	Average
(2) Female	7.93	19.99	Low	8.80	42.63	Above Average
(1) Left Brain Dominant	8.11	18.88	Low	10.48	40.49	Above Average
(2) Right Brain Dominant	2.89	22.67	Average	10.35	43.92	Above Average
Mathematics Achievement	6.47	19.52	Low	9.82	40.47	Above Average
(1) Male	0.08	19.81	Low	17.02	36.62	Average
(2) Female	7.33	19.45	Low	8.74	41.56	Above Average
(1) Left Brain Dominant	7.57	18.49	Low	10.20	39.80	Average
(2) Right Brain Dominant	1.97	21.93	Average	10.69	42.37	Above Average

Note for Description: Very High, 80.01-100%; High, 60.01-80.00%; Above Average, 40.01-60.00%; Average, 20.01-40.00%; Low, 0-20.00%.

As shown in Table 2, critical thinking and problem solving skills have improved based on mean percentage after an enhancement program MEC was given to the students. These skills are congruent to moderately difficult competencies [34]. It implies that MEC could be a good enhancement program to cultivate critical thinking skills consequently the Mathematics Performance of the students. Improving the level of critical thinking and problem solving skills in the new normal was very hard to achieve. Currently aligned to the Basic Education – Learning Continuity Plan [3], distance learning was considered as an alternative to face to face teaching and learning process. Most public schools in the country have adopted modular distance learning, thus, it is timely to consider Mathematics Engagement Clinic grounded in brain dominance as an enhancement program to bridge the gap of school and teacher presence in the teaching and learning process.

It was revealed in the study of Alcantara [33] that there is a positive weak correlation between problem solving solving skills and Mathematics performance among students. It was also noted that the competency that a competency considered as moderately difficult to master was problem solving involving sets.

Integrating the study of Alcantara [33] to the result of the study as shown in table 2, if MEC enhancement program can improve the problem solving skills then difficulties in competencies such as problem solving in sets concept can be aided by teachers easily. It implied that the enhancement program MEC was alligned to the current mathematics curriculum framework [4] where its operation was more focused on understanding, critical thinking, problem solving, reasoning, communicating, and making connections, representations and decisions in real life.

The result implied that one of the male participants might have improved better than the other. Since MEC was grounded on brain dominance, it seemed to oppose the result of [35] where his study revealed no significant relationship between brain hemisphere dominance and academic achievement in mathematics for boys and girls.

The study showed that left and right brain dominant participants have improved their level in mathematics achievement. Hence, MEC grounded on brain dominance have improved the level of mathematics achievement of the participants. The result has confirmed the study of Riasat. [36] study the impact of brain based learning on students' academic achievement to see the effect of brain based learning environment in secondary schools. It was revealed from the study that brain based learning has a positive effect on student's academic achievement [36].

When the participants were taken as an entire group, the mean percentage score of the participants before the enhancement program of Mathematics Engagement Clinic (MEC) with low level of Mathematics Achievement have improved tremendously to above average level of Mathematics Achievement. It implied that MEC grounded on brain dominance have improved the mathematics achievement of the participants. Specifically, for right – brain dominant participants, the spread of the data was narrow before the enhancement program MEC (SD=1.93). After the intervention, the spread of the data was broad (SD = 10.69). For female participants and left – brain dominant participants, the spread of the data showed a slight difference before and after the enhancement program MEC was implemented. It was revealed that one participant among the right brain dominant participants have improved better than others.

[37] designed a research study that aims to determine the effects of right and left brain intelligence on mathematics learning achievement in junior high school students. The results of the

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research showed that there was an influence between the intelligence of the right and left brains on students' mathematics learning achievement. The influence of right brain intelligence is 28% and left brain intelligence is 46.7%.

Comparing the result of Ref.[37] to the findings of the study, It showed that preference in learning and thinking differed based on achievement. Based on the findings of the level of mathematics achievement when grouped by sex and brain dominance, and the spread of the data before and after the enhancement program, the researcher may have inferred that the enhancement program MEC can improve the level of Mathematics achievement of the participants most especially to the male right – brain dominant participant. The said difference was referred to as an increase in the level of mathematics achievement as a whole but the increment differed, referring to the case of the male right–brain dominant participant in the study. Based on table 2, one group or a specific participant has improved better in mathematics achievement than the other groups or participants. The said assumption was still inconclusive because there was only one male right–brain dominant participant in the study. With the small number of participants in the study, it needs thorough research on the effect of the enhancement program MEC ground on brain dominance. Future researchers may increase the number of participants to ensure homogeneity and normal distribution of data.

