Effect of Brain-Based Learning on Conceptual Change in Acid, Base and Salt among Chemistry Students of Varied Cognitive Ability in Onitsha Education Zone

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ABSTRACT

The study investigated the effect of brain-based learning on conceptual change in acid, base and salt among chemistry students of varied cognitive ability in Onitsha Education Zone. Three research questions guided the study and five hypotheses were tested at 0.05 alpha level. Quasi-experimental design was used in the study, specifically, the pretest-posttest non-equivalent control group design. The study population comprised 3, 103 SS2 students offering chemistry in Onitsha Education Zone, out which 108 students were selected using random and purposive sampling techniques. The instruments used for data collection were Test of Logical Thinking (TOLT) adopted from Tobin and Capie (1981) and Chemistry Students' Conceptual Change Test (CSCCT) adopted from Zudonu (2013). Data was generated for the study by administering the instruments as pretest and posttest. Research questions were answered using mean and standard deviation while analysis of covariance was used to test the null hypotheses. The findings of the study showed that students taught acid, base and salt chemistry using brain-based learning had significantly higher mean conceptual change scores than those taught using lecture method. Also, there was a significant influence of cognitive ability level and gender on students' conceptual change. It was recommended that seminars and workshop should be organized for chemistry teachers by school administrators to acquaint them with the effective ways of integrating brain-based learning into the teaching process of chemistry.

Keywords: Brain-based, conceptual, acid, base, salt, chemistry

INTRODUCTION

The subject of chemistry has continued to pose several challenges in the process of teaching and learning that students encounter serious barriers to the proper understanding of the subject. One of the common barriers encountered by secondary school students in learning chemistry is that of misconception (Nwanze and Okoli, 2020). Misconceptions are erroneous perceptions of what is universally accepted as physical laws that have been experimentally established (Imre, 2017). They are according to Okoli (2018) beliefs, wrong assumption or understanding, and preconceived notions that are based on superficial, commonplace considerations, improper or incorrect conceptual framework which contradict accepted scientific theories. Thus, chemistry learners bring chemistry ideas into the classroom which differs from those accepted by the scientific community.

One of the common areas of misconception among secondary school chemistry students is the area of acid, base and salts (Konyefa & Nwanze, 2020). Some of the misconceptions that students have in chemistry especially in acid, bases and salts include among others; that all acids are strong, is any substance that contain 'H' is an acid and those containing the functional group 'OH' are bases. Students' misconceptions also include the fact that: when a proton donor acid reacts, the nucleus of an atom loses proton and that strength of an acid means the same thing as the concentration of the acid. Students also hold the misconception that a neutral solution always has a pH equal to 0 and that neutralizations reactions produce neutral solutions (Nelson, 2017). To some students, a concentrated acid is a pure substance and concentrated acids are more hazardous than concentrated bases and salts.

Some of the misconceptions that students hold in chemistry arise mainly from cultural practices, beliefs and understandings, intuitive thoughts, peer discussion, pedagogical impediments, textbooks, the media, ignorance of new scientific findings and teachers' conception (Cahyanto et al., 2019). Therefore, for meaningful learning to occur and for students to have proper understanding of chemistry in a manner sufficient to remedy their misconception, chemistry teachers must make effort to ensure that conceptual change occur during teaching and learning processes. Conceptual change according to Heddy et al. (2018) involves the alteration of existing concepts or the complete change of previous cognitive structures over a phenomenon. Conception change occurs when a student moves from misconception to a scientifically accepted conception. Some many instructional strategies such as the use of problem-solving method, demonstration method, metacognitive instructional strategy, brain-based learning and guided inquiry can be employed by the teacher to bring about conceptual change. Although, these methods especially brain-based learning that is not often employed by chemistry teachers have been shown in literature to be effective for teaching chemistry, there is no in-depth understanding as to their effectiveness in remedying students' misconception to bring about conceptual changes in acid, base and salt. The need arises for a study to be conducted to investigate the effectiveness of brain-based learning in leading students to a change of their previous erroneous conceptions in acid, base and salt chemistry.

