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Students' Perceptions and Learning Gains Using Whole Brain Teaching Strategy in the STEM Strand of K to 12 Education

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ABSTRACT

In this study, the researchers explored the effectiveness of Whole Brain Teaching (WBT) in teaching circuits to Senior High Students (SHS), particularly Academic track, STEM strand of K to 12 curriculum. Learning activities in electric circuits were developed as WBT strategy and administered in a pretest-posttest design. To further analyze the effectiveness of WBT, learning gains of respondents were compared to students exposed to the traditional method of teaching of electric circuit. The result showed that SHS students attained 19.3% learning gain which is considerably small. However, comparative statistical results gave a significant difference ($t = 2.62$, $p = 0.007$) in favor to WBT approach. Further, a survey instrument was developed, validated, and administered to assess if using varied teaching strategies could be linked to positive student perceptions of the teaching intervention. Further, regression analysis was conducted to determine if such approaches were predictive to learning gains. Results showed that perceptions of the student have no significant effect on their learning and no quadrant of the brain can be considered predictive on the learning gains. Therefore, the result of the study may support the significance of catering the four brain quadrants in teaching for conceptual understanding.

Keywords: Perceptions, STEM K to 12, Whole Brain Teaching (WBT) strategy

INTRODUCTION

One of the core subjects in the SHS STEM strand of the Academic track is General Physics. Researches have shown that generally, student performed low in Physics among other sciences. This poor performance can be accounted to school-related and teacher-related factors (Orleans, 2007). According to Orleans (2007), factors affecting conceptual understanding and lack of enthusiasm towards learning science subjects, especially physics, are the following; repetitive learning approaches such as memorizing, note copying which is exam-oriented, traditional teaching strategies such as lectures with minimal student participation, and laboratory activities with prescribed practical procedures. Another factor is the prior conception that Physics is a difficult subject that would also result in the student's lack of interest in Physics classes (Orleans, 2007). Therefore, it is a challenge for every physics teacher to provide a learning environment that wards this misconception off and maximizes student engagement in the learning process.

Since education is designed to enhance the brain, educators ought to figure out how the brain works and process information. One of the most significant models that have attempted to explain the brain's structure, mechanisms, and learning processes is the Herrmann Whole Brain Model (HWBM) (Torio, 2016) which emphasized that the learning characteristics of the upper and lower brain differ and that the brain is further subdivided into right and left hemispheres. As quoted in the study conducted by Bawaneh (2011) "The upper brain deals with abstract and conceptual concepts, while the lower brain deals with emotional and organic ideas. The upper left quadrant deals with logic and quantity, whereas the lower left quadrant deals with sequence and organization. In contrast, the upper right quadrant deals with conceptual and visual constructs, whereas the lower right quadrant deals with interpersonal and emotional concepts." Accordingly, it would be better than teaching should target these four brain compartments.

The Whole Brain Teaching (WBT) method stresses providing equal learning opportunities for different learners, where each of the four brain compartments will be exercised during the whole period of class. Previous studies (Bawaneh et al., 2012; Torio et al., 2016) showed the effects on the use of WBT in Physics classes. Thus, it is highly encouraged to implement WBT method in senior high school Physics classes.

In this study, the proponents explored the effectiveness of the WBT method in teaching direct circuits in senior high school students for the first time in the

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Philippine context. Moreover, a study on how the said strategy directly impacts learning outcomes is still needed due to the limited research available as of this time (Van Hosen, 2017). In addition, the present study explored the possibility that varied teaching strategies could be linked to positive student perceptions of the teaching intervention. Basing research reviews, perception survey built on HWBM compartmentalized learning contexts was developed and validated for the first time in this present study.

This study envisioned to develop teaching materials and approaches that cater to the four brain areas of the learner as a holistic approach in addressing brain-based needs. In addition, a survey instrument that would measure the association of WBT and learning basing on the student's perceptions is being developed and validated. Specifically, the study aimed to: develop four main learning activities in electric circuits as WBT strategy; determine the effect of WBT on students' conceptual understanding; develop a survey instrument to measure the student's perceptions of the WBT strategy; and correlate perceptions of the students in the implementation of WBT to their learning gains.

