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The Effect of a Brain-Based Teaching Method on Conceptual Change in Students' Understanding of Electricity

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Abstract
The purpose of this study was to investigate the extent to which a Brain-Based Teaching Method could correct misconceptions and change eighth grade Jordanian students' understanding of concepts of electricity. The randomly selected sample (N=357) included students from the Bani Kenanah Directorate of Education in Jordan. A brain-based teaching method was used to instruct 183 students (98 male and 85 female), while conventional teaching method was used to instruct 174 students (82 male and 92 female). Two instruments were developed: a multiple-choice test of the misconceptions of electricity commonly held by eighth grade students and an inventory that classified participants based on students' levels of learning process. Data analyses used the SPSS software package to perform a 2-way ANCOVA and post hoc tests with the split file technique at an α level of 0.05. The results indicated that the brain-based teaching method surpassed conventional method in correcting misconceptions and changing students' concepts of electricity. However, the results also demonstrated that meaningful learners outperformed in-between and rote learners with regard to conceptual change and that rote learners exhibited the poorest performance. Study results, which were consistent with earlier findings, suggest that curriculum developers should take characteristics of brain learning into account in developing curricula and textbooks and those instructors should consider brain characteristics when planning science lessons.

Keywords: Conceptual change, Brain-based teaching method, Students' levels of learning process, Misconceptions regarding electricity

Introduction

Instruction is the art of developing the brain (Connel, 2005); hence, instructors should learn how the brain functions and processes data to improve their teaching and enhance student performance. A number of studies have proposed that the results of brain research be incorporated into the instructional process (Kaufman et al., 2008; Bawaneh, Zain & Salmiza, 2010a). Wasserman (2007) has argued that everything one hears, sees, thinks of, or touches is transmitted to the brain as electrical signals and that processing and storing these pulses stimulates the brain and increases the brain's cognitive capabilities.

To augment the brain's ability to process data and to stimulate knowledge acquisition at the individual level, educators should use the findings of brain research to provide optimal school environments. The connection between how the brain processes data and the learning process is well documented. Evans (2007) has argued that brain development and growth is

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dependent on an individual’s experiences. Jensen (2008) has highlighted instruction that accommodates how the brain learns and has described brain-based instruction based on the three concepts of engagement, strategies, and principles. This research encourages educators to consider brain functionality and information processing that maximizes student learning when designing instruction.

However, instructors must also be aware that levels of cognitive development vary by age and grade level. Sprenger (2007) has argued that middle school students (sixth through eighth grade), who are coping with higher hormone levels, tend to focus on the search for self-identity and forging social relationships. During this critical stage, early adolescents experience many gender-based biological and psychological changes that continue through the secondary school level. For example, Sousa (2006) found that females’ memory in early adolescence was strongly systematic due to estrogen levels, whereas males developed a larger larynx due to increased levels of testosterone, which could cause emotional reactions due to voice changes. During early adolescence, student learning may be adversely affected by these hormonal changes and is characterized by hyperactivity, curiosity, questioning, etc. Tate (2007) has argued that for effective learning to take place during early adolescence, students should be exposed to a variety of activities such as projects, simulations, technology, and cooperative learning as well as increased use of school labs that encourage experimentation.

In the context of brain-based learning, meaningful learning cannot be overlooked. Kaufman et al. (2008) have argued that to facilitate meaningful learning, the classroom environment should be student-centered so that the teacher plays a supportive role and the student is the focus of the instructional process.

Ausubel (2000) has argued that individuals decide whether learning is meaningful based on their internalized cognitive and conceptual constructs and that an individual's prior knowledge is the most significant psychological principle that influences teaching and learning-teaching process. Because inaccurate schemas would be constructed if inaccurate knowledge were acquired, Ausubel (2000) has proposed that meaningful learning is based on the containment principle in which new knowledge is integrated horizontally and vertically with an individual's previous knowledge and advised teachers to explore and use of learners’ prior knowledge as the basis of their teaching. Many studies (Bawaneh, Zain & Salmiza, 2010b; She, 2005; Novak, 1991) have found that meaningful learning is more effective and longer lasting than rote learning due to the associations created during the learning process.

Based on the these views as well as the results of prior studies that have compared brain-based teaching methods with conventional teaching methods, the present study investigated the effects of a teaching method grounded in the Herrmann Whole Brain Model -HWBM- on conceptual change in eighth grade students in Jordan (Herrmann, 1988).

Rote learning approaches that are exam oriented and target easier topics, memorization, copying notes, teacher-centered instructional strategies, and inflexible instructions have been identified as factors that make it difficult to induce conceptual change and interest in science in students (Syed Zin & Lewin 1993; Ngah Razali et al. 1996; Sidin 2003; Syed Zin 2003). Because the learning environment is more complex, the educational process currently demands more from students than it did in the past. To ensure that the learning process is effective, the latest neuroscience findings form the basis of the Inclusive Approach (Caine & Caine 1991; Jensen 1996; Caine et al. 2005), which is a more appropriate teaching methodology, and have contributed to the development of the Brain-Based Teaching Method –BBTM-.