Brain-based learning involves teachers creating conditions that increase student motivation, engagement and long-term retention by tapping into the natural ways the brain receives processes and stores information (Okatahi et al., 2020). It refers to teaching strategies, lesson designs, and school programs that are based on the latest scientific research about how the brain learns, including such factors as cognitive development, how students learn differently as they age, grow, and mature socially, emotionally, and cognitively. The overall goal of brain-based education is to attempt to bring insights from brain research into the arena of education to enhance teaching and learning. In the present study, the principles of brain-based learning (BBL) developed by Caine and Caine (2001) was used. Caine and Caine (2001) synthesized educational and scientific research to establish a brain-based theory of learning with 12 basic principles that apply to learning of varied subjects including chemistry.

The 12 principles suggests that teachers of chemistry should take cognizance of each students' brain uniqueness, understand that emotions are critical to learning especially to drive attention, meaning and memory, and that information is stored and retrieved through multiple memory and neural pathways that are continually being formed. The principles further noted that all learning is a mind-body process and that the brain is a complex and adaptive system. It suggests also that meaning is more important to the brain than information with learning being often rich and non-conscious, and that the brain develops better in concert with other brains. Caine and Caine (2001) further asserted that the brain develops with various stages of readiness and can grow new connections at any age as well as that cognitive skills develop better with music and motor skills. The principles were subsumed into three conditions of learning used in the present study which are relaxed alertness, orchestrated immersion and active processing.

Brain-based learning is known to improve engagement and motivation, memory and recall, and enhances the students' problem-solving skills. It also increases creativity and innovation while improving overall academic achievement of students in varied subject areas. . The findings of Funa et al. (2024) showed that the uses of BBL principles and strategies have a significant large and positive effect on students' conceptual

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understanding. Amjad et al. (2022) reported that BBL significantly improved students' academic performance in mathematics. Despite the potential benefits of BBL, the effectiveness may vary for chemistry students depending on their cognitive ability levels.

Cognitive abilities are skills your brain uses to complete essential day-to-day tasks like thinking, learning, reading, remembering, speaking and walking. It is a general mental capability involving reasoning, problem solving, planning, abstract thinking, complex idea comprehension, and learning from experience. Students' ability may vary within the classroom, appearing either as high, middle/average and low and is known to be affected by a lot of factors among which is gender. Literature shows that male students outperform females in tests of visual-spatial ability, and mathematical reasoning, whereas females do better in memory and language. There is often a greater female ability in episodic memory involving verbal or both verbal and visual-spatial tasks while a higher male ability that only involves complex visual-spatial episodic memory. Owing to these gender differences, Ani et al. (2021) noted that gender has no significant influence on students' academic achievement in basic science. Oladejo et al. (2021) on the other hand reported that the use of computer simulation significantly bridged the gap between male and female students performance in chemistry. It is therefore pertinent to investigate the influence of gender and cognitive ability on students' conceptual change in acid, base and salt chemistry be also examined.

Purpose of the Study

The purpose of the study was to investigate the effect of brain-based learning on conceptual change in acid, base and salt among chemistry students of varied cognitive ability in Onitsha Education Zone. Specifically, the study sought to determine:

1. the difference in the mean conceptual change scores of taught chemistry(acid, base and salt) using brain-based learning and those taught using lecture method.
2. the difference in the mean conceptual change scores of low, middle and high ability students taught chemistry (acid, base and salt) using brain-based learning and those taught using lecture method.
3. the difference in the mean conceptual change scores of male and female students taught chemistry (acid, base and salt) using brain-based learning and those taught using lecture method.
4. Interaction effect of instructional strategies and cognitive ability level on students' conceptual change score in chemistry.

Research Questions

1. What is the difference in the mean conceptual change scores of students taught chemistry (acid, base and salt) using brain-based learning and those taught using lecture method?
2. What is the difference in the mean conceptual change scores of low, middle and high ability students taught chemistry (acid, base and salt) using brain-based learning and those taught using lecture method?
3. What is the difference in the mean conceptual change scores of male and female students taught chemistry (acid, base and salt) using brain-based learning and those taught using lecture method?