REVIEW OF RELATED LITERATURE

There are several varieties of the brain-based pedagogy. One brain-based strategy is known as Whole Brain Teaching (WBT). According to Torio and Cabrillas-Torio (2016), WBT is a brain-based teaching strategy rooted in the concepts developed by Biffle (2013) and Hermann (1998). This strategy treats every child to have four brain areas that require close attention. The four brain areas correspond to four learning activities to address the holistic need of an individual. The four learning activities are (1) lecture; (2) individual work; (3) group work; and (4) practical display.

Whole brain teaching strategies emphasize active learning. This type of instructional approach was derived from studies such that when you tap into both hemispheres of the brain (left and right), learners are better able to make connections. In whole brain learning, teachers may play music during instruction or use guided meditation to help build a more relaxed atmosphere, while students are encouraged in visualizing, drawing, and acting out what they are learning. Essentially, whole brain teaching strategies are tapping into the way the brain works best. It is just teaching strategies that you are already using in a new, unique way (Cox, 2000).

It is believed by the advocates of the Whole Brain Teaching approach that each learning opportunity ought to have the capacity to address the four areas of the brain. To address the four areas implies giving exercises or activities that will invigorate the brain functions of every region. The WBT approach is used to target the four learning areas of the brain for the holistic development of individual students/learners. The idea is that to cater to the holistic development of an individual, the four learning areas of the brain should be satisfied.

Herrmann (2000) discussed the four areas of the brain with different learning styles associated with each area. Figure 1 shows the Whole Brain Model by Ned Herrmann. The upper left quarter (A) represents external learning wherein learners within this category traditionally learn best through lectures, textbooks, and teachers as knowledge dispensers. The lower left quarter (B) refers to procedural learning. Procedural learners characterized by a step-by-step approach, in which practice, repetition, hands-on activities, abstract cognition, and common sense are most emphasized. The lower right quarter (C) describes interactive learning where interrelations and kinesthetic work are emphasized. Interactive learners perform best in an environment created by experience, feedback, listening, physical experimentation, and shared thinking. The upper right quarter (D) represents internal learning in which the ideal learning context is characterized by insightfulness, idea construction, and concept understanding that occur instantly, totally, comprehensively, and intuitively.

According to Pedersen (2011) and Lepper (2011) from Calhoun (2012), learning more effectively took place when connections were made between the right and left hemispheres of the brain. The left brain was associated with cognition, while the right brain was associated with creativity. Activating both hemispheres of the brain encouraged effective learning and student engagement. This approach specifically addressed the commands and techniques used as part of the whole brain learning experience.

Torio and Cabrillas-Torio (2016) conducted a study to determine the effect of the use of whole brain teaching on students' learning gains and motivation in thermodynamics. In their study, WBT strategy was used as a means to target the performance of students as well as motivation. Their study was conducted in the laboratory school of Philippine Normal University. The two sections of grade 10 students made up the two groups as respondents of the said study. A set of six lessons were planned and delivered to these two groups in their physics class. Learning gain was measured by getting the difference between pretest and posttests using a validated 40-item test items. The study identified academic performance as a weakness in the Philippines and meant to be addressed by considering a teaching strategy, the WBT. The researchers concluded that academic performance is a complex interplay of a lot of school factors. The teaching strategy is just one of the many factors that can bring positive changes to the performance level of students. Another big factor that affects performance is motivation. Also, the results of the study revealed that there is an average learning gain of 20% after facilitating classes under WBT. The results revealed positive effects on academic performance and motivation could be derived from the use of WBT as a teaching strategy. The researchers also added that the motivation component is highest in terms of intrinsic sources followed by extrinsic sources. This teaching innovation is just one of the many possible teaching strategies that can be explored by practitioners in the field. The positive learning gains that resulted after the introduction of the strategy is indicative that the effort to innovate and improve teaching and learning is paying off.

Whole Brain Teaching advocates the concept of providing varied tasks to address four learning areas of the brain (Bawaneh and Saleh, 2011). The results of the study conducted by Bawaneh, Zain, Saleh, and Abdullah (2012) showed that Herrmann Whole Brain Teaching Method (HWBTM) surpassed the Conventional Teaching Method (CTM) in enhancing students' motivation towards science learning. In HWBTM, students preferred thinking styles towards motivation in science learning are not significantly different. However, there were shown differences across CTM.

Palasigue (2009) conducted a study to seek ways on how to create a more engaging learning environment for the students by using the WBT teaching method. The researcher concluded that the students who were used to WBT approach had become more engaged in every lesson on a day to day basis. Results showed that students were more eager for the next day's lesson and the accountability that was given to them through the WBT method.