The Herrmann Whole Brain Model (HWBM)

One of the most significant models that have attempted to explain the brain’s structure, mechanisms, and learning processes is the HWBM (Herrmann, 1988). Adopting McClean and

Sperry's theories, Herrmann (1988) proposed that the learning characteristics of the upper and lower brain differ and that the brain is further subdivided into right and left hemispheres. 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 (Figure 1).

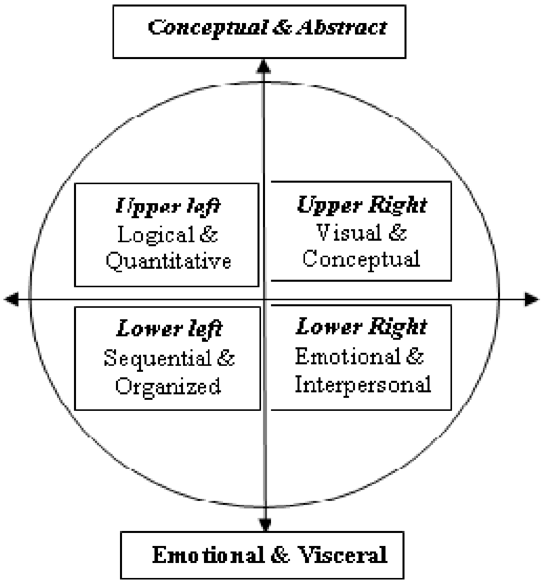

Figure 1. The Herrmann Whole Brain Model

Many studies (Bawaneh, Zain & Salmiza, 2010a; She, 2005; She, 2003) have described the four brain quadrants in light of the HWBM and have proposed teaching methods adapted to each quadrant (Herrmann, 1988). For example, the upper left quadrant, which is logical and rational, depends on facts, quantitative and mathematical analyses, and realistic thinking. In contrast, the lower left quadrant focuses on sequentially organized details, plans, specific scheduled procedures and risk avoidance. For Herrmann, the lower right brain quadrant is emotional, intuitive, kinesthetic, sensational, and enjoys reading and writing. It differs from the lower left quadrant with regard to risk taking. Finally, the upper right quadrant, which exhibits a more comprehensive and integrated approach to thinking, prefers learning through pictures and drawings. This part of brain tends to be imaginative and innovative, often spontaneously intuiting facts and completing assignments.

The Brain-Based Teaching Method (BBTM)

Herrmann's Whole Brain Model describes the brain as consisting of two major hemispheres and two limbic halves that are closely associated and linked together to function systematically, with each component performing complementary mental tasks. In addition, the HWBM is systematic and inclusive because it focuses on how learners develop skills. The teaching method proposed in the present study is compatible with the brain characteristics identified by the model and devotes one quarter of class time to each of the four brain quadrants (Bawaneh, Zain & Salmiza, 2010a). To identify students' preferred learning method and to promote student interest, lessons are designed by questioning students about lesson topics without providing answers. The instructor directs the students to work on activities or experiments either individually or cooperatively with their peers. This period focuses on acquiring skills, such as planning, organizing, arranging, identifying presentation methods, collecting data, installing devices, taking notes, drawing associations between variables and reporting results. Further, the teacher asks leading questions and encourages students to discuss their contributions to provoke excitement, interest and curiosity so that learning from practical activities occurs in an integrated and inclusive manner. Next, the teacher uses basic ideas written on the board to guide effective student-student and student-teacher discussions. Students are instructed to find solutions to problems in the classroom either individually or in groups. Additionally, the students are assigned homework. In light of the previously discussed research, the proposed teaching method accommodates brain characteristics described in the Herrmann Model in ways that traditional teaching cannot (Bawaneh, Zain & Salmiza, 2011).

Meaningful and Rote Learning

In meaningful learning, the individual is able to apply learning to new situations. In contrast, in rote learning, which occurs when isolated facts are impressed into cognitive construct memory, these facts can be retrieved from memory but cannot be applied to solve novel problems (Okebakola, 1990).

Ausubel (1978) has argued that the constructs forming an individual's conceptual framework are the primary factor that determines whether the material to be learned is acquired or retained. As a result, the relations between the conceptual constructs students already have acquired and new facts should be clarified and established. Thus, Ausubel states "should I summarize educational psychology in one principle it should be: the significant factor influencing learning is individual's preconceptions, so check it and teach accordingly". However, meaningful learning is best described as a "process by which new facts are linked with cognitions already held by individual i.e. one's conceptual construct". In comparison to rote learning, meaningful learning is more effective and long-lasting because of the links, connections, and integration that occur during the learning process (Novak & Gowin, 1984; Novak, 1991; She, 2005). The facts acquired in this way are stored in long-term memory and are incorporated into previous knowledge (Novak, 1991).

In contrast, many research studies (Van Rossum & Schenk, 1984; Watkins, 1983) have demonstrated that students with shallow knowledge may nevertheless exhibit excellent learning outcomes. Similarly, Watkins, Reghi & Astilla (1991) have emphasized that students who acquire a profound understanding of textbook content tend to associate new knowledge with their previous knowledge structure and succeed academically.

