The Effects of Brain-Based Learning on Academic Achievement and Retention of Knowledge in Science Course*

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Abstract

The aim of this study is to investigate the effects of brain-based learning in a 5th grade Science course on academic achievement and retention of previously acquired knowledge. This experimental study, which was designed as pre- and post-test control group model, was conducted in 2004-2005 academic year at Kütahya Abdurrahman Paşa Primary School in Kütahya, Turkey. Two classes, namely 5-A and 5-B, were determined as experimental and control groups respectively. The participants of this study were 22 fifth graders from each group. The study lasted 11 days for a total of 18 class hours. During the research process, the experimental group was administered a brain-based learning approach, while the control group was administered a traditional teaching approach. Analysis of post-test and retention level tests revealed a significant difference between the groups favoring brain-based learning.

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Introduction

Today, new theories and approaches (e.g. constructivism, multiple intelligence, active learning, Inquiry-based learning) are put forward to eliminate the limitations of the traditional way of teaching and to improve the quality of instruction. Also, various theoretical (Taber, 2006; Wink, 2006; von Glasersfeld, 1995; Gardner, 1993) and practical (Akkus, Gunel & Hand, 2007; Barrington, 2004; Sivan, Leung, Woon & Kember, 2000; Watts, 1999; Cho, Yager, Park & Seo, 1997) studies are carried out to come up with different views for teaching. One of these views is brain-based learning.

Brain-based learning can be defined as an interdisciplinary answer to the question of "what is the most effective way of the brain's learning mechanism" (Jensen, 1998). Caine and Caine (2002) define brain-based learning as "recognition of the brain's codes for a meaningful learning and adjusting the teaching process in relation to those codes."

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Studies (Hari & Lounasmaa 2000; Posner & Raichle, 1994) in the field of neurobiology have improved understanding of how the brain functions and how learning is formed. Educators who work in collaboration with neurobiologists integrate knowledge of the functions of the brain and adapt them to learning principles (Cross, 1999; Wortock, 2002). Brain-based learning aims to enhance the learning potential and, in contrast to the traditional approaches and models, provides a teaching and learning framework for educators (Materna, 2000).

The Principles of Brain-based Learning

The principles of brain-based learning provide a theoretical framework for the effective learning and teaching process, seeking the best conditions in which learning takes place in the brain. Based in neurobiology, these principles guide educators to select and prepare learning environments. Caine and Caine list these principles as follows (2002):

- Brain is a parallel processor,
- Learning engages the entire physiology,
- The search for meaning is innate,
- The search for meaning occurs through patterning,
- Emotions are critical to patterning,
- Every brain simultaneously perceives and creates parts and wholes,
- Learning involves both focused attention and peripheral attention,
- Learning always involves conscious and unconscious processes,
- We have at least two types of memory systems: spatial and rote learning
- The brain understands and remembers best when facts and skills are embedded in natural spatial memory
- Learning is enhanced by challenge and inhibited by threat,
- Every brain is unique.

The principles of brain-based learning propose that effective learning could occur only through practicing real life experiences. Learning becomes more expressive when the brain supports the processes in search of meaning and patterning. Accordingly, it enables the learners to internalize and individualize learning experiences. Therefore, it is essential that learners be encouraged to participate in the learning and teaching process actively and that teaching materials be chosen according to their learning preferences.

Various teaching strategies which enable learners to feel secure in the learning environment, to enrich learning and to assist the learning process should be utilized. Moreover, classroom activities should be encouraging and should eliminate the learners' redundant fears and anxiety. In short, brain-based learning puts forward some basic principles such as practicing real life experiences in the learning environment, establishing an effective communication with learners, and guiding learners through their learning processes. By putting these principles into practice, the quality of learning and the level of implementation of the objectives will be promoted.

Learning and Teaching Process in Brain-based Learning

Brain-based classrooms are called “brain friendly places.” These classrooms are the learning environments where the brain’s functions and their roles in learning are regarded in terms of teaching and learning process. These classes also have an emotionally enriched environment where learners are immersed into challenging experiences. Finally, in brain-based classrooms, it is believed that learners are unique and that former knowledge serves as a baseline for new learning (Fogarty, 2002).