Calhoun (2012) says brain-based learning is a way of activating all the parts of the brain during the learning process. Schools that have implemented brain-based teaching and learning have shown increases in student achievement over some time. Effective teachers use brain-based techniques to keep students actively engaged in the learning process. When students are actively engaged in the learning process, both hemispheres of their brains can be activated to increase learning. While most students prefer one learning style, modality, or hemisphere over the other, activating both left-brain and right-brain activities can increase student achievement. Teachers also must recognize their own learning preferences and adjust their lessons to reach both types of learners. Research has shown brain-based strategies to be effective, engaging, and exciting in the education environment. Many strategies, including whole brain teaching, can and should be employed in the classroom to activate the brain and increase learning in students.

METHODOLOGY

The participants were senior high school students in the STEM curriculum strand, General Physics 1 at Central Mindanao University taking electric circuit. The researcher did not randomly assign participants, which means, WBT intervention was given to the entire STEM classes to avoid possible complaints of impartial treatment. The electric circuit class composed of science education students was taken as the control group. The subject content and their prior knowledge in this set-up were most-likely comparable.

There were 240 respondents composed of seven (7) sections in General Physics 2 in which the electric circuit was one of the major topics. Table 1 shows the profile in terms of age and gender for WBT and control group, respectively. Most of the respondents were female students, with a total of 147 (61.2%). In terms of age, the majority were 18 years old (70%), followed by 17 years old (17.1%) and 19 years old (12.1%). Two students were 26 and 27 years of age during the conduct of this study.

Table 1

Profile of the Respondents in Terms of Age and Sex

		WBT		Control	
		N	Percentage	N	Percentage
SEX	Male	93	38.8	17	61.2
	Female	147	61.2	11	38.8
	TOTAL	240	100	28	100
AGE	17	41	17.1	0	0
	18	168	70	3	10.7
	19	29	12.1	14	50
	20	0	0	6	21.4
	21	0	0	4	14.3
	22	0	0	1	3.6
	26	1	0.4	0	0
	27	1	0.4	0	0
	TOTAL	240	100	28	100

Male students (61.2%) outnumbered the female in the control group. Half of the students were 19 years of age, 18 years old for the youngest, and one student in his 22 years of age, which was the oldest in the class.

Research Design

This study used a quasi-experimental design which involved the administration of pre-test and post-test. Determining and Interpreting the Resistive Electric Circuit (DIRECT) instrument was used as the assessment tool for conceptual understanding. The pre-test measurement served as the baseline assessment for normal gain computation. The normal gain scores indicated the precise change of scores from pretest to posttest which serve as the basis for assessing conceptual understanding. The computation of normal gains was based on Hake's model or normalized gain (Hake, 1998). Comparative statistical and graphical analysis were conducted to assess the effectiveness of WBT. DIRECT pre and post-tests were the basis of comparison using Analysis of Covariance (ANCOVA).

Data Gathering Procedure

The study started with the Capability Building. Collaborators, who are license physics teachers, were briefed with WBT strategy- theoretical background, features of the strategy and how it will be delivered in a classroom setting. Then, research collaborators developed the Lesson Guides (LG) in electric circuits as WBT lessons. These lesson guides consist of activity sets or teaching approaches that cater to four chambers of the brain following the Hermann Brain Dominance Theory. The template includes the following features:

a. Objectives of the lesson
b. Topic/Subject Matter
c. Procedure:
    i. Pretest (five-item multiple-choice)
    ii. Lesson proper in the WBT approach
    iii. Manual work

iv. Group work
v. Practical Display
vi. Posttest (five-item multiple-choice test)

Collaborators conducted a teaching demo with their lesson guides of the WBT strategy. The teaching demonstration phase ensures that the flaws of prepared LG were addressed before the conduct of actual classroom teaching. Physics instructors/professors who were handling or have taught circuit classes were invited to observe and give comments/suggestions for the improvement of WBT lesson guides. There were suggestions and minor revisions raised in which collaborators and researcher agreed, and thus LG was modified. Capability building activity ended with all the evaluators favorably endorsing the use of WBT learning guides for STEM circuit classes.

The DIRECT pretest was first given in a four weeks gap before the implementation of the posttest to avoid retention problems. The collaborators implemented LG to STEM physics classes, and the DIRECT posttest was administered at the end of the two weeks of intervention. To further verify the effectiveness of the approach, a comparative study was conducted. One electric circuit class, composed of science major education students, was taken as the control group. The DIRECT pretest was given to them before a traditional method of discussions and posttest after covering the whole circuit topic.