Statement of the Problem

Many international studies, such as the 1999 Trends in International Mathematics and Science Study -TIMSS-R- (Martin et al., 2000), the 2003 TIMSS (Martin et al., 2004), the 2007 TIMSS (Martin et al., 2008), and the 2006 Program for International Student Assessment –PISA- (OECD, 2009), have reported poorer performance of Jordanian students compared with those from other countries. The 2003 TIMSS (Martin et al., 2004) found that Jordanian students did not demonstrate adequate understanding of scientific concepts and did not exhibit satisfactory applied skills. They lacked accurate understanding of physical science concepts, such as electricity, thermal connectivity, and material construction. They were often unable to communicate scientific explanations, and they also were also unable to provide scientific explanations of the causes of different phenomena. Many domestic studies (Bawaneh, Zain & Salmiza, 2010b; Bawaneh, Zain & Ghalazi, 2010; Baz & Bawaneh, 2008; Mulhall & Gunstone, 2008; Jabber, 2004; Ashab, 2001) have confirmed these international findings and have documented that the educational system in Jordan has failed to achieve the desired levels of student performance and that the Jordanian educational system needs to focus on classroom and school-wide environments. The present study investigated the extent to which conceptual change in eighth grade students in Jordan was influenced by a student-centered, brain-based teaching method that reflected the way the brain processes information. In addition to involving learners in classroom-based activities, experiments, and problem solving, the proposed method also promoted cooperative learning with the teacher assuming the role of facilitator and guide.

Study Objectives

This study investigated the effect of the proposed BBTM on conceptual change (CC) among eighth grade students compared to conventional teaching methods (CTM). The study examined the effects BBTM, students' level of learning process, and of gender on CC in the students' knowledge of electricity by comparing their pre- and posttest scores following exposure to the BBTM.

Significance of the Study

The primary purpose of the present study was to investigate the effects of the proposed BBTM on CC in eighth grade students' knowledge of electricity. Understanding of this multifaceted issue would promote CC in students and the acquisition of accurate scientific concepts, which is a basic goal of science education (Rutherford, 1990; Lewis & Linn, 2003). Instructors would be able to use the BBTM to identify and correct their students' misconceptions. Curriculum developers could also take brain-based instruction methods into account when designing curricula, texts, and teacher manuals to improve the teaching and learning process in different grades. The present study sought to answer two specific questions:

- Are there any significant main effects of teaching methods and students' levels of learning process or an interaction effect of teaching methods and students' levels of learning process on the posttest scores of students' CC in electricity when the effects of the pretest results of students' CC in electricity are controlled?
- Are there any significant main effects of teaching methods and students' gender or an interaction effect of teaching methods and students' gender on the posttest scores of students' CC in electricity when the effects of the pretest results of students' CC in electricity are controlled?

Operational Definitions

Conceptual Change (CC): A process through which the learner abandons misconceptions and adopts scientifically accurate concepts. In this study, conceptual change was operationalized as the difference between pretest and posttest scores on a measure of students' conceptual understanding.

Students' level of learning process: The types of cognitive skills students employ during learning measured by the Inventory of Learning Process Scale (She, 2005), which is based on Bloom's (1956) cognitive taxonomy. She's (2005) cutoff points were used to classify students' level of learning process.

Methodology

Population and Sample

The study population consisted of students of both genders enrolled in the eighth grade in the Bani Kenanah Directorate of Education during the second semester of the 2009-2010 academic year. Seven randomly chosen schools from this Directorate provided the sample of 357 eighth grade students. The BBTM was used to instruct 183 eighth grade students (male = 98, female = 85), and 174 eighth grade students (male = 82, female = 92) were taught using

CTM. Students were taught in their usual classrooms. Teachers with similar levels of education and teaching experience at the eighth grade level were selected. Teachers were trained in the use of the BBTM over two one-hour sessions. Then, teachers from the randomly selected schools served as the experimental group.

Study Design

The quasi-experimental factorial design included the experimental group, which was taught using the proposed BBTM, and the control group, which was taught using CTM. Both groups participated in the pre- test and posttests.

Variables: The study addressed the following variables:

Independent variables:

Two types of teaching methods:

- Brain-Based Teaching Method (BBTM)
- Conventional Teaching Method (CTM)

Students' levels of learning process:

- Meaningful learners
- In-between learners
- Rote learners

Students' gender:

- Male
- Female

Dependent variable:

Conceptual Change (CC) in concepts of electricity in eighth grade students.

Instruments

Conceptual Test (CT): Prior to developing the CT, the researcher conducted face-to-face interviews with a randomly selected sample of 58 students (male = 31, female = 27) from two schools in the study population to identify students' misconceptions regarding the concepts presented in the eighth grade science textbook used during the 2009-2010 academic year. The primary misconceptions identified were as follows:

▪ When charging an accumulator (liquid battery), the positive pole of the accumulator is connected with the negative pole of the charging source, and the accumulator's negative pole is connected with the positive pole of the charging source.