3.2 Participants' Thinking Process and Reflections in MEC

These research findings discussed the participants' process of thinking based on their journals, pictures, and videos. These quoted facts represent fragments of the processes of thinking of the participants during the enhancement program Mathematics Engagement Clinic (MEC) was implemented. It specifically answered the third specific research question and validated the result of the quantitative analysis above that answers the third specific research question; how do the participants in each group of dominant brain hemispheres solve mathematical problems and construct critical inquiries and assumptions?

Following the thematic analysis process [26] [29], the researcher identified first the initial themes and, later, the main themes were identified. The initial identified prevalent themes during the thematic analysis of the data from the Journals, and researchers' notes from observation, pictures, and, video coding and analysis were: (1) the participants showed considerable understanding of the activities; (2) the participants identified more than one approach in solving problems and intervention activities; (3) participants showed evidence and questions accuracy and relevance of their answers; (4) participants identified conclusions, implications, or consequences on the intervention activities with considerable understanding; (5) most left brain dominant participant tended to do confirmation with their answers to the other participants on most sessions; (6) participants showed difficulty on some of the activities; and (7) as a whole, participants enjoyed the activities in MEC.

In conclusion, by drawing and verifying the collected data, there were two general or main themes (1) the participants showed critical thinking and problem-solving skills as thinking processes in connecting the information given in the activities, and, (2) the participants have freely discussed their thoughts about the enhancement program. Before moving to the main themes, the theoretical implication found in this study was conceptualized based on sub-theme 5.

Most left-brain dominant participants tended to do confirmation with their answers to the other participants in most sessions. In the researchers' notes, the researcher noted, that one participant (kept) asking her seatmate during the session… I checked and compared their answers but found no similarity… On the second session, one participant was teased by her friends seating next to her chair and another adjacent to the other… they are comparing their answers… I heard one said, "kanami ka drawing mo ba (you have a nice drawing) …" I checked and compared their answers but found no similarity…

Participants also clarified their process of thinking. In addition, the researcher has noted, (Fifth session) a group of participants were checking each other's answers… one participant said "pano ni ho? (do you know how to do this?) …" and another replied, "Sunda lng ang instruction ukon ang procedure (just follow the instruction or procedure) …ay! insakto man na (wait! That's correct) …" I checked and compared their answers but found no similarity. It showed that the participant simply asked for affirmation on their answers.

Theme 1: Participants used Critical Thinking and Problem Solving Skills as Thinking Processes in Connecting the Information

The participants showed critical thinking and problem solving skills as thinking processes in connecting the information from the activities. On one session, a picture of a map was shown. The participants were asked to create a route passing through the islands and the bridges. However, there was a constraint. The route must pass each bridge only once. One participant has noted, "it can't cross each bridge exactly once. It is impossible because the number of island is even (4) and the number of bridges is odd (7). It can be possible if both bridges and island is even."

The participant suggested an assumption to satisfy the current conditions. Another participant suggested a different assumption; he noted that "…you can cross if you re-arrange the bridges [different possibilities]." It showed that the participant demonstrate characteristics with a good analysis and evaluation by making it a continuous activity. It is 'Continuous' in the sense that the participant is making an assumption while keeping the current conditions cultivating "different possibilities". This is a critical thinking process. As defined by different authors and researchers on critical thinking, it is thinking that proceeds on the basis of careful evaluation of premises and evidence and comes to conclusions cautiously through the consideration of all pertinent factors [38] [10] [8] [9]. While doing the analysis, the researcher remembers the birth of non-Euclidean geometry in which famous mathematicians negated the fifth postulate of Euclid while holding true to the first four postulates. As a result, they formed a new view of Geometry. Are the participants aware of their cognition?

Another participant noted, "I cannot find any solution to find a tour through the town that crosses each bridge exactly once that (is) why I just use some logic. What does she mean by logic? From her journal the researcher noted, the participant created routes using two diagrams where one of it she transferred one bridge to another setting… and another she proposed that passing through the bridge can be done under the bridge by swimming."