Development and Implementation of Perception Survey Instrument

A survey instrument was developed to assess the perceptions of the students on the conduct of WBT. Each statement was constructed in such a way that it could address specific brain quadrant or target a specific learning area. A sample item is a statement "The teacher provided an environment where you can listen and share ideas with your classmates," which addresses quadrant C, the interpersonal and emotional aspect. Further, each statement or item in the survey was subjected to content validation through consultations with collaborators and physics teachers who willfully gave their comments. Common and sensible suggestions were taken into consideration in drafting the final survey items.

Data Analysis

Learning gains were computed basing pretest and posttest data gathered from student respondents. Statistical t-test analysis was conducted to compare experimental (STEM students) and control (physics education students) groups. Cronbach's alpha was computed to determine the reliability of the WBT perception survey. Each quadrant has Cronbach's alpha greater than 0.7 which indicates that the items in the respective quadrants formed a scale that has reasonable internal consistency reliability.

Correlation analysis was done to assess if perceptions of the students on WBT implementation affects their learning gains. Further, to determine if learning is predictive with respect to a specific brain quadrant, regression analysis was conducted.

RESULTS

Testing the Effectiveness of WBT strategy

The DIRECT instrument was administered before and after the implementation of the said teaching strategy both for the experimental and control group to test the effectiveness of the WBT strategy. The validity of DIRECT instrument was supported by these data; internal consistency (KR-20) = 0.71, item reliability of 0.33 (higher than ideal value of 0.2) and the average difficulty index of 0.49 which is in between the ideal value range of 0.40 to 0.60 (Engelhard & Beichner, 2004). Though DIRECT was developed and validated in another country, its validity and reliability were already tested in local researches. Examples are the studies conducted by Dr. Teresita D. Taganahan (2014) and Dr. Cecilia Bucayong (2016).

Table 2 shows the descriptive statistics. Control group had a minimum score of 6 and a maximum of 18, while scores in the experimental group ranged from two (2) to 17. Both groups demonstrated improvement in conceptual understanding, but the experimental group got the highest score of 22 compared to only 19 in the control group. On average, the control group was considerably higher during the pretest, but the reverse happened in the posttest. Thus, the experimental group obtained an average score gain difference of 1.92, which is 47% higher than the control group.

Table 2

Mean Score Distribution for Both Experimental and Control Groups

	Group	Mean	SD	Min	Max	Average Scores
Pretest	Experimental	2.609	9.91	2	17	9.91
	Control	2.109	11.05	6	18	11.05
Posttest	Experimental	2.796	13.65	6	22	13.48
	Control	2.159	12.81	8	19	12.81
Gain	Experimental	3.048	3.69	-12	11	3.68
	Control	2.189	1.76	-2	5	1.76

The significant difference between experimental and control groups was statistically analyzed with assumed unequal variances due to different sample sizes. Table 3 shows the results. Pretests results were significantly different, t (26) = 2.32, $p < 0.05$, d = 0.54 which means that control group performs better in the pretest.

Table 3

Independent t-test Comparing Experimental and Control Groups in Various Tests

Test Scores	t-value	df	p-value	Interpretation
Pretests	2.32	25.7	0.029	Significant
Posttests	1.67	26.3	0.107	Not significant
Gain	3.7	27.3	0.001	Significant

Results in the posttest revealed that scores in the experimental and control groups were not significantly different, t (26) = 1.67, p > 0.05, with a smaller magnitude of the difference (d = 0.32). However, computing the differences in their learning gains, the t-test result showed that the experimental group is significantly higher than the control group, t (27) = 3.7, p < 0.05, with larger effect size than typical (d = 0.88).

Since the pretest scores showed a statistically significant difference, ANCOVA analysis was conducted to test this difference. Levene's test and normality check were carried out, and assumptions were met, as shown in Table 4. As p > 0.05, equal variances can be assumed.

Table 4

Levenes' Test of Equality of Error Variances using Posttest as the Dependent Variable

F	df1	df2	Sig.
2.060	1	258	.152

Result of ANCOVA analysis in Table 5 showed a significant difference in the posttest [F (1,257) = 5.859, p = 0.016] between control and WBT groups.

