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The Effect of Brain Based Learning on Academic Achievement: A Meta-analytical Study*

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Abstract

This study's aim is to measure the effect sizes of the quantitative studies that examined the effectiveness of brain-based learning on students' academic achievement and to examine with the meta-analytical method if there is a significant difference in effect in terms of the factors of education level, subject matter, sampling size, and the countries where the studies were carried out. Meta-analysis is the method employed in order to statistically combine the quantitative data collected from many studies of the same topic, and to reach a general conclusion from the results. In this respect, following the literature research, 31 studies (42 effects) which investigated the effectiveness of brain-based learning on students' academic achievement between the years 1999-2011 met the inclusion criteria, were reported in English and Turkish, and were included in the meta-analytical research. The findings indicate that 35 out of 42 comparisons had positive effect sizes. It revealed that brain-based learning has a positive but medium effect (d=.640) on students' academic achievement. In addition, when compared with the studies conducted in Turkey and the USA, it drew the conclusion that there is a significant difference between the groups while there is no difference in any effect sizes in terms of education level, subject matter and sampling size.

Key Words

Academic Achievement, Brain-Based Learning, Meta-analysis, Neuroscience, Neurophysiologic Learning.

In recent years, electrophysiological studies, neuropsychological tests and the use of imaging techniques (Vaid & Hall, 1991; Vigliocco, Vinson, Druks, Barber, & Cappa, 2011; Weintraub, 2000) have created opportunities for researchers in the structural and functional studies of the human brain which have provided clues resulting in big changes for the field of education.

By knowing how the brain works, brain-based learning supports learning by discovering the ways of maximum learning (Carolyn, 1997). This approach associates learning with the brain and the way it works, and mentions the positive effects of the brain's features and its enhancing performance on learning. Therefore, it is mainly interested in the development of the brain. Through neuroscience, investigating the relationship between the brain, the neural system and our cognitive behaviors, brain-based learning is increasingly supported by studies, especially with the improvement of MRI, PET and MEG technologies (Hansen & Monk, 2002). Today, tests are carried out with the use of these new technologies. The position of neurons in a living human brain can be color-imaged by

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systems such as the positron emission tomography and Nuclear Magnetic Resonance Imaging (NMRI). In this way, several variables like memory, emotion, attention, mapping and their effects on learning are studied (Soylu, 2004; Taşçıoğlu, 1994; Thomas, 2001; Weiss, 2000). These studies, both in our country and around the world, provide us with interesting data. For instance, it is revealed that cell clusters examined by imaging techniques don't have systematic structures as supposed, or that the linguistic part of a person isn't in the same place as that of another person (Ergenç, 1994).

The essential point of brain-based learning is meaningful learning. Mapping is required to maintain meaningful learning. Mapping means that new knowledge is linked to previous knowledge and the new knowledge is put into the current system (Keleş & Çepni, 2006).

The phrases of brain-based learning are the ones that make learning meaningful and permanent (Hasra, 2007, p. 40). These phrases are relaxed alertness, orchestrated immersion, and active processing. Caine and Caine (1990) explain these:

Relaxed Alertness: It means to create the optimal emotional and social climate for learning. A challenging learning environment with minimal threats should be provided (Gülpınar, 2005). When a person is interested in something, s/he is open to learn, or vice versa. A relaxed and open brain can learn more easily. Findings show that some learning is influenced positively in a relaxed environment, but it is suppressed when threat and tiredness are felt (Combs & Suygg, 1959 as cited in Caine, Caine, & Crowel, 1999).

Orchestrated Immersion: It refers to a students' concentration on the contents they encounter. They will have to use their memory to explore the content when wholeness and correlativity are available (Caine & Caine, 2002).

Active Processing: A learning brain is actively processing. For instance, to make an experience meaningful, memory naturally reacts to new objects incompatible with the previous maps. Thus, the brain tests the experiences that are contrary to the known (Duman, 2007).

Caine and Caine (1990), who have many books and articles on brain-based learning, have stated the core principles of brain-based learning. Wolfe (2001), an educational counselor, has done brain research which includes its application in the classroom. Intensely studying brain-based learning, brain compatible strategies, and super learning, Jensen (1998), after considering the brain researches, introduced useful strategies and techniques that can be applied in classrooms. Nunly (2002), a biology teacher, carries out brain-based learning researches and curriculum development studies at the University of Utah. However, no meta-analytical study has been done either in our country or in any other country to reveal the effectiveness of brain-based learning on academic achievement from a broader point of view.

With regard to learning and teaching, it seems that brain research has a long way to go. When it becomes clearly defined how knowledge is formed, organized, and stored in the brain, it is certain that there will be fundamental changes (Soylu, 2004, p. 175).