Hypotheses

1. There is no significant difference in the mean conceptual change scores of students taught chemistry (acid, base and salt) using brain-based learning and those taught using lecture method.
2. There is no significant difference in the mean conceptual change scores of low, middle and high

bility students taught chemistry (acid, base and salt) using brain-based learning and those taught using lecture method.

3. There is no significant difference in the mean conceptual change scores of male and female ability students taught chemistry (acid, base and salt) using brain-based learning and those taught using lecture method.
4. There is no significant interaction effect of instructional strategies and cognitive ability level on students' conceptual change score in chemistry.
5. There is no significant interaction effect of instructional strategies and gender on students' conceptual change score in chemistry.

METHOD

The study adopted the quasi-experimental design, specifically, the pre-test post-test no-equivalent control group design with a 2 by 3 factorial background. The area of the study was Onitsha Education Zone of Anambra State, Nigeria. The population of the study was 3,103 Senior School One (SS1) students offering chemistry in Onitsha Education Zone of Anambra State. The sample size for the study was 108 SS1 students obtained using a multi-stage sampling procedure. Two local government areas out of the three local government areas in Onitsha Education zone was drawn using random sampling technique. Two coeducational public senior secondary schools were each selected from each local government area using purposive sampling technique to ensure that only schools with functional laboratory were involved in the study. In each school, the chemistry students in SS2 were involved in the study. The experimental group school had 53 students (27 males, 26 females) while the control group school had 55 students (24 males and 31 females).

The instruments for data collection were Test of Logical Thinking (TOLT) and Chemistry Students' Conceptual Change Test (CSCCT). Test of Logical Thinking (TOLT) adopted from Tobin and Capie (1981) was designed to measure students' cognitive ability levels. TOLT consists of eight two-tier multiple-choice items and two items where students are required to complete a list of reasoning abilities namely: proportional reasoning, probabilistic reasoning, controlling variables, correlational reasoning, and combinatorial reasoning. The students answer to the questions by selecting a response from five possibilities and from five justifications provided. The correct answer was the correct choice plus the correct justification. The reliability of TOLT as determined by Tobin and Capie (1981) using Cronbach's alpha was 0.81. The scoring involved giving each item of the TOLT a numeric value of 1 if both response and reason were correct, and 0 if incorrect, except for the last two items that required students to list combinations. In these two items, the score ranged from 0 to 1 depending on the number of combinations listed by the student. The total score for the test is ten (10). The criteria for determining the students' cognitive ability level in the test was that scores (4-10) indicated high ability, (2-3) average ability while (0-1) indicated low ability. in any of the areas of the reasoning abilities.

Chemistry Students' Conceptual Change Test (CSCCT) adopted from Zudonu (2013) measured the conceptual change of students freshly enrolled into the senior secondary school one-level of education, in practical chemistry (acid, base and salt). CSCCT comprised a twenty item test designed to identify students' misconception in practical chemistry. The items in CSCCT included one common misconception and four reasonable and plausible distracters. CSCCT was designed by examining literatures to determine the students' conception of practical chemistry areas of acid, base and salt, with reference to the curriculum objectives. Each item was scored 5 marks giving a total of 100marks for all correctly answered questions. The validity of the instrument was established by two science teacher educators from the Department of Science Education, University of Nigeria, Nsukka for the correctness of content, representation of the practical chemistry concepts used and its appropriateness. The reliability of the instrument was established using Cronbach's Alpha which yielded a coefficient of internal consistency of 0.65.

The treatment was conducted in two phases. First, the research assistants who were the regular chemistry teachers in the schools involved in the study were briefed on the objectives of the study, how to administer the instrument and how to collate the data. The second phase was the treatment using brain-based learning for the experimental group and lecture method for the control group. The experimental and control group was first administered with the CSCCT to determine some of the misconceptions students held and also as a pretest. The students' performance were analysed to identify the misconceptions that students held, and together with those identified in literature, a lesson plan was developed by the research. The experimental group lesson plan covered practical chemistry (acid, base and salt) and was designed using brain-based learning. The control group also had the same content but the lesson was structured using the lecture method of teaching.