Table 5

Analysis of Covariance Evaluating the Effect of WBT in the Posttest

Variable	df	F	Sig.
Control	1	5.859	.016
Experimental	257		

Table 6 shows the pretests and posttests percentage scores. The control group obtained a higher percentage pretest score of 38.10 % over the experimental group, with only 34.18%. However, there was reversed turn out in the posttest result with 46.88% for the experimental group compared to 44.17% in the control group. Thus, the normalized gain for the experimental group was 9.5% higher than the control group. The researchers used Hake's model in computing normalized gain (Hake, 1998), which resulted in 19.3% and 9.8 % average gain for the experimental and control group, respectively. The normalized gain was preferably used since differences in their pretests scores would not necessarily affect the average gain in this computation model.

Table 6

Normalized Gain for both Experimental and Control Groups

	Pretest(%)	Posttest(%)	Normalized Gain
Experimental	34.18	46.88	19.3%
Control	38.10	44.17	9.8%

Perception Survey

The "Students' Perceptions on WBT Implementation Survey Questionnaire" was first drafted basing on the four quadrants of the brain modeled by Herrmann (Herrmann, 2000). The survey questionnaire was categorized into four constructs according to quadrants, specifically; Quadrant A, Quadrant B, Quadrant C, and Quadrant D. The first draft was then subjected to the opinions, constructive suggestions and editing of all the research collaborators and physics teachers who are knowledgeable on the content of the study. Originally, there were 40 items in the survey, but seven items were discarded after a thorough evaluation in terms of clarity, content, and construct relating to brain quadrants. Thus, the survey questionnaire was finalized with 33 items on a 4-point Likert scale from "very true" rated as four to "not at all true" with the rating of one (1). Please see the supplementary material accompanying the article.

Cronbach's Alpha was computed based on the gathered data to assess the internal consistency of the survey questionnaire. Table 7 provides reliability statistics for all items in the respective quadrants. Two hundred forty students answered the survey, but only 234, 231, 237, and 235 valid subjects (without missing items) for quadrants A, B, C, and D, respectively. Quadrant A had the greatest number of perception questions with a total of nine items, whereas only seven items for quadrant D with the least alpha value. However, all quadrants had the Cronbach's alpha greater than 0.7, which indicates that the items in the respective quadrants formed a scale that has reasonable internal consistency reliability. Thus, all the 33 items in the questionnaire were retained, as shown in the supplementary material.

Table 7

Reliability Statistics of WBT Perception Survey Questionnaire

Quandrant	N Valid	No. of Items	Cronbach's Alpha
A	234	8	0.74
B	231	9	0.71
C	237	8	0.73
D	235	7	0.70

To assess whether students' perception affects the conceptual understanding of the students, correlation analysis between these variables was conducted. Descriptive statistics are given in Table 8.

Table 8

Descriptive Statistics for Learning Gains and Perception in the Four Quadrants(N = 240)

	N	Min.	Max.	Mean	Std. Deviation	Skewness	
	Stat	Stat	Stat	Stat	Stat	Stat	Std. Error
Quad. A	235	2	4	3.11	.436	-.382	.159
Quad. B	232	2	4	3.06	.412	-.143	.160
Quad. C	237	2	4	3.02	.431	-.224	.158
Quad. D	235	2	4	2.99	.456	-.286	.159
Gain	240	-12	11	3.68	3.048	-.125	.157

All the quadrant variables had missing cases except for learning gains with total N statistics of 240. The minimum and maximum values are within the Likert scale range of one to four. On the contrary, learning minimum gain value is -12, which means some students incurred lesser posttest compared to their pretest scores, which may contribute to a greater standard deviation. However, means and standard deviations are within reasonable values. Skewness statistic values were all less than plus or minus one (< +/- 1.0), which can be assumed that variables are approximately normally distributed.

Table 9 shows the inter-correlations of learning gains to the perceptions of students as categorized in different quadrants. Statistical analysis shows that no specific quadrant was significantly correlated to the learning gains, n = 235, r < 0.08, p > 0.05.