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It showed that the participant has defined logic as making possibilities or solutions from a different perspective by re arranging the bridge or swimming under the bridge.

On another session, one participant has noted "Clues (were); (1) the victim was found in the floor on his office; (2) The time of death 5:50 AM based on the body temperature of the victim and the room temperature; (3) There are 5 suspects mentioned by the investigator. He added; that based on my observation, the suspects (are) B and D. Suspect B because there is no such secretary in the restaurant also she said that she saw the victim in his chair but the victim was found on the floor in his office. And suspect D because he said that they were the last ones to see the body in the building and the time they arrived was before the time of death of the victim." The participant examined the given fact by noting down clues. He made conclusions based on his justified collected facts. This is a thinking process specifically problem-solving skills. As defined by [39], problem-solving is an activity that involves the students' engagement in a variety of cognitive actions including accessing and using previous knowledge and experience.

Lifting all these quoted statements from their journals, the researcher noted …participants show and apply critical thinking and problem-solving skills by connecting information or ideas from a given fact to a real and observable experience. The participants have created connections from a given fact to a real and observable experience. Real and observable experiences may be rooted in their thinking preferences. Comparing their manner of processing information based on their journal, the researcher has noted right brain dominant participants process their thoughts through stories making them more sensitive and personal…

In one of the participants' journals, he noted, "the victim was sleeping then the murderer or assailant came. While the assailant (is) standing near the sleeping victim, the victim woke up and saw that a knife is coming near him he used his left hand to stop the murder weapon but it slides through his hand and harmed his left eye then he kick the assailants with his right foot but the assailant uses the murder weapon and it causes wound to his right ankle. (While) trying to stand up the victim was then stabbed in the right thigh. The victim was dead because of too much blood loss."

Another participant noted, "(I'm) not sure of my answers. I'm sorry if I judged them directly based on their words I need more clues, and yes fingerprint is strong evidence."

For left brain dominant participants, the researcher has noted left brain dominant participants are more direct, numeric, and specific in connecting information to arrive at a significant conclusion…. In one of the participants' journals, the participant noted, "suspect A, helper, because he can kill the victim. Since he [arrives] early... He can do whatever he wants because there (are) no people (in there) except two of them. He already [knows] what his boss's habit (is) every day. He [kills] his boss while sleeping." The participant was more direct and specific, and opposite in organizing his idea than a right-brain dominant participant quoted above.

Another participant noted, "it can't cross each bridge exactly once. It is impossible because the number of the island is even (4) and the number of bridges is odd (7). It can be possible if both bridges and island are even." The participant was focused on the number (bridges and islands). It implies that the participant has seen the activities as more numeric, hence, making inferences based on numbers. Unlike one right-brain dominant participant that noted the bridges should be rearranged implying that the participant sees its structure viewing it as a whole.

The activities allow me to think critically, one participant directly noted this. Can the participant define and scoop the term critical thinking based only on the experiences during the intervention? One participant noted; that I enjoyed the activity, especially in the first part. It [enhances] my mathematical skills. Can the participant identify their mathematical skills? Another participant quoted that I liked this activity because it made me think about how to find the values of each material/organism. This activity improved my skills in analyzing mathematical problems with the use of pictures. I hope that there's more. The participant has mentioned improved skills in analyzing mathematical problems. It shows that the participants have independently conceptualized these terms based only on their experiences because these terms are critically defined and grounded on theories and empirical research. Such terms were not discussed but may be mentioned by their teachers. But the fact that they noted it in their journal brings significant implications to their learning.

In addition to specific and distinct behavior in one brain dominance group of participants, a particular behavior was noted by the researcher. Most left-brain dominant participants tended to do confirmation with their answers to the other participants in most sessions. In the researchers' notes, the researcher noted, One participant was keep asking her seatmate during the session… I checked and compared their answers but found no similarity… In the second session, one participant was teased by her friends seating next to her chair and another adjacent to the other… they are comparing their answers… I heard one say, "kanami ka drawing mo ba…" I checked and compared their answers but found no similarity… Participants also clarified their process of thinking. In addition, the researcher noted, in (Fifth session) a group of participants was checking each other's answers… one participant said "pano ni ho?" and another replied, "sunda lng ang instruction ukon ang procedure…ay! insakto man na…" I checked and compared their answers but found no similarity. It showed that the participant simply asked for affirmation on their answers. (See appendixes for pictures) It implied that this distinct behavior was evidence of behavioral cognition. In what is perhaps the most influential definition [40] [41] in [42], cognition was a mental process by which external or internal input is transformed, reduced, elaborated, stored, recovered, and used… such mental processes involve the generation and use of internal representations to varying degrees, and may operate independently (or not) at different stages of processing… these processes can to some extent be observed or at least empirically probed, leading to a scientific investigation utilizing methods akin to those of the natural sciences. In general, this behavioral cognition of left-brain dominant participants in the study may be called affirmation behavioral learning.