The lesson plan for treatment group was design following the principles of brain-based learning (BBL) developed by Caine and Caine (2001) together with the three conditions of learning (relaxed alertness, orchestrated immersion and active processing). Following the principle, the teacher used an electronically projected chart to inform the students about the objectives of the instruction. Thereafter, other projections of the neutralization reactions of different acids and bases and their end products which are salts were made using simulated videos. To ensure that the students are relaxed, the teacher gave the students 3 minutes break to go and ease themselves and drink water to ensure that their brains are relaxed. On their return, the teacher followed the identified misconceptions, elaborated on the meaning of acids, bases and salts, showed pictorial and video example of acids, bases and salts. Video projections were used to show the physical and chemical properties of acids, bases and salts and their methods of syntheses. Students were thereafter motivated to reflect on what they have learnt and ask questions. Having addressed the questions from the students, the teacher employed the metacognitive strategy where probing questions were asked students to uncover any remaining misconceptions. As misconceptions were uncovered, more cognitive conflicts were created by the teachers by asking questions that followed-up on the misconceptions discovered until students were able to integrate previous knowledge with the new knowledge until meaningful learning occurred. To further probe into the level of conceptual change that has occurred , the teacher asked the students to infer and state the uses of acids, bases and salt during each week's lesson respectively. The teachers ensured that the learning environment and classroom condition was the sort that each student had the freedom to express themselves and did not allow any particular student to dominate the class. Students who answered the questions correctly were given accolades to serve as incentive to energize their brains when solving and answering other questions and to boost their self-esteem. A simple experiment on acid, base and salt with the correspondent calculations were made during each lesson.

The teacher at the end of each lesson grouped the students according to either birth months, first alphabets of their names, number of siblings or age. This was done each week and was intended to facilitate peer interaction over what was learned with guiding questions for the students to solve, followed with deep thinking. The interactions involved some role play and group presentations as well as group projects. The guiding questions were mostly experimental in nature and students were allowed to express their fears, confusions and ideas as regards what was taught. The curiosity arising from the questions was used by the teacher to further develop the students' existing cognitive structures and remedy any further misconceptions that remained. Students were further encouraged to perform individual tasks and the questions asked were used to identify any knowledge or cognitive deficiencies for which the teacher differentiated the instructions to meet the objectives of the lesson. The same content was taught to the control group using lecture method, and no projections or grouping were made. The students were also not given any projects. At the end of the lesson, students were given post-test and their score were used for data analysis.

The analysis of data was done using mean, standard deviation, and analysis of covariance. The hypotheses were tested at 0.05 level of significance. The decision rule was that where the P-value was equal to or less than 0.05, the null hypothesis was rejected and where the P-value was greater than 0.05, the null hypotheses was not rejected.

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RESULTS

Research Question 1: What is the difference in the mean conceptual change scores of students taught chemistry (acid, base and salt) using brain-based learning and those taught using lecture method?

Table 1: Mean Conceptual Change Scores of Students taught Acid Base and Salt Chemistry using Brain-Based Learning and Lecture Method

Method	N	Pretest Mean	Pretest SD	Posttest Mean	Posttest SD	Gained Mean
BBL	53	21.49	4.70	80.00	9.10	58.51
LM	55	25.51	7.31	67.55	3.05	42.04

Table 1 showed that students taught acid, base and salt chemistry using BBL had mean conceptual change score (58.51) than those taught using lecture method (42.04).

Hypotheses 1: There is no significant difference in the mean conceptual change scores of students taught chemistry (acid, base and salt) using brain-based learning and those taught using lecture method.