Learners are encouraged to gain some skills during the brain-based learning process. They learn not only how to use thinking in learning process but also about the thinking process itself (Fogarty, 2002). The teaching and learning process is formed in three important phases; orchestrated immersion, relaxed alertness and active processing. Although these phases are not separated from each other with distinct lines, they invigorate components of each other in the teaching and learning process (Caine & Caine, 2002; Acikgoz, 2003).

The main focus of orchestrated immersion is to make the gist of the subject meaningful and vivid in learners’ minds. If learners grasp the gist through various sense organs, retention level of the new input will be increased. This phase helps learners establish patterns and associations in their brains while providing them with rich and complex experiences for them, making learning more permanent (Materna, 2000).

The relaxed alertness means challenging learners in a proper way but with a low level of threat (Caine & Caine, 1995). Learners need to feel secure so that they can take risks. If the objective is to change the thinking styles of learners through establishing associations between the old and new knowledge, then learners need to be secure and require a challenging relaxed alertness (Pool, 1997).

Orchestrated immersion and relaxed alertness play a significant role in the ongoing process of searching for meaning in the brain. However, the brain should work consciously in order to increase the patterning in its utmost level and perceive the experiences and additional possibilities. This process of brain-based learning is called active processing (Cram &Germinario, 2000).

Active processing is the theoretical organization and internalization of the meaningful information by learners (Caine & Caine, 2002), and should be regarded as a focus on meaningful learning rather than memorization. As Materna (2000) states, the brain struggles to form meaningful patterns from experiences as it processes information. Learners make associations in order to set up permanent learning prior to grasping the newly encountered information and storing it for the further use.

One of the components of active processing phase is evaluation (Caine & Caine, 1995). The context, the emotions, the physical environment, the process and the organization are the five components of a reliable evaluation in the brain-based learning. These areas of evaluation involve mental, physical and emotional processes as well as past, present and future (Jensen, 2000). Contrary to traditional evaluation procedures,

such kind of evaluation does not involve the evaluation activities that exist at the end of each unit or the subject. The evaluation in this procedure is ongoing and cumulative. The aim of the evaluation activities is to figure out the interests and the weak and strong learning styles of the students. In order to achieve this goal in evaluation, the procedure should not be threatening, but should have motivating factors for learners (Stevens & Goldberg, 2001).

Brain-based Learning in Science Teaching

The subjects of science courses are inseparable units of various academic fields (e.g. physics, chemistry, biology, mathematics, social studies) and intermingled with real life experiences. Students come across various theories of physical science, definitions of chemical composites, and cell structures. They also come up with anxieties about the ecosystem, earthquakes and volcanic events. Extraterrestrial life, the movements of the planets and solar and lunar eclipses attract students' attention throughout their lives. It is only natural that they are affected by these events. In order to comprehend the continuous developments in the field of science, students should be aware of the basic science terms and they should gain the science skills throughout their schooling process (Fogarty, 2002).

The learning and teaching process in science courses should be based on exploration and inquiry. Since the brain inquires meaning and attempts to set associations in a natural way, exploration and inquiry based science teaching might function compatibly with the principles of brain-based learning approach (Mangan, 1998). Brain-based learning aids teachers in facilitating the learning and teaching process. One way of relieving the process is to give learners more responsibilities for their own learning and encourage them to establish associations with the formerly learned subjects and new knowledge in order to form the learning. In order to establish this easiness in the learning and the teaching process, metaphors, thematic teaching, integrated teaching and open ended questions should be used in the learning environment.