In order to analyze the effect of brain-based learning, 31 research studies (42 effects) were identified and the main research questions that guided the analysis was 'to what extent does brain-based learning influence students' academic achievement?'. In addition, it was analyzed to see if there is a significant, measurable difference between the effect sizes of brain-based learning studies in terms of subject matter, education level, sampling, and the countries where the studies were carried out.

Method

Inclusion Criteria, Literature Research and Coding

The quantitative studies that were carried out between 1999 and 2012 were examined in this meta-analytical study. To collect data, academic articles, conference papers, theses and dissertations were reviewed online. A clear and detailed coding form was prepared. This form was composed of three sections: study identity, study content, and study data.

Considering that experimental studies and quasi-experimental studies can be included in a meta-analytical study (Glass, McGaw, & Smith, 1981; Hunter & Schmidt, 1990), some studies were excluded because either they were not experimental studies, there was a lack of data to extract effect sizes, or they did not investigate the effect of brain-based learning on academic achievement. 345 theses and dissertations and 108 articles were reviewed. However, the experimental ones with control groups were included. As a result, 31 studies (42 effects) that met the criteria were included in this analysis.

Variables

The dependent variables are the effect sizes that were extracted from the studies included in this meta-analysis. Effect sizes were given standardized values since every study used different measurement tools (Tarım, 2003). The study characteristics (independent variables) are subject matter, education level, sampling and the countries where the studies were carried out.

Meta-analysis Procedures and Inter-rater Reliability

In order to carry out the calculations for meta-analysis, the Comprehensive Meta Analysis (CMA) statistics package and MetaWin were used. The current study used *"study effect"* meta-analysis for the analysis of the data. The aim of this method is to calculate the difference between the mean values of the control and the experimental groups in experimental studies represented by the formula d= (Xe-Xc)/SD (Hunter & Schmidt, 2004). The effect size 'd' is just the standardized mean difference between the two groups (Cooper, 1989). The significance level for the analysis was chosen as .05.

In order to test if there is heterogeneity between the studies, the (Q-statistic) chi-square heterogeneity test with degree of freedom (k-1), being the simplest and most common one, was used. The test of heterogeneity tests the null hypothesis that all studies assess the same effect (Higgins, Thompson, Deeks, & Altman, 2003).

The model of meta-analysis is essential in gathering the different effect sizes via meta-analysis. These models are the fixed effects model and the random effects model. Under the fixed effects model we assume that there is one true effect size which is shared by all the included studies. By contrast, under the random effects model we allow that the true effect could vary from study to study. Accordingly, the standard deviations of the effect sizes for all of the studies are different from zero (Ellis, 2010).

For inter-rater reliability analysis, 25% of the studies (n=7) were selected randomly. They were coded by two raters who know English at an advanced level. Following this, their forms were compared. Reliability of the analyzed studies was calculated according to the following formula: [agreement / (agreement + disagreement) x 100] (Miles & Huberman, 1994) and the reliability was found to be at 100%.

Findings

Study Characteristics

42 independent effect sizes could be abstracted from the study corpus of 31 studies. Of the studies included in the analysis, only the immediate post-test results of the longitudinal study by Erland (1999) were included in the comparison. The total number of students in the studies included in the meta-analysis was 3194, 1473 of whom are in the experimental groups and 1721 of whom are in the control groups. The types of learners in these studies were mostly students in K-12 schools. Most of the studies involved quantitative subjects like math and physics as subject matter, and in terms of the countries where the studies were conducted, Turkey contributed 19 studies to the analysis, 9 studies came from the USA, and Taiwan, Pakistan, and Malaysia each contributed 1 study.

The Entire Distribution of Effect Sizes

The studies included in this meta-analysis were combined into effect sizes with standard error and variance. 35 of the studies have positive effect sizes (Figure 1). This shows that the performance is in favor of experimental groups. If an estimated effect size is found to be negative, it means the performance is in favor of the control group at the effect size level (Wolf, 1986, p. 26). As a result, 83.34% of the studies indicated that the effectiveness of brain-based learning is positive.

In Figure 1, the center of the shape indicates the average effect, and the width of the shape indicates the average confidence interval (Ried, 2006). While the largest confidence interval is İnci (2010), the smallest ones are Pennigton (2010) and Tremarche, Robinson, and Graham (2007). In the classification of Cohen, Welkowitz, and Ewen (2000) 18 effect sizes were found to be medium while 9 effect sizes were medium in the classification of Thalheimer and Cook (2002). The results of the meta-analysis conducted based on the fixed effects model indicate that academic achievement was higher in brain-based learning. The standard deviation was 0.037, the upper limit of the 95% confidence interval was 0.560 and the lower limit was 0.414. The mean effect size was ES= 0.487. The mean effect size, calculated as 0.487, was accepted to be medium in the classifications of both Thalheimer and Cook (2002) and Cohen et al. (2000). Z test calculations were revealed as statistically significant at .05 level (z= 13.030; $p<0.05$). At the end of the homogeneity test, the Q-statistical value was calculated to be

