The effects of neuroscience- and non-neuroscience-based thinking strategies on primary school students’ thinking

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Abstract

This study investigates the difference between the effects of neuroscience-based thinking (NBT) and non-neuroscience-based thinking (NNBT) strategies on the thinking skills of 62 standard five students at two primary schools in Malaysia. A quasi-experimental design method was employed through NBT and NNBT groups. The findings revealed significant differences in the total posttest scores of creative thinking, flexibility, originality, and thinking performance scores of science task in favor of the NBT group, except in fluency, showed no significant advantage. Thus, the study implies that educators should use neuroscience-based thinking strategies to enhance creativity and