▪ Electric current runs in an open circuit until it reaches the disconnection point, where it ceases running.

▪ Either there is no relationship between the difference in potential and current intensity in an electric circuit, or there is a reverse relationship between the difference in potential and current intensity in an electric circuit.

▪ Lamps connected in parallel have an equal (constant) electric current but a varying difference in potential.

▪ The equivalent resistance for resistances connected in parallel equals the sum of all the resistances.

▪ According to the unipolar model (sink theory), one wire between a light bulb and a battery is enough to light the bulb, and any additional wire provides unnecessary extra security.

▪ According to the clashing current (two-component model), positive current transmitted from the positive terminal and negative current transmitted from the negative terminal of the battery meet and produce energy in the light bulb.

▪ According to the closed circuit model, electrical current flows in a given direction around a circuit. Because each device in the circuit uses up some of the current, the current weakens so that sequentially connected lamps consume the electric current.

▪ A series of light bulbs always produces more brightness.

▪ The CT designed to determine the CC occurring in students was based on common misconceptions identified by the survey. The final version of the CT was a 27-item; multiple-choice test that measured the extent to which students' knowledge was accurate or inaccurate. Each question had four options with one correct answer. The test development process can be summarized as follows:

▪ Based on previous studies, students' misconceptions regarding electricity were identified through interviews conducted by one of the researchers (Baz & Bawaneh, 2008; Bawaneh, Zain & Ghazali, 2010). Only misconceptions related to concepts found in eighth grade science textbooks in Jordan during the 2009-2010 academic year were included. The items developed to measure CC identified electricity concepts commonly held by Jordanian eighth grade students.

▪ To validate the CT, it was reviewed by a panel of five experts that included a teacher, an educational supervisor and faculty members from Jordanian Universities. The feedback they provided led to the modification of some test items.

▪ To confirm the reliability of the CT, it was administered to a pilot sample of 43 students from the ninth grade that had been exposed to electricity concepts the previous year. The Cronbach's alpha coefficient was 0.71. Because the Livingston equation was used as the test criterion reference (Odeh, 1993; Crocker & Algina, 1986), an adjusted reliability coefficient of 0.94 was used. Jaber (2004) and Baz & Bawaneh (2008) performed a similar analysis. The poorer test performance of the participants in the pilot study confirmed the extent of students' misconceptions regarding electricity.

▪ Students' responses on the CC pretest and posttest were scored with one point for each correct item. The scores were aggregated, tabulated and entered into the computer for statistical analysis, which was performed using the Statistical Package for Social Sciences (SPSS, V. 17).

Inventory of Learning Process (ILP): Based on She's (2005) research, a measure to categorize students' level of learning process was designed and adapted for the Jordanian school environment. She's (2005) instrument classifies students into three levels: meaningful learners, in-between learners, and rote learners (r=0.88). The following procedures were used to create this instrument:

▪ She generously sent the English version of her 32-item scale (She, 2005) at the researchers' request.

▪ Three faculty members in the Departments of Science Education Methods and Educational Psychology in Jordanian universities who graduated from schools in the US and UK independently translated the questionnaire into Arabic.

▪ An Arabic researcher then compared the translations and composed the initial items.

▪ To establish the validity of the questionnaire, five expert faculty members with doctorates in psychology and education reviewed the instrument. Several items were modified based on their suggestions and comments.

▪ To establish reliability, the questionnaire was administered to two eighth grade classes (N = 41) from the original population. Cronbach's alpha coefficient was 0.83, indicating adequate reliability (Odeh, 1993).

Determining Students' Learning Level using the Instrument: The questionnaire that was modified and adapted to the Jordanian classroom included with 32 true-false questions and registration on our system was based on Bloom's taxonomy (Bloom 1956; She, 2005; Schmeck et al., 1977, cited in She, 2005). Higher levels of cognitive skills were associated with higher student scores on the questionnaire. On the She (2005) scale, students with scores of 22 or above were categorized as meaningful learners, students with scores 11- 21 were categorized as in-between learners, and students with scores of 10 or below were categorized as rote learners. In the present study, students were categorized following She's (2005) procedures, and student scores represented the aggregate "T" responses to the ILP items.

Instructional Content: The chapter on electricity from the eighth grade science textbook for the 2009-2010 academic year was used in the present study. For the experimental group, the researchers designed fifteen instructional booklets based on the BBTM for the lessons in accordance with the BBTM, whereas no instructional booklets were provided to the teachers in the control group. In both groups, teachers presented the instructional content four times a week for six weeks, resulting in a total of 24 classes. Follow-up classroom visits and phone calls were made to the groups at their respective schools.

Statistical Analysis

Means and standard deviations were computed to test group differences. A 2-way ANCOVA and post hoc tests employing a split file technique were performed with α level set at 0.05.