Table 2: ANCOVA on Difference in the Mean Conceptual Change Scores of Students taught Acid, Bases and Salt Chemistry using BBL and Lecture Method

Source of variation	**SS**	**Df**	**MS**	**F**	**P-value**	**Decision**
Corrected Model	6933.351[a]	12	577.779	26.633	.000	
Intercept	23153.500	1	23153.500	1067.254	.000	
Pretest	101.765	1	101.765	4.691	.033	
Method	3876.512	1	3876.512	178.687	.000	Sig.
Ability	212.257	2	106.129	4.892	.010	Sig.
Gender	855.430	1	855.430	39.431	.000	Sig.
Method * Ability	158.834	2	79.417	3.661	.029	Sig.
Method * Gender	574.749	1	574.749	26.493	.000	Sig.
Ability * Gender	189.602	2	94.801	4.370	.015	Sig.
Method * Ability * Gender	148.301	2	74.151	3.418	.037	Sig.
Error	2060.973	95	21.694			
Total	594939.000	108				
Corrected Total	8994.324	107				

Table 2 shows that there was a significant main effect of the treatment on students' conceptual change in acid, base and salt chemistry; $F(1, 95) = 178.687$, $P < .05$. Therefore, the null hypothesis is rejected meaning that, there is a significant difference in the mean conceptual change scores of students taught chemistry (acid, base and salt) using brain-based learning and those taught using lecture method in favour of BBL.

Research Question 2: What is the difference in the mean conceptual change scores of low, middle and high ability students taught chemistry (acid, base and salt) using brain-based learning and those taught using lecture method?

Table 3: Mean Conceptual Change Scores of High, Middle and Low Cognitive Ability Students taught Acid Base and Salt Chemistry

Method	Cognitive Ability	N	Pretest Mean	Pretest SD	Posttest Mean	Posttest SD	Gained Mean
BBL	High	14	22.43	4.54	83.00	7.25	60.57
	Middle	25	19.88	3.11	80.36	11.20	60.48
	Low	14	23.43	6.31	76.36	4.75	52.93
LM	High	13	23.23	8.02	67.00	1.42	43.77
	Middle	20	26.30	7.36	68.10	3.81	41.80
	Low	22	26.14	6.89	67.36	3.03	41.22

Table 3 shows that high cognitive ability students taught acid, base and salt chemistry using BBL had the highest mean conceptual change score (60.57) while those with low cognitive ability level had the least conceptual change score (52.93). Again, high cognitive ability students taught acid, base and salt chemistry using lecture method had the highest mean conceptual change score (43.77) while those with low cognitive ability level had the least conceptual change score (41.22).

Hypotheses 2: There is no significant difference in the mean conceptual change scores of low, middle and high ability students taught chemistry (acid, base and salt) using brain-based learning and those taught using lecture method.

Table 2 above shows that there was a significant influence of students' cognitive ability level on mean conceptual change score in acid, base and salt chemistry; $F(2, 95) = 4.892$, $P < .05$. Therefore, the null hypothesis is rejected meaning that, there is a significant difference in the mean conceptual change scores of low, middle and high ability students taught chemistry (acid, base and salt) using brain-based learning and those taught using lecture method.

Table 4: Scheffe Post Hoc Analysis

(I) Cognitive Ability Level	(J) Cognitive Ability Level	Mean Difference (I-J)	Std. Error	Sig.[a]
High	Middle	0.793	1.621	0.63
	Low	3.314	1.722	0.06
Middle	High	-0.793	1.621	0.63
	Low	2.521	1.521	0.1
Low	High	-3.314	1.722	0.06
	Middle	-2.521	1.521	0.1

Table 4 shows that high cognitive ability students had higher mean conceptual change score than students with low cognitive ability students.

Hypotheses 3: There is no significant interaction effect of instructional strategies and cognitive ability level on students' conceptual change score in chemistry.