	Hedges's g	Standard error	Variance	Weight (%)
Aydin, 2008	0,670	0,311	0,097	2,33
Usta, 2008	1,535	0,301	0,091	2,36
Peder, 2009	1,395	0,292	0,085	2,39
Oner,2008	0,481	0,267	0,071	2,46
Inci, 2010	8,449	1,226	1,503	0,62
Demirel et al., 2002	1,150	0,324	0,105	2,30
Avci, 2007	1,395	0,290	0,084	2,39
Sunbul et al., 2004	0,987	0,337	0,114	2,26
Bas, 2010	1,005	0,275	0,076	2,44
Hasra, 2007	1,969	0,318	0,101	2,31
Celebi, 2008	0,363	0,246	0,061	2,51
Bastug, 2007	0,670	0,266	0,071	2,46
Ozden, 2005	0,786	0,314	0,099	2,33
Tufekci, 2005-1	0,017	0,224	0,050	2,57
Tufekci, 2005-2	0,916	0,236	0,056	2,54
Cengelci, 2005	0,719	0,327	0,107	2,29
Yagli, 2008	0,304	0,314	0,099	2,32
Cengiz, 2004	1,675	0,317	0,100	2,32
Duman,2006	1,137	0,250	0,063	2,50
Samur et al., 2011	0,590	0,250	0,062	2,50
Ali et al., 2010	1,083	0,305	0,093	2,35
Pennington, 2010	-0,072	0,120	0,014	2,79
Blackburn, 2009	-0,709	0,336	0,113	2,26
Saleh, 2011	1,466	0,226	0,051	2,57
Omotunde, 2006	1,521	0,180	0,032	2,68
McNamee, 2011	0,761	0,316	0,100	2,32
Outhouse, 2008-1	-0,562	0,223	0,050	2,57
Outhouse, 2008-2	-0,198	0,219	0,048	2,58
Outhouse, 2008-3	-0,240	0,219	0,048	2,58
Outhouse, 2008-4	-0,236	0,219	0,048	2,58
Erland, 1999-1	0,308	0,282	0,079	2,42
Erland, 1999-2	0,224	0,306	0,094	2,35
Erland, 1999-3	0,673	0,349	0,122	2,22
Erland, 1999-4	0,385	0,342	0,117	2,24
Erland, 1999-5	0,221	0,340	0,116	2,25
Erland, 1999-6	0,531	0,345	0,119	2,23
Erland, 1999-7	0,271	0,341	0,116	2,25
Chang, 2004	0,612	0,235	0,055	2,54
Tilton, 2011	-0,861	0,260	0,068	2,48
Tremarche, 2007-1	0,432	0,121	0,015	2,79
Tremarche, 2007-2	0,170	0,120	0,014	2,79
Griffee, 2007	0,910	0,446	0,199	1,94
	0,634	0,108	0,012	