Findings

Before the 2-way ANCOVA was performed, data screening was conducted to determine whether the assumptions of normality, linearity, and homogeneity of regression slopes were met. Following the study design, the pretest of the CC in electricity (the covariate) was measured prior to the teaching method treatment (Pallant, 2007) so that scores on the covariate would not be influenced by the treatment. Because the values for skewness and kurtosis values were close to zero and within the range of the values suggested by George and Mallery (2000), the distribution of the pre and post-test scores for the CC in concepts of electricity met the assumption of normality. The scatter plots revealed a linear relationship for each group, indicating that the assumption of a linear relationship between the dependent variable and the covariate was met. Finally, the assumption of the homogeneity of the regression slopes was met (Pallant, 2007).

To answer the first research question, which related to the independent variables of teaching methods and students' levels of learning process, the means and standard deviations were calculated for students' CT scores (Table 1).

Table 1 presents the overall means and standard deviations of the posttest scores for student levels of learning process in the two teaching method groups. The mean scores of the CTM (control) group for rote learners (M = 10.60), in-between learners (M = 11.22) and meaningful learners (M = 11.14) revealed differences in mean scores on the posttest for CTM based on students' levels of learning process. The mean scores for the experimental group BBTM for rote learners (M = 19.40), in-between learners (M = 22.11) and meaningful learners (M = 25.35) indicated that there were differences in the mean scores on the posttest for BBTM based on students' levels of learning process.

Table 1. Means and standard deviations of the posttest scores by teaching methods and student levels of learning process

Group	Student levels of learning process	Mean	SD	N
Control	Rote Learner	10.60	3.04	60
	In-between Learner	11.22	3.12	59
	Meaningful Learner	11.14	2.25	55
Experimental	Rote Learner	19.40	1.01	61
	In-between Learner	22.11	1.17	80
	Meaningful Learner	25.35	.790	42
Total	Rote Learner	15.04	4.96	121
	In-between Learner	17.48	5.83	139
	Meaningful Learner	17.29	7.29	97

After controlling for CC pretest scores, the results presented in Table 2 revealed a significant main effect of teaching methods, $F_{(1, 350)} = 2383.908$, $p < 0.05$, and the partial eta squared of 0.872 indicated a large effect size (Cohen, 1988), which demonstrated that teaching methods influenced CC in students' knowledge of electricity.

Table 2. ANCOVA results for the CC in students' knowledge of electricity based on teaching methods and students' level of learning process

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	11639.851[a]	6	1939.975	428.860	.000	.880
Intercept	8580.439	1	8580.439	1896.832	.000	.844
pre_s2_d	2.509	1	2.509	.555	.457	.002
Group	10783.759	1	10783.759	2383.908	.000*	.872
Levels of learning process	564.819	2	282.409	62.431	.000*	.263
Group * levels of learning process	390.576	2	195.288	43.171	.000*	.198
Error	1583.247	350	4.524			
Total	111691.000	357				
Corrected Total	13223.098	356				

a. R Squared = .880 (Adjusted R Squared = .878), * sig. at p < .05.

Table 2 also reveals that after controlling for students' pretest scores, there was a significant main effect of students' levels of learning process, $F_{(2, 350)} = 62.431$, $p < .05$, which indicated that students' levels of learning process affected their CC. After controlling for students' pretest scores, the results from Table 2 also revealed a significant interaction between types of teaching methods and students' levels of learning process, $F_{(2, 350)} = 43.171$, $p < 0.05$. The interpretation of this interaction is presented in Figure 2, which displays the interaction between the two teaching methods and students' levels of learning process at the meaningful learning, in-between learning and rote learning levels for students' CC.