Teachers should provide learners with a secure classroom atmosphere which has a rich learning environment challenging learners to learn. To that end, the classrooms should have a bulletin board, an aquarium, various models, computer technology and simulations. Additionally, lesson plans should be flexible and serve learners' emotional needs (Mangan, 1998). Teachers should be able to link science courses with its sub-disciplines as well as other disciplines such as physics, chemistry and biology. This integration of courses makes them more meaningful and interesting for learners as well as facilitating them for the learners who have different learning strategies (Mangan, 1998). There are various ways for teachers to integrate science courses with other disciplines. For instance, while teaching refraction of light, teachers might integrate the subject with another discipline's subject, namely the subject of "the colors" in art, or a composition course's subject such as "writing a report."

In order to teach and learn science, the brain's thinking processes should be known. Teaching and learning science mostly depends on the use of social and emotional

learning processes (Konecki & Schiller, 2003). Brain-based learning enriches input by operating various teaching approaches while establishing a secure classroom environment where learners are encouraged to take risks (Jacobs, 1997).

The process of science teaching, according to the brain-based learning approach, should employ thematic learning skills with a rich language which should be natural but complex at the same time. It should also include long-term structured projects and various evaluation techniques (Holloway, 2000). The use of abovementioned elements of brain-based learning yields three important effects on learners and learning process. First of all, learners grasp the gist of how learning takes place since they are involved in the learning process actively. Secondly, they discover that learning depends on their abilities to externalize their knowledge rather than focus on the marks they get in their exams. Finally, they understand that knowing how to think will support their studies.

The Aim of the Study

The aim of this study is to determine the effects of a teaching process based on the principles of brain-based learning on academic achievement and retention of formerly gained knowledge in a 5^{th} grade science course.

Concerning the above-mentioned aim, the following hypotheses are proposed:

1. The experimental group using the principles of brain-based learning approach will perform significantly better than the control group using traditional instruction on the achievement test designed for this science course.

2. The experimental group using the principles of brain-based learning approach will perform significantly better than the control group using traditional instruction on the retention test designed for this science course.

Methodology

This section covers the definition of the research method, participants, data gathering and analysis procedures, and interpretation of the data.

Research Model

Designed as pre- and post-test control grouped model, this experimental study was conducted in order to determine the effects of the brain-based learning on academic success and retention of formerly gained knowledge in a 5^{th} grade science course. The study was carried out with two intact classes selected randomly. One of the classes was defined as the experimental group and the other as the control group. Both classes were tested before and after the experiment.

Participants

The participants of this study were 5th graders, namely 5-A and 5-B, in 2004-2005 academic year at Abdurrahman Paşa Primary School. The groups were determined by drawing lots, then 5-A was defined as the control group and 5-B as the experimental group.

The reasons why the experiential study was conducted in Abdurrahman Paşa Primary School were that the school administration and the teachers had a supportive attitude towards scientific research and that the physical facilities of the school were suitable for the research. The fifth graders were chosen as the study group because they were assumed to possess the skills and abilities to study, examine and search scientific matters and had access to various resources to get information. Besides, they had a developed muscle and hand coordination and a strong and natural desire for learning.

Equalization

In order to equalize the participants of the study, a personal information survey was administered and they were paired accordingly. The participants who could not be paired concerning his/her personal information and those who did not take one of the pre-tests, post-test and retention test were excluded from the study. Twenty-two students out of forty-two in each class were paired and a total of forty-four students participated in the study. The characteristic features of the equalized participants are represented in Table 1.

As is depicted in Table 1, both groups have equal number of participants in terms of gender and of getting private science lessons or not. Furthermore, the personal information data depict that the participants display similarities in terms of the incomes of their families and educational backgrounds of their parents. Thus, it can be claimed that the participants in both groups have similar socioeconomic and educational backgrounds.