Based on the first theme, as a whole, the enhancement program Mathematics Engagement Clinic (MEC) brought different effects to left and right-brain dominant participants in terms of their thinking processes such as critical thinking and problem-solving skills. Right-brain dominant participants have shown more intimacy and personal in connecting information from a given fact to real and observable experiences. While, left-brain dominant participants have shown more specific, direct, and numeric in connecting given facts to a real and observable experience. In addition, left brain dominant participants have a

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distinct behavioral cognition which the researcher called affirmation behavioral learning.

Hence, based on thematic analysis with the identified themes and main themes and integration of their identified sub-constructs, critical thinking, and problem-solving skills can be redefined congruent to the result of the study. Critical thinking skill is the thinking process of participants in the study in connecting information through assessment, clarification, making inference and judgment, and, strategies formations with, for left brain dominant participants, a behavioral cognition through affirmation. And, problem-solving skills are a thinking process of participants in connecting information through comprehension, organization, and strategy with, for left-brain dominant participants, a behavioral cognition through affirmation.

Theme 2: Participants Freely Discusses their Thoughts

The participants freely discussed their thoughts while writing their journals. One participant has noted the story is entertaining wherein it is a way that can make the problem more relaxing since it gives real-life scenarios and examples. The activities given were a bit confusing and entertaining as well. It helps us think outside the box for possible clarifications and explanations. The participant showed a conflicting statement confusing and entertaining clarifications and explanations which the participant freely stated in his journal. Another participant mentioned that "the task is quite confusing but it challenges me to do the task." The participant was confused but challenged another conflicting statement that reflects the participants' thoughts and feelings.

Most participants have freely stated that they enjoy the activities. Such as; "the activity is challenging and enjoyable;" "The story was fun and exciting, some sort of challenges logic at the same time values and discipline was taught. I liked it;" "It was challenging and tricky it was hard to know who is the true assailants. Yet, I enjoyed the activities given;" "I enjoyed the activity. It is really interesting to solve;" "I enjoyed the activity;" "I enjoyed this activity. It made me curious to tell who the suspect is. I hope that there are more activities like this one!" and many others.

Some participants freely discussed their thinking processes. One participant noted, (for) me, I'm having a hard time analyzing the problem. I can't find a way that crosses each bridge exactly one. Also, if you want to go to the town why bother crossing all the bridges? Maybe, there was a ship trying to sail below the bridge. The participants' moods could be felt from those lines. Another participant has stated; that this session makes me feel as if I'm a detective. Solving this kind of situation is also fun because you would never know who is/are the suspect/s. It is also interesting. The participant's mood was 'excited'. It was a sign that the participant was ready and motivated for the next activity. The researcher noted, "… the participants are eager to receive their activity sheets."

Another participant stated that this type of problem brings no pressure, all you do is solve calmly for there are illustrations that will guide you. It implies dependent learning of the participant to the module but independent because it was student-centered and independent of teachers' feed. One participant noted that the activities boost your imagination and vocabulary to formulate your plot for the problem. The participant did not mention 'teacher' in his statement though the participant directly stated that the activities boost… imagination and vocabulary. It implies the participant can learn on their own if given these activities. Again, the participant freely discussed their thoughts about the activities.

Some participants freely reflect their views on the activities. One participant noted, "…to be honest, I didn't know that there are companies that are scams. I enjoyed checking the digit but there's no correct answer." Another participant has noted in his journal; that I enjoyed the story. It is not boring and hard to understand as it interestingly presents the text/problem. If variables x and y were used in that problem, I think I will be getting hard time to solve for it. Another participant noted, "…the 2nd story 'session 3' (is) inference. I do not know if I have written the correct answer. It was just my perspective. I can't judge people by their words. I will use their fingerprint instead, it is much more concrete. I can't feel that justice relies on my hand." The participant added "… (I'm) not sure of my answers. I'm sorry if I judged them directly based on their words I need more clues and yes fingerprint is strong evidence."