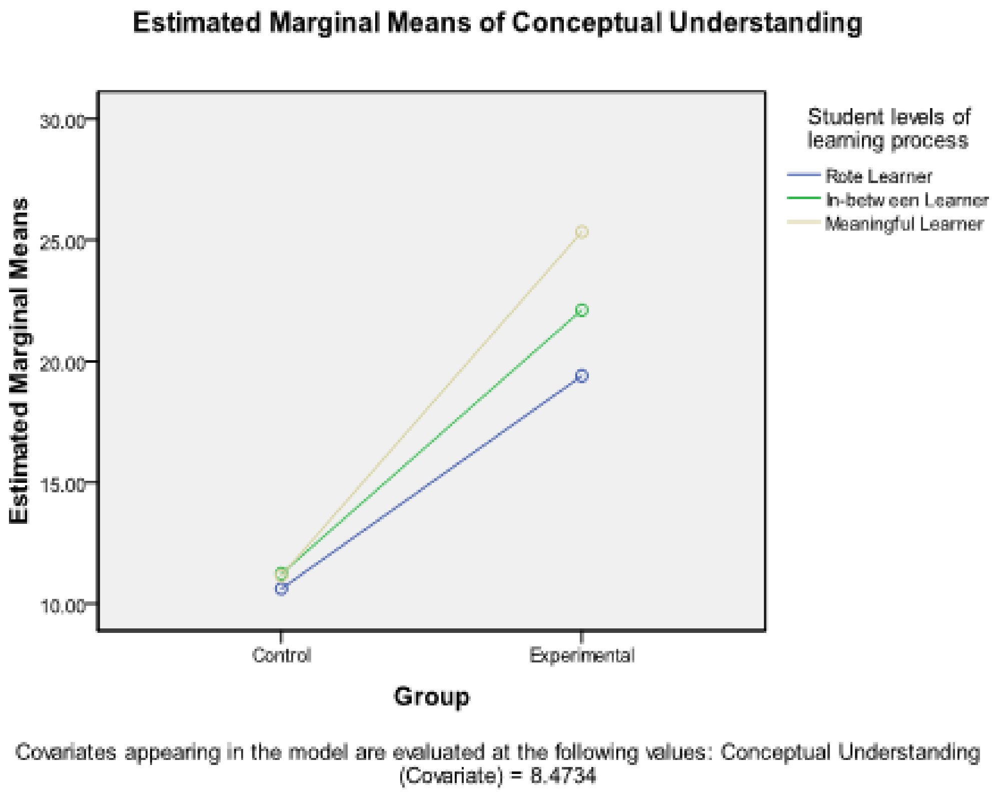

Figure 2. Interactions between teaching methods and students' levels of learning process in students' CC.

Figure 2 presents the interaction between the teaching methods and students' levels of learning process at the meaningful learning, in-between learning and rote learning levels for students' CC. Students with different levels of learning process exhibited differences when taught using the BBTM compared to the CTM, indicating that the effects of the teaching methods on CC depended on students' levels of learning process.

Table 3. Post Hoc Pair wise Comparisons

Group	(I) Student levels of learning process	(J) Student levels of learning process	Mean Difference (I-J)	Std. Error	Sig.
Control	Rote Learner	In-between Learner	-.6203-	.52262	.463
		Meaningful Learner	-.5455-	.53211	.562
	In-between Learner	Rote Learner	.6203	.52262	.463
		Meaningful Learner	.0749	.53426	.989
	Meaningful Learner	Rote Learner	.5455	.53211	.562
		In-between Learner	-.0749-	.53426	.989
Experimental	Rote Learner	In-between Learner	-2.7027-*	.17755	.000
		Meaningful Learner	-5.9473-*	.20943	.000
	In-between Learner	Rote Learner	2.7027*	.17755	.000
		Meaningful Learner	-3.2446-*	.19903	.000
	Meaningful Learner	Rote Learner	5.9473*	.20943	.000
		In-between Learner	3.2446*	.19903	.000

The error term is Mean Square (Error) = 1.091. * P < 0.05.

Post hoc pair-wise comparisons were performed with the split file technique, using Tukey's HSD test to identify significant mean differences in students' CC at the different levels of learning process in the CTM and BBTM groups. Table 3 summarizes the results of the post hoc pair wise comparisons.

The post hoc analyses indicated that for students in the BBTM group, the in-between learners (M = 22.11, SD=1.179) improved more than the rote learners (M = 19.4, SD = 1.01) in CC, P <0.05. At the same time, meaningful learners (M = 25.35, SD = .790) improved more than the in-between learners (M = 22.11, SD = 1.179), P < 0.05 or the rote learners (M = 19.4, SD = 1.01) in CC, P <0.05. In summary, the differences in CC from pretest to posttest in the BBTM group exhibited the following overall pattern: meaningful learners > in-between learners > rote learners.

To answer the second research question, which related to the independent variables of teaching methods and students' gender, means and standard deviations were calculated for students' CT scores (Table 4).

Table 4 presents the overall means and standard deviations of post test scores for male and female students in the two teaching method groups. In the control group, the mean score for male students was 10.97, compared to 10.98 for female students; in the experimental group, the mean score for male students was 21.82, compared to 22.10 for female students. These results indicate that within each group, the differences between males and females were minimal.

Table 4. Means and standard deviations of the posttest scores by student types of learning process and teaching methods

Group	Gender	Mean	SD	N
Control	M	10.97	2.59	82
	F	10.98	3.06	92
Experimental	M	21.82	2.50	98
	F	22.10	2.36	85
Total	M	16.88	5.98	180
	F	16.32	6.20	177

After controlling for pretest scores, the analysis revealed a significant main effect of teaching method, $F_{(1,\ 352)} = 1493.972$, $p < 0.05$, and the partial eta squared of .809 indicated that the effect size was large (Cohen, 1988), which confirmed that teaching methods influenced the CC in students' knowledge of electricity.

Table 5 also reveals that after controlling for students' pretest scores, the main effect of students' gender was not significant, $F_{(1,\ 352)} = .227$, $p = .634$, which indicates that gender does not affect students' CC posttest scores. Similarly, after controlling for students' pretest scores, the analysis found no significant interaction between teaching method and gender, $F_{(1,\ 352)} = .220$, $p = .640$.

Table 5. ANCOVA results for the CC in students' knowledge of electricity based on teaching methods and gender

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	10747.217[a]	4	2686.804	381.987	.000	.813
Intercept	8463.853	1	8463.853	1203.320	.000	.774
pre_s2_d	3.158	1	3.158	.449	.503	.001
Group	10508.224	1	10508.224	1493.972	.000*	.809
Gender	1.594	1	1.594	.227	.634	.001
Group * Gender	1.545	1	1.545	.220	.640	.001
Error	2475.881	352	7.034			
Total	111691.000	357				
Corrected Total	13223.098	356				

a. R Squared = .813, Adjusted R Squared = .811, * p < .05.