Table 9

Inter-correlations between Learning Gains and Student Perceptions by Quadrant (N = 235)

Quadrant		A	B	C	D	Gain
A	Pearson Correlation	1				
	Sig.(2-tailed)					
B	Pearson Correlation	0.735**	1			
	Sig.(2-tailed)	0.000				
C	Pearson Correlation	0.625**	0.657**	1		
	Sig.(2-tailed)	0.000	0.000			
D	Pearson Correlation	0.645**	0.642**	0.624**	1	
	Sig.(2-tailed)	0.000	0.000	0.000		
Gain	Pearson Correlation	0.043	-0.008	0.068	-0.002	1
	Sig.(2-tailed)	0.516	0.903	0.294	0.971	

**. *Correlation is significant at the 0.01 level (2-tailed).*

Since the correlation of variables gave only their corresponding associations, the researcher opted to use regression analysis to determine the predictive ability of brain compartments to the conceptual understanding of the students basing on their learning gains. Table 10 shows the result of multiple regression analysis.

Table 10

Simultaneous Multiple Regression Analysis for Learning Gains and Brain Quadrants (n = 235)

	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
(Constant)	2.779	1.703		1.632	0.104
Quadrant A	0.704	0.771	0.098	0.914	0.362
Quadrant B	-1.062	0.819	-0.142	-1.296	0.196
Quadrant C	1.158	0.684	0.162	1.692	0.092
Quadrant D	-0.519	0.649	-0.078	-0.801	0.424

Dependent Variable: Conceptual Understanding

Note: R2 = 0.019; F (4, 221) = 1.077, p > 0.05

Simultaneous multiple regressions result in Table 8 shows that no brain quadrants could significantly predict learning gains. A combination of variables can only predict learning gains with F (4, 221) = 1.077, p > 0.05, which means not significant. Beta gives correlation coefficients, and it has shown that values in all quadrants were minimal. The adjusted R square value was only 0.019. This means that only 1.9 % of the variance in learning gains can be explained by the assumed predictors.

The findings showed that the WBT approach in teaching with the use of researcher-made learning guides was effective in creating an impact on the students learning gains. Though the normal gain of 19.3% belongs to a “lower” category according to Hakes’ Model, the comparison of this result to other studies conducted may give significant insight. The WBT conceptual assessment outcome is considerably higher than previous studies conducted with the same assessment tool but using different teaching pedagogies. Previous studies resulted in less than 12% of learning gains (Taganahan, 2014; Sangam & Jesiek, 2012; O’Dwyer, 2012; Lakdawala, Zahorian, Gonzalez, Amit, Leathrum, 2002; Engelhardt & Beichner, 2004). Though there was one study in electric circuit context for engineering students using intentional learning pedagogy, which resulted to a normal gain of 23.6% (Bucayong, 2018), still a 19.3% learning gains in WBT is justifiable because the respondents for WBT were Senior High School (SHS) students.

Inter-correlation analysis revealed that no specific quadrant was significantly correlated to the learning gains. Simultaneous regression analysis was conducted to assess further, if there could be a somewhat predictive factor to the conceptual understanding of the student. The result showed that no specific brain quadrant was a significant predictor in understanding electric circuit lessons.

CONCLUSIONS

A holistic teaching approach by addressing four quadrants of the brain known as WBT strategy in teaching circuits was developed for this study. Learning gains in DC Circuits among students taught with the WBT approach with those taught without the WBT strategies were compared.

Results revealed that WBT is an effective pedagogy in the context of electric circuits.

Further, a survey questionnaire was developed and statistically validated for the assessment of students' perceptions of WBT per brain quadrants. Data obtained served as the basis for determining the degree of association of a specific brain quadrant teaching strategy to the learning gains. Results showed that no specific quadrant was significantly correlated to the learning gains. Further, the regression analysis supported this finding by showing that no brain quadrants could significantly predict learning gains.

Thus, teaching strategy should not necessarily be focused on the logical, emotional, sequential or integrated approach which addresses a specific brain quadrant. Rather, teaching strategy should be holistic by addressing the four quadrants of the brain. This result significantly verified the importance of WBT strategy or the holistic approach in teaching.

RECOMMENDATIONS

The study implies the significance of WBT strategy in teaching electric circuits. The result may provide awareness on the part of the teachers and curriculum designers of the pedagogy that best fits a specific context. Nevertheless, the researcher recommends that WBT strategy will also be tested in other contexts especially in the fields that assumed to require more of an analytical approach.

In addition, an investigation with regards to learning retention is also recommended. This is to check whether conceptual understanding using four quadrants of the brain promotes learning retention better than other approaches.

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Compliance with Ethical Standards:

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Ethical Approval: This article does not contain any studies with animals performed by the author. All procedures performed in studies involving human participants were following the ethical standards of the institutional research committee.

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