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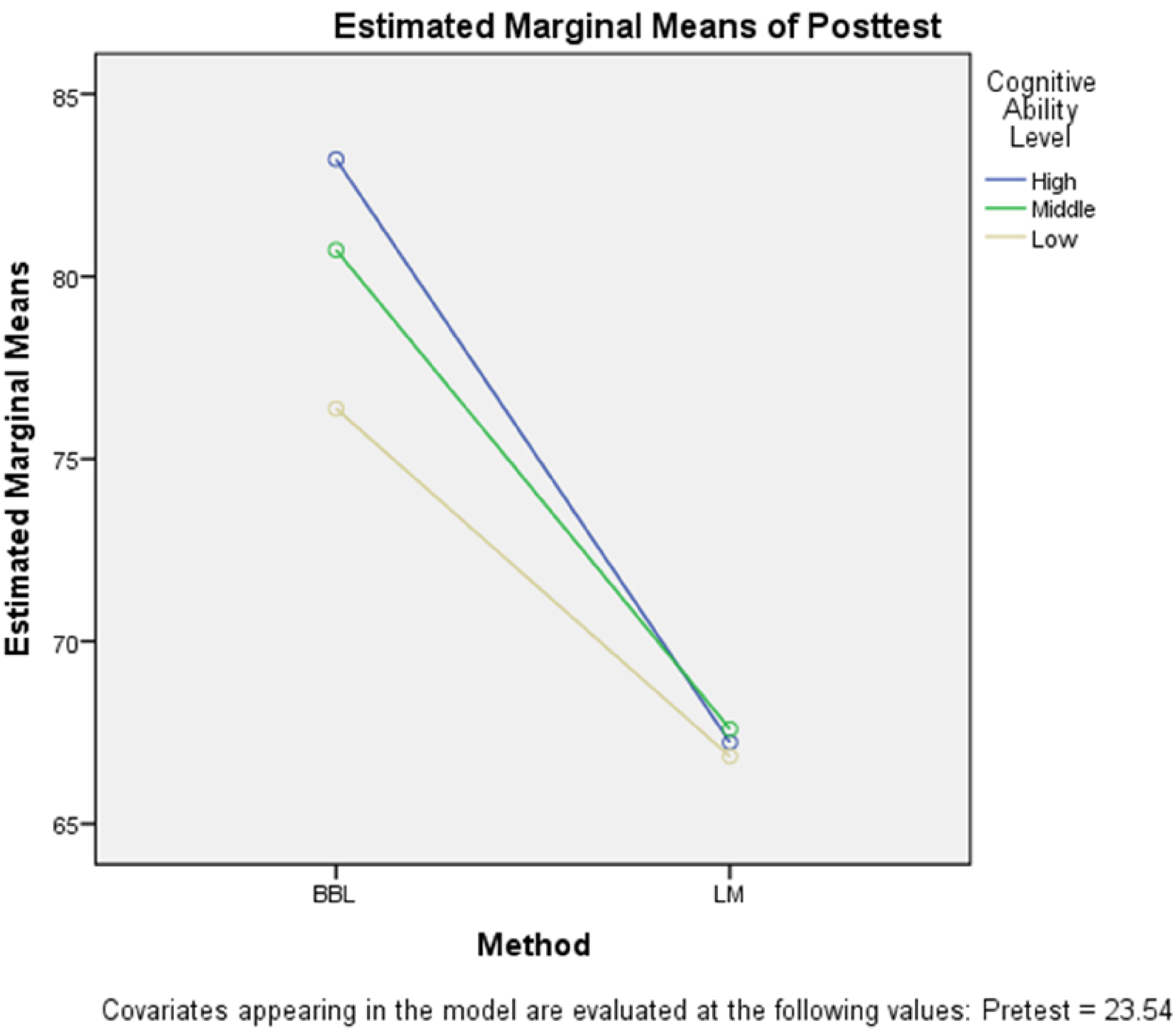

Figure 1: Plot of Interaction Effect of Instructional Strategies and Cognitive Ability Level on Students' Conceptual Change in Chemistry (Acid, Base, Salt)

The plot of interaction effect of instructional strategies and cognitive ability level is significant and disordinal. Thus, the instructional strategies are cognitive ability sensitive.

Research Question 3: What is the difference in the mean conceptual change scores of male and female students taught chemistry (acid, base and salt) using brain-based learning and those taught using lecture method?

Table 5: Mean Conceptual Change Scores of Male and Female Students taught Acid Base and Salt Chemistry

Method	Gender	N	Pretest Mean	Pretest SD	Posttest Mean	Posttest SD	Gained Mean
BBL	Male	27	20.59	4.08	86.00	7.94	64.41
	Female	26	22.42	5.18	73.77	5.23	51.35
LM	Male	24	21.37	5.49	80.00	9.10	58.63
	Female	31	28.71	6.99	67.42	1.53	38.71

Table 5 shows that male students taught acid, base and salt chemistry using BBL had the higher mean

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conceptual change score (64.41) the female students (51.35). Also, male students taught acid, base and salt chemistry using lecture method had the higher mean conceptual change score (58.63) the female students (38.71).