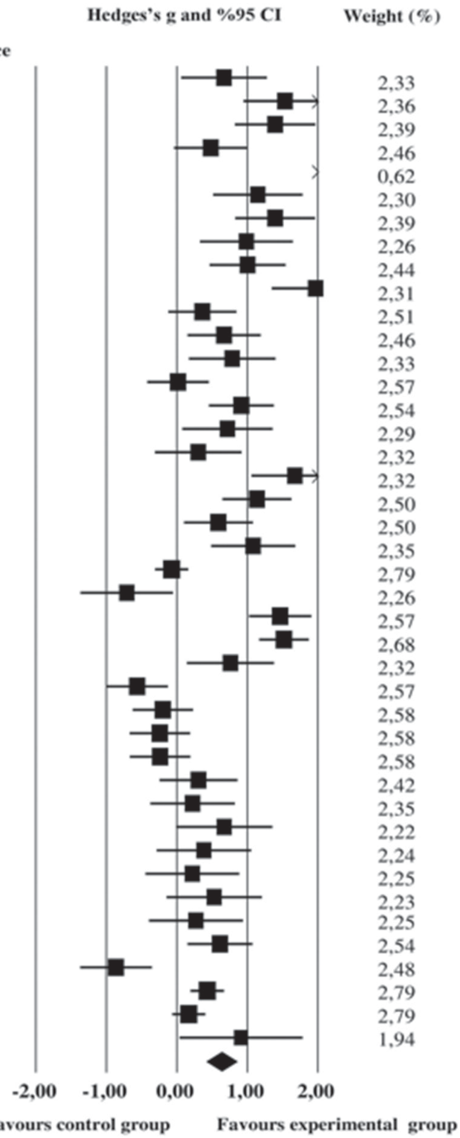

Figure 1.
Forest Plot of the Meta-analysis

333.166. As found on the χ^2 table, 42 degrees of freedom at a 95% significance level was 56.942 (Kmietowicz & Yannoulis, 1988). The Q-statistical value was found to exceed the critical value of chi-square distribution. These values indicated that the distribution of the effect sizes of the studies were heterogeneous in terms of the fixed effects model. The studies being heterogeneous as indicated by the Q-statistical value means that the effect size variance is bigger than the variance that could be expected as a result of any sampling error (Özcan, 2008). Thus, the assumption that there is only one true effect which is estimated from the findings of different studies cannot be warranted (Akgöz, Ercan, & Kan, 2004). As a result, through analyses based on the random effects model, illusions caused by the heterogeneous sample can be eliminated (Demirel, 2005; Yıldız, 2002). For this reason, the effectiveness of brain-based learning was compared based on the random effects model.

According to the random effects model, data from the 42 effects yielded the standard error of 0.110, with 95% confidence intervals of 0.419 and 0.861, and an effect size of 0.649. The magnitude of the effect size is medium according to both Thalheimer and Cook (2002) and Cohen et al.'s (2000) classification. Thus, it can be concluded that brain-based learning has a positive contribution to academic achievement.

Effectiveness of Brain-based Learning by Subject Matters

As a result of the homogeneity test, the Q-statistic is calculated at 2.757. According to the chi-square table with 4 degrees of freedom and confidence intervals of 95%, the critical value is considered to be about 9.488. In this study, since the Q-statistic (2.757) is smaller than the critical value of 9.488, the hypothesis of homogeneity of the distribution of effect sizes has been accepted according to the fixed effects model. In other words, the distribution is homogeneous and there are no significant differences in the effect sizes (Q_B=2.757; p= 0.599) among different subject matters.

Effectiveness of Brain-based Learning by Education Levels

As a result of the homogeneity test, the Q-statistic is calculated at 6.568. According to the chi-square table with 3 degrees of freedom and confidence intervals of 95%, the critical value is considered to be about 7.815. In this study, since the Q-statistic (6.568) is smaller than the critical value of 7.815, the hypothesis of homogeneity of the distribution of effect sizes has been accepted according to the fixed effects model. In other words, the distribution is homogeneous and there is no significant difference in the effect sizes (Q_B=6.568; p= 0.087) among different education levels.

Effectiveness of Brain-Based Learning by Sampling Size

As a result of the homogeneity test, the Q-statistic is calculated at 0.139. According to the chi-square table with 2 degrees of freedom and confidence intervals of 95%, the critical value is considered to be about 5.991. In this study, since the Q-statistic (0.139) is smaller than the critical value of 5.991, the hypothesis of homogeneity of the distribution of effect sizes has been accepted according to the fixed effects model. In other words, the distribution is homogeneous and there is no significant difference in the effect sizes in terms of sampling size.

Effectiveness of Brain-Based Learning by Country

As a result of the homogeneity test, the Q-statistic is calculated at 17.986. According to the chi-square table with 1 degree of freedom and confidence intervals of 95%, the critical value is considered to be about 3.841. In this study, since the Q-statistic (17.986) is bigger than the critical value of 3.841, the distribution is heterogeneous and there is a significant difference in the effect sizes in terms of the countries where the studies were carried out.

Discussion and Conclusion

The results of the meta-analysis suggest that brain-based learning leads to greater academic achievement than traditional teaching methods. This finding is consistent with the results of other national and international studies (Ali, Hukammad, Shahzad, & Khan, 2010; Aydın, 2008; Baş, 2010; Baştuğ, 2007; Çelebi, 2008; Çengelci, 2005; Demirel, Erdem, Koç, Köksal, & Şendoğdu, 2002; Erland, 1999; Griffee, 2007; Hasra, 2007; İnci, 2010; Özden, 2005; Peder, 2009; Sünbül, Arslantaş, Keskinkılıç, & Yağız, 2004; Tüfekçi, 2005).

The findings revealed that there was no significant difference in the effect sizes in terms of subject matter, education level, and sampling size. However, it was found that there was a significant difference in effect sizes in terms of the countries where the studies were conducted. That difference was in favor of Turkey. The quality of a meta-analytical generalization depends on how the studies included in the meta-analysis are presented. A convenient study is related to both the research environment and the presentation of the study's content (Rust, 1990). In some of the included studies, unknown information such as the experiment time and the treatment process hinders the ability to determine the source of the heterogeneity. Nevertheless, it is meaningful that the effect sizes of the studies conducted in Turkey are larger than the ones done in the USA.

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