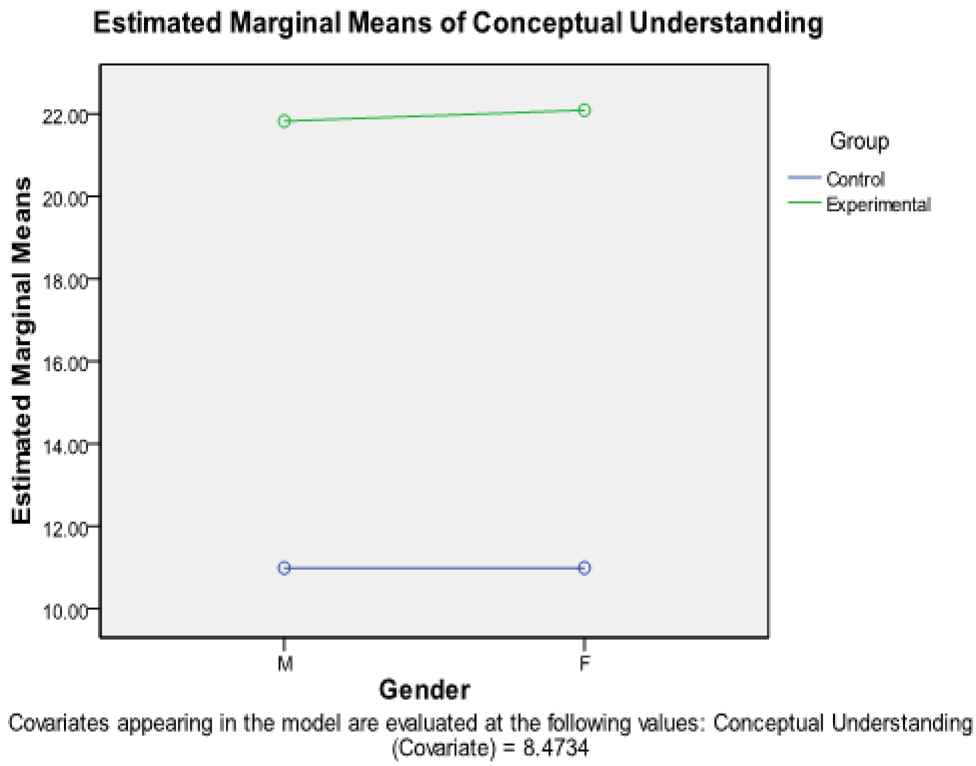

Figure 3. Interaction between teaching methods and student gender.

Figure 3 reveals the absence of an interaction effect between teaching methods and gender because male and female students exhibited similar levels of CC whether they were taught using the BBTM or the CTM. Thus, the effect of the teaching methods on students' CC was not related to gender.

Discussion

In general, the findings revealed improvements in students' knowledge of electricity concepts from pretest to posttest in both the experimental and control groups. Improvement was measured by mean differences in pretest and posttest scores. The results also revealed that the BBTM was superior to the CTM in correcting students' misconceptions and improving their conceptual understanding of electricity. This result is consistent with findings of other studies that investigated the effectiveness of BBTM to bring about CC (She, 2003; She, 2005; Salmiza, 2010; Bawaneh, Zain & Salmiza, 2010a). A number of factors may explain why CC was greater in the BBTM group compared to the CTM group.

- BBTM simulates the brain. As noted previously, because it was based on the HWBM, BBTM took brain characteristics into account and provided equal learning opportunities to different types of learners. Other research supports this finding. For example, Slaity (2008) concluded that classroom practices that harmonize with brain structure effectively contributed to the teaching and learning. Kovalik and Olsen (2000) noted that providing essential elements such as an enriched environment, meaningful experiences, cooperation and collaboration, hands-on activities, sufficient time, and alternative choices promoted brain growth. She (2005) also found that students exposed to teaching methods based on brain functionality surpassed peers who were taught by CTM. Salmiza (2010) found that brain-based teaching methods improved students' understanding of physics concepts compared to traditional teaching methods. Moreover, BBTM emphasizes experiments and classroom activities that require student action in the classroom. Activity stimulates the brain to release a brain-derived neurotrophic factor (BDNF), which fosters thinking, reduces tension and improves learning (Obeidat & Abu Al Samid, 2006).
- Because the BBTM was based on the HWBM, it addresses individual differences and is designed to respond to students' preferred learning styles. Sultan and Jones (1995) found that teaching methods that took individual differences among students into account and varied the methods through which scientific content was being delivered stimulated higher levels of motivation in students and improved their attitudes to learning. This result is consistent with the findings of Salmiza (2010) and She (2005), which emphasized the importance of taking individual differences into account due to their role in reinforcing SMTSL.
- BBTM includes cooperative learning, which influences student learning through interaction with the content being delivered. Obeidat and Abu Al Sameed (2006) stressed the importance of cooperative learning for brain growth and argued that traditional teaching methods, which require students to remain quietly in their seats, are unable to stimulate the brain. Learners learn through communication and need to exchange ideas, opinions and varied experiences to promote learning and enrich their overall experience (Obeidat & Abu Al Sameed, 2006). Vygotsky (1978) argued that individuals learn more effectively when interacting with peers who are older and more skilled. Vygotsky (1978) also claimed that when a student with more skill and knowledge learns a concept before his peers, he is then able to demonstrate it to them.
- BBTM teaches scientific concepts by designing specific experiments for concepts that the students conduct themselves, either individually or through cooperative learning in groups. Salamat (2010) argued that involvement in activity and experiment, whether directly, through cooperative learning groups, or through practical displays by teachers enhances thinking, language, and symbol assimilation by students and generates mental images that aid contemplation, form new concepts, and associate them with established cognitive constructs. Further, She (2005) and Bawaneh, Zain and Salmiza (2010a) reported that BBTM increased the time students spent thinking, planning, and implementing experiments, which improved concept assimilation and enhanced their motivation to learn science.