Table 1
Characteristic Features of the Participants

	Experimental Group		**Control Group**	
Characteristic Features	N	Percentages	N	Percentages
Gender				
Female	12	54.6	12	54.6
Male	10	45.4	10	45.4

Average income				
Less than 200 million Turkish Liras	1	4.6	-	-
Between 201-400 million Turkish Liras	2	9.0	2	9.0
Between 401-600 million Turkish Liras	3	13.7	3	13.7
Between 601-800 million Turkish Liras	5	22.8	6	27.2
Between 801 million and 1 milliard	2	9.0	3	13.7
Turkish Liras	9	41.0	8	36.3
1 milliard and over Turkish Liras				
Educational Background of Mother				
Illiterate	-	-	-	-
Literate	1	4.6	-	-
Graduate of Primary School	7	31.9	7	31.9
Graduate of Secondary School	2	9.0	2	9.0
Graduate of High School	4	18.1	10	45.4
Graduate of University	8	36.3	3	13.7
Educational Background of Father				
Illiterate	-	-	-	-
Literate	-	-	-	-
Graduate of Primary School	5	22.8	2	9.0
Graduate of Secondary School	3	13.7	4	18.1
Graduate of High School	7	31.9	7	31.9
Graduate of University	7	31.9	9	41.0
Getting Private Lessons or Not				
Students getting private lessons	5	22.8	5	22.8
Students not getting private lessons	17	77.2	17	77.2

In the equalization process, not only the information received from the personal information questionnaire, but also the students' pre-test scores were taken into consideration. After the application of the achievement test as the pre-test, a difference (0.16) favoring the experimental group was found between the means of the student scores in the two groups. To test the significance of this difference, a "t-test" was applied to the score means of the groups and 't value' was found to be 0.43. This value is under (2.021) with 42 Df and .05 point significance level. This result shows that the difference between the arithmetic means of both groups is not significant in statistical terms. In other words, before the experiment, there was not a significant difference between the experimental and control group students' achievement level in the Movement and Power Unit.

Background of the Instructors

Both of the teachers who designed teaching activities in experimental and control groups are male. Teaching activities of the experiment group were carried out by the researcher, whereas, the teaching activities of the control group were carried out by the teacher of the class. The researcher did not participate in the teaching-learning process of control group to provide neutrality for the research. However, in order to provide validity

for the research, the researcher met the teacher one day per week and discussed the course plans, and they mutually shared their views about the teaching process of the control group. In terms of teaching experience, the classroom teacher is an experienced with 27 years in the field whereas the researcher has only one and half years teaching experience. The researcher works as a research assistant at a university and does not work as a teacher at any public school before. He has reviewed several articles on brain based methods of teaching prior to conducting his research. Moreover, he practiced a 6-hour-instruction on brain-based methods of teaching in a classroom environment at a public school and examined how the brain based learning process could possibly work. Additionally, he held some meetings with two experts in this field at the university in order to exchange views about how to practice brain-based learning in the teaching-learning process in classrooms. One of those experts is a research assistant, who has completed a master's thesis on the brain-based learning and the other one is the supervisor of the first author. When the present study was conducted the first author was an M.A student in the field of Primary Education and took several courses such as Methods of Social Science Research, Learning-Teaching Process in Primary Education, Child Development and Mature Psychology, Teaching and its Problems in Primary Education, Seminar, Curriculum Development In Education, Children Literature and Education. In addition to the field specific courses the researcher also took the courses related to science education such as Science Teaching and Laboratory Applications. The second author of the present study is also M.A thesis advisor of the first author. He is an experienced instructor with 20 years of experience in the field education. His areas of interest are program development, teacher education, primary education programs, teaching and learning process of new approaches.

Data Gathering Procedure

In order to establish a theoretical framework for the study, the suggestions made by several experts in the field were reviewed and discussed. The data gathering instruments used in the present study, on the other hand, were developed by the researchers. These instruments include "The Participants' Personal Information Survey," which was mainly used for equalization of the participant groups; "Achievement Test of the Unit Movement and Power," which was used in pre-tests, post-tests and retention tests; "Lesson Plans of the Unit Movement and Power," which were prepared in accordance with brain-based learning principles; and "Teaching Materials," which were used in those courses.