Hypotheses 4: There is no significant difference in the mean conceptual change scores of male and female ability students taught chemistry (acid, base and salt) using brain-based learning and those taught using lecture method.

Table 2 above shows that there was a significant influence of students' gender on mean conceptual change score in acid, base and salt chemistry; $F (1, 95) = 39.431$, $P < .05$. Therefore, the null hypothesis is rejected meaning that, there is a significant difference in the mean conceptual change scores of male and female ability students taught chemistry (acid, base and salt) using brain-based learning and those taught using lecture method in favour of the males.

Hypotheses 5: There is no significant interaction effect of instructional strategies and gender on students' conceptual change score in chemistry.

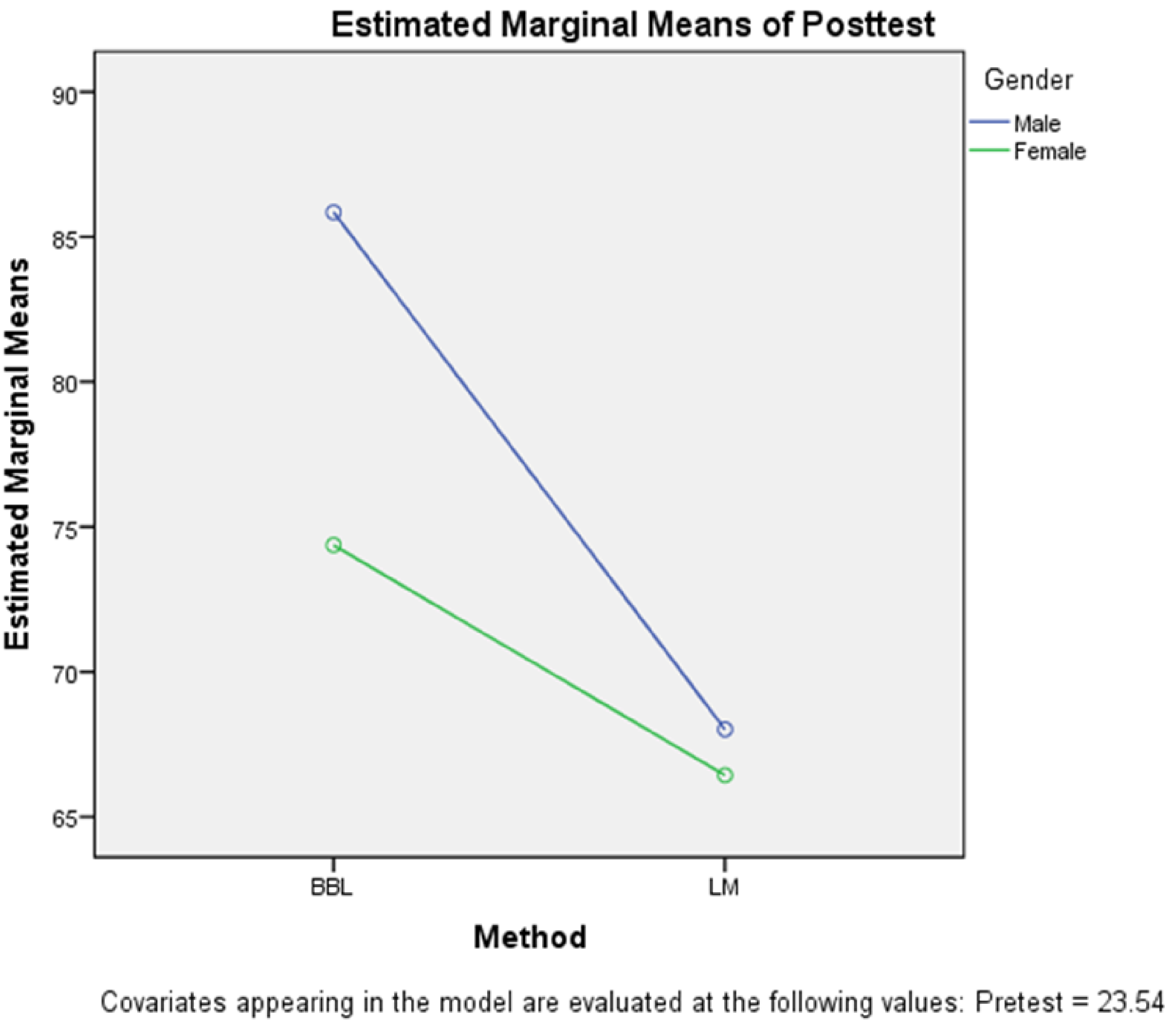

Figure 2: Plot of Interaction Effect of Instructional Strategies and gender on Students' Conceptual Change in Chemistry (Acid, Base, Salt)

The plot of interaction effect of instructional strategies and gender is significant and ordinal. Thus, the instructional strategies are gender-biased, meaning that male students are favoured by the two instructional strategies employed in the study than female students.

DISCUSSION

The findings of the study revealed that BBL significantly improved students' conceptual change in acid, bases and salt chemistry. The observed finding can be hinged on the fact that the strategy of BBL develops neuroplasticity (the brain's ability to change and grow) through repetition and practice. As a result, the brain creates and reinforces neural pathways to learn new habits and skills, which motivates children to learn more. Brain-based learning helps students build their memories and retention. The peer-teaching principle, in particular, leads to increased memorization and understanding of information. It also enabled students to have greater interaction with the learning materials leading to proper conceptualization to remedied any misconceptions held. BBL enabled the students to reach meaningful learning by integrating the new knowledge with existing cognitive structure and using previous knowledge to facilitate the deeper understanding of the concepts of acid, base and salts. The resultant effect was a conceptual change by which students understanding is enhanced and performance improved. The findings of the study lend credence to the findings of Funa, Ricafort, Jetomo and Lasala (2024) that the uses of BBL principles and strategies have a significant large and positive effect on students' conceptual understanding. The findings of the study also support the findings of Amjad, Habib and Saeed (2022) that BBL significantly improved students' academic performance in mathematics.