As a whole, the participants freely discussed their thoughts about the activities. Based on the second theme, the enhancement program MEC could identify, determine, and enhance their thinking process through journaling. Both right and left-brain dominant participants showed that they freely discussed their thoughts during the activities. Its' differences in thinking processes and preferences in connecting information were stated in the narrative of the first theme.

Journaling was used as means by participants to explore, create connections, reflect on activities, and freely discussed thoughts during every session. For the researcher of the study, journaling becomes convenient to gather data from the participants. This implication was seen by other researchers. [43] [44] [45] [13] agreed that journal writing as a part of the mathematics curriculum encouraged a deeper understanding of mathematics and enabled students to construct meanings, make connections, and take ownership of their learning. It may imply that journaling as a part of mathematics teaching will give a positive analysis, assessment, and evaluation for educators as well as learners.

3.3 Inferential Analysis Result

Considering all the assumptions, the researcher has identified and decided to use a non-parametric test. Wilcoxon-Signed Rank Test was used to determine if there is a significant difference between the percentage scores on pre-test and post-test. A large value of mean percentage score difference between before and after the enhancement program was revealed. This indicated that the enhancement Mathematics Engagement Clinic program was effective in increasing and improving critical thinking and problem-solving skills, and mathematics achievement.

Table 12
Wilcoxon – Signed rank test results for critical thinking and problem-solving skills, and mathematics achievement before and after the enhancement program

Category	Mean			Z	Significance
	Before	After	Difference		
Mathematics Achievement	19.52	40.57	21.048	2.803*	0.005
Critical Thinking Skill	19.15	39.86	20.704	2.803*	0.005
Problem Solving Skill	20.02	41.52	21.505	2.805*	0.005

Note: $p^*<0.01$

As shown in table 2, the participants whether grouped in sex or brain dominance have improved their critical thinking and

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problem-solving skills, and mathematics achievement to their preference. Since MEC was grounded on brain dominance, the result seemed to affirm the general notion for brain dominance to have "expected differences", since, "individuals' physical and intellectual abilities and their ability to solve problems are strongly influenced by the individual's preference to apply one part of the brain as opposed to the other" [46] [47]. It implies that constructing an enhancement program grounded on brain dominance does not discriminate the participants' preferences to learn, think and act, and sex but rather increases and improves the thinking processes, and mathematics achievement of the participants. However, the implication of the result needs further research to substantiate or disprove the claim by increasing the number of participants and ensuring a normal distribution, and homogeneity of data.

4 CONCLUSION

There were different effects on the left and right brain dominant participants in terms of their critical thinking and problem-solving skills. Right-brain dominant participants have shown more intimacy and personal in connecting information from a given fact to real and observable experiences. While, left-brain dominant participants have shown more specific, direct, and numeric in connecting the given facts to a real and observable experience. Also, left brain dominant participants have a distinct behavioral cognition which the researcher called affirmation behavioral learning. Hence, based on a thematic analysis of the identified themes and main themes, critical thinking and problem-solving skills can be redefined congruent to the result of the study. Critical thinking skill is the thinking process of participants in the study in connecting information through assessment, clarification, making inference and judgment, and, strategies formations with, for left brain dominant participants, a behavioral cognition through affirmation. And, problem-solving skills are a thinking process of participants in connecting information through comprehension, organization and strategy with, for left brain dominant participants, a behavioural cognition through affirmation. Moreover, as based on the inferential analysis, there was a significant difference in critical thinking and problem-solving skills, and mathematics achievement before and after the enhancement program. In conclusion following transformative worldview through participatory action research design, the effect of the enhancement program Mathematics Engagement Clinic (MEC) grounded on the whole brain theory or brain dominance can hone thinking processes such as critical thinking and problem-solving skills, and thereby, improve mathematics achievement. It implied that the enhancement program MEC grounded on brain dominance could improve the critical thinking and problem solving mental processes of the participants. Despite the abnormality distribution of participants in the study, the enhancement program has managed to cater to the participants' preferences. Hence, MEC grounded on brain dominance does not discriminate the participants' sex and preferences to think, act and learn.

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