The Achievement Test of the Movement and Power Unit consisted of 40 multiple-choice questions. In order to determine the reliability of the test, "halving the test method" was used. Accordingly, the achievement test was administered to only a certain part of the students with all group characteristics rather than the whole sample group. Test results were examined in accordance with "halving the test method," which indicated the reliability of the half of the test. In order to determine the reliability of the whole test, on the other hand, Sperman-Brown formula was used and the reliability coefficient was found to be .82. Tekin (2000) states that the reliability coefficient ranges

from (0.00) to (+1.00), and it is nearly impossible to develop tests with (+1.00) reliability. Therefore, .82 value was considered to be sufficient for the reliability of the test.

While developing the brain-based learning materials, a literature review was conducted and data regarding the application of brain-based learning approach were gathered. After determining the specific objectives of the Movement and Power Unit, the lesson plans and the brain-based learning materials to be used in the class were designed.

Experimental Process

Once the experimental and control groups were defined, the participants were informed about the research process and its scope. Both groups were administered an achievement pre-test on the subject of Movement and Power. The experiment process took 18 class hours, six class hours per week, between May 02 and May 23, 2004. Throughout the experiment process, the experimental group practiced the brain-based learning approach, whereas the control group practiced the traditional teaching approach. At the end of the experiment process, both groups were administered an achievement post-test on the subject of Movement and Power. Three weeks later, the same post-test was administered again with the purpose of assessing the retention level of the participants.

In the application of the brain-based learning, the science laboratory in the school was used. Students were asked to sit forming a "U"shape to let them see the board, television, and the slide show better. Also, this type of sitting arrangement promoted the interaction among the students. When group work was needed, the class was organized in a way allowing 4 or 6 students to work together at a time. When the pre, post, and retention tests were applied to the students, they were asked to sit alone, so four additional classrooms were also used in this process.

The Movement and Power Unit in the science course curriculum in Turkey aims at enabling students to comprehend the different movement types, speed, how the location changes in time, the effects of Power, and the basic Powers in the nature by means of observations, applications, experiments, and different activities. In this respect, the Movement and Power Unit is composed of two main titles: "Each Object is Moveable" and "Power Means Push and Pull." The title "Each Object is Moveable" is composed of several sub-titles: Different Movement Types Around, Gauge Your Location and Find Your Way, How Location Changes in Time, and How to Find Speed. The sub-titles of "Power Means Push and Pull" are Power Has Various Effects, Push and Pull Exist Together in the Universe, and Gravity Determines the Weight.

The following section summarizes the brain-based learning process in the experiment:

The researchers designed the learning and teaching process based on the three basic fundamentals of brain-based learning, namely 'orchestrated immersion', 'relaxed alertness', and 'active processing'. During the 'orchestrated immersion' phase, power-

point presentations, cartoons and comic strips, documentary films and various pictures were used in order to help students grasp the subject matter in general. After each presentation, participants were guided either to individual work or to group work concerning the subject of the presentation.

In the phase of 'relaxed alertness,' heterogeneous groups were formed in order to make the participants collaborate with each other and become proficient in any subject. Hence, the knowledge that the participants get during the orchestrated immersion phase become internalized in the relaxed alertness phase. In this phase, in order to form schemata, the researchers prepare some work sheets and participants were asked to write short stories, poems and they were also asked to draw comic strips related to the subject matter. Additionally, the participants were given opportunities to design projects, and they were encouraged to discuss and share the findings of their projects within groups and the whole class. Furthermore, the participants were encouraged to ask questions to other groups regarding the groups' fields of expertness.

During the 'active processing' phase, on the other hand, simulations, group discussions, role plays and dramatization techniques were used in order to ensure the retaining of the obtained knowledge and to ease the structuring of this knowledge as well as applying it into new situations. Also, during the phases of 'relaxed alertness' and 'active processing,' the participants were listening to classical music. During the brain-based learning process in the experimental group, the researcher walked around the groups in the class, acting as a member of a group when it was necessary. Thus, he actively participated in the learning and teaching process and also answered questions of the students. Hence, while he assisted the groups, he provided a classroom atmosphere where the groups worked in a planned manner.