The findings of the study also showed that ability level and gender significantly influenced secondary school students' conceptual change in acid, base, salt chemistry with high ability students and male students respectively favoured. The findings of the study can be explained from the fact that high ability students are able to encode key information more quickly and accurately in memory, thus, enabling the brain to output more and more effectively. High ability students are also able to process information more logically and such thinking conversion is known to significantly improve academic achievement. The higher conceptual change in chemistry observed among males could be due to the gender-stereotype inherent in science learning where male students pay more attention to science subjects than female students. The findings of the study support the findings of Shi and Qu (2022) that cognitive ability can significantly and positively affect academic achievement. The finding of the study contravene the findings of Ani et al. (2021) that gender had no significant influence on students' academic achievement in basic science. The findings of the study is at contrast with the findings of Oladejo et al. (2021) that the use of computer simulation significantly bridge gap between male and female students performance in chemistry.

CONCLUSION

It can be concluded from the findings of the study that brain-based learning positively improves students conceptual understating of chemistry (acid, base and salt) and heightens their ability to remedy misconceptions relating to chemistry learning. The study also establishes that brain-based learning is an effective strategy for enhancing the conceptual understanding of male high and middle ability students in chemistry.

RECOMMENDATIONS

The following recommendations are made based on the findings of the study.

1. Seminars and workshop should be organized for chemistry teachers by school administrators to acquaint them with the effective ways of integrating brain-based learning into the teaching process of chemistry.

2. School counsellors should design cognitive-based chemistry activities together with chemistry teachers to aid the enhancement of students' cognitive ability level.

3. Chemistry teachers should make effort to ensure that the classroom activities are not gender-stereotyped. This they can achievement by giving female chemistry students a equal attention towards their learning just as they give to the male students.

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