- Students' CC in the BBTM group also surpassed CC in the CTM group because they associated scientific concepts with experiences in their environment. As a result, the BBTM emphasis on experimentation and hands-on participation in activities improves learning compared to CTMs, which most often depend on memorization (Tsai, 2003; Shorman, 2006). In CTMs, the primary objective is not student understanding of scientific concepts but for students to effectively respond to test questions (Salmiza, 2010).

The present study also found that meaningful learners outperformed in-between and rote learners. This finding was consistent with She (2003; 2005) and Bawaneh, Zain and Salmiza (2010b) and indicated that the BBTM took brain characteristics into account, which provided equal learning opportunities for different learners. This result is supported by other research. For example, Slaity (2008) concluded that classroom practices that harmonized with brain structure effectively contributed to the process of teaching and learning. Similarly, Bull, Montgomery and Kimball (2000) recommended exposing students to instructional content that addressed individual differences among learners and corresponded to students' different needs. They urged that instructional content be based on students' levels of learning process. This recommendation was adopted in the BBTM designed for the present study. In addition, the BBTM focused on identifying and targeting student misconceptions by allowing students to correct their mistaken concepts. Ausubel's original theory, which is based on meaningful learning, links new knowledge with prior cognitive structure, and learning occurs when a new notion takes on a potential meaning and the learner acquires concepts that can be consciously anchored in earlier cognitive constructs. Consequently, an individual's cognitive constructs determine whether new knowledge will be meaningful, acquired, or retained. Other research (Watkins et al., 1991) has found that students who acquired information from textbooks and associated new concepts with their previous cognitive constructs tended to succeed academically. Educators (Alexopoou & Driver, 1996; Basconas & Novak, 1985) have emphasized that the quality and quantity of cognitive constructs determines whether facts are retrievable and helpful, and Ausubel (2000) emphasized the learner's readiness to learn new facts. However, it might be that the meaningful learners who outperformed in-between and rote learners had been more affected by misconceptions, and their ability to modify these mistakes had been improved through the BBTM teaching and learning process. Ordinarily, learners who are more susceptible to misconceptions are more likely to have fragile concepts because they do not have established and coherent cognitive constructs (Jaber, 2004).

The present study did not find that gender influenced students' CC. This finding was consistent with Baz & Bawaneh (2008), Nawafleh (2008) and Obeidat (2000) and occurred because social, economic, and cultural conditions were similar for students and parents. Male and female students also had equal opportunities to learn in similar classrooms and within the same time period. Because teachers in the present study had similar academic backgrounds and teaching experience, the male and female science teachers provided equivalent technical and academic instruction. Additionally, Jordanian parents currently believe that male and female students should have equal opportunities to learn due to programs that explicitly emphasize the need to provide girls with higher levels of education. This trend is reflected by the male-female ratio among the University student body as well as in the workforce in various sectors in Jordan. The analysis found no interaction between teaching method and gender, indicating that both male and female students were influenced by a particular teaching method in similar ways. The positive effects of the BBTM affected both males and females equally because this method developed instructional content that took brain characteristics into account.

Conclusion

The BBTM is a teaching strategy based on the Brain-Based Learning theory, which posits that learning occurs when the brain is not prevented from fulfilling its normal functions (Caine et al., 2005). The present study demonstrated that the BBTM was effective in encouraging conceptual change in misconceptions of electricity held by eighth graders in Jordan. The BBTA assumed that learners involved in relevant activities would not feel as though they had been ignored or excluded from the learning process, which allowed them to acquire concepts in a positive learning environment.

Based on the results, curriculum developers and textbook authors should take the brain characteristics and functions described by the HWBM into account in the curricula and textbooks they design. In addition, teachers should consider attending workshops that train instructors to employ brain-based teaching methods, and science teachers should focus on students' levels of learning process in their lessons.

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