In the traditional way of teaching, the teacher's role is to acquire knowledge and skills and then, to transmit them to the students. For this reason, this process is called direct teaching. In other words, teachers teach and students learn. In fact, the students' real task is to reinforce and internalize the target material by listening to the teacher, taking notes and doing the assigned tasks (Caine & Caine, 2001). In the control group, a teacher centered teaching approach was adopted. Therefore, the participants in the control group were asked to read relevant subjects and explain those subjects to the class. Furthermore, they were asked to listen to the explanations of their teacher, and make experiments in the way that their teacher made.

In both control and experiment groups, the focus of teaching was the unit of Movement and Power. The lesson plans that the teacher prepared for the control group were reviewed each week to see whether any activities other than traditional teaching activities were used or not. The traditional teaching activities, mentioned above are some teacher based activities such as note taking and correction type laboratory activities, which can be defined as any kind of activity that carried out to prove a theory or an experiment of which the results are already known. Subsequent to performing the activities in the courses, the researcher and the teacher held regular meetings and the

researcher interviewed the teacher so as to clarify and identify the procedures that took place during the teaching-learning process.

As soon as the experiment period was over, both groups were administered an achievement post-test. Three weeks later, the same achievement test was administered again to evaluate the retention level of the participants.

The Analysis and Interpretation of the Data

After the experimentation process, the data obtained through achievement tests were analyzed in order to determine the effects of brain-based learning approach on the achievement and retention levels of the experimental group. The data obtained by the pre-test, post-test and retention test were scored. Since the achievement test included forty items, each correct item was graded as 2.5 points out of 100 in general.

The mean scores and standard deviations of the grades obtained via pre-test, post-test and retention test administered to both groups were calculated. Results from t-tests were used to compare the achievement and retention levels of the experimental and control groups. The SPSS 12.0 software program was used in the statistical data analysis procedure and "p" value was determined as .05 for the cutoff level of significance.

Findings

An achievement test was administered as a pre-test to the experimental and control groups in order to test the first hypothesis, which claims that the experimental group using principles of brain-based learning will perform significantly better than the control group using traditional instruction on the achievement test designed for this science course. Then, the mean scores and standard deviations of the scores received by the participants from the pre-test were statistically evaluated and the differences between the mean scores were examined by means of t-test. The pre-test scores of the experimental and control groups are summarized in Table 2.

Table 2
The pre-test scores of the experimental and the control groups

Participants	Number of Participants (N)	Mean ($\overline{X}$)	Standard Deviation (Sd)	t value	Degree of freedom (Df)	Significance level (P)
Experimental Group	22	48.18	10.83	0.43	42	> .05
Control Group	22	48.06	06.16			

t table= 2.021

As is seen in Table 2, there is a slight difference (0.12) between the pre-test mean scores of experimental and control groups. In order to test the significance of this

divergence, a t-test was conducted with the means of the group's scores and t=0.43 value was determined. It is observed that this t value is below the (2.021) within 42 Df and .05 p value. This fact shows that there was not a significant difference between experimental and control groups. In other words, before the experiment process there was not a significant difference among the participants in both groups in terms of their achievement scores on the subject of Movement and Power.

Additionally, in order to evaluate the effects of the experiment process, the divergence of the post-test scores of the participants in both groups were analyzed in terms of their statistical difference. The post-test scores of experimental and control groups are summarized in Table 3.

Table 3.
The post-test scores of experimental and control groups

Participants	Number of Participants (N)	Mean ($\overline{X}$)	Standard Deviation (Sd)	t Value	Degree of freedom (Df)	Significance level (P)
Experimental group	22	72.38	9.71	2.65	42	<.05
Control Group	22	64.31	10.44			

t table= 2.021

As Table 3 depicts, there is a difference (8.07) between the post-test mean scores of the experimental and control groups. In order to test the significance of this divergence, a t-test was made with the means of the groups' scores and t=2.65 value was defined. It is observed that the t value obtained is higher than the table value (2.021) within 42 Df and .05 p value. This finding shows that the teaching procedures between control and experimental groups have different effects on the participants' achievement level. This finding also suggests that the brain-based learning approach is more effective than the traditional teaching procedures in science courses. As a result, the first hypothesis is not rejected.

After a three-week postponement period, a retention test was administered to test the second hypothesis, which claims that the experimental group using the principles of brain-based learning approach will perform significantly better than the control group using traditional instruction on the retention test designed for this science course. The mean scores and standard deviations of the participants' scores on the retention test were calculated and the differences between the scores were reviewed through a t-test.

Table 4.
The retention test scores of the experimental and control groups

Participants	Number of Participants (N)	Mean ($\overline{X}$)	Standard Deviation (Sd)	t value	Degree of freedom (Df)	Signifiance level (P)
Experimental Group	22	71.93	10.32	3.25	42	<.05
Control Group	22	57.38	18.24			

t table= 2.021

As is summarized in Table 4, there is a significant difference (14.55) between the retention tests' mean scores of the experimental and control groups. In order to test the significance of this divergence, a t-test was made with the means of the groups' scores and t=3.25 value was defined. It is observed that this t value is above the table value (2.021) within 42 Df and .05 p value. This finding suggests that the teaching procedures between control and experimental groups have different effects on the participants' achievement and retention. As a result, the second hypothesis is not rejected.

However, this finding is obviously depicted that there is a greater loss in retention by the traditional method than the brain based teaching method. Regarding the reasons behind the loss in retention by the traditional method in the science courses it can be explicated that the traditional instruction does not focus on the learning process. On the other hand, the brain based method of teaching primarily based on process learning. As it is obviously known the process-based learning, which is a part of brain based method of teaching, the process of teaching and learning focuses on higher level learning, profound thinking and permanence as well as transfer of knowledge. The very first aim of such a teaching and learning process is to enable the learners to organize and internalize newly encountered information. However, this organization and internalization should be regarded as an emphasis on meaningful learning rather than memorizing. Moreover, learners in such a teaching method make associations in order to set up permanent learning prior to grasping the newly encountered information and storing it for the further use. Therefore it can be claimed that there is a greater loss in retention by the traditional method than the brain based teaching method.

Discussion and Implications

Regarding the findings of this study, the brain-based learning approach appears to be more effective than the traditional teaching procedures in science courses in terms of improving students' academic achievement. This finding, which suggests that the brain-based learning approach is more effective than the traditional teaching procedures, shows similarities with the studies of Cengelci (2005) and Wortock (2002). Cengelci (2005), for instance, found out that the brain-based learning approach improved student achievement in social science courses. Moreover, the results of the study by Wortock (2002) indicated

that the web-based teaching procedures designed in accordance with the principles of the brain-based learning approach were very effective in enhancing the students' achievement.

The findings of this study also suggests that the brain-based learning approach appears to be more effective than the traditional teaching procedures in science courses in terms of enhancing the retainment of the gained knowledge as well. This suggestion is similar to those of other studies in literature, particularly the studies of Getz (2003) and Cengelci (2005).

In light of the findings of the present study, the implications and suggestions are as follows:

The teachers of science courses in primary schools can take advantage of implementing the brain-based learning approach in their teaching procedures on account of enriching their students academic success and retainment of the previously learned subjects. The materials, which were developed within the framework of the present study for the purposes of in-class practice procedures of the brain-based learning approach, can be adapted or modified by the teachers of science courses in primary schools.

An in-service training program on the implementation of the brain-based learning approach in the science courses in primary schools can be offered to teachers. In collaboration with the teachers, some additional materials which are based on the brain-based learning principles, can be modified for the science courses in the 6^{th} and 7^{th} grades of primary schools. The syllabus of science teaching courses in primary school teacher training programs of educational faculties can be reshaped based on the principles of the brain-based learning approach.

The following topics can be suggested for further research: the effects of the brain-based learning approach on student attitudes towards science courses, the effects of the brain-based learning approach on the students' thinking skills and comprehension, the effects of the brain-based learning approach on the improvement of students' attitudes towards cooperative and group work, the effects of the brain-based learning approach on the students' achievement and retention in other courses, and the effects of the brain-based learning approach on the students' critical thinking and problem solving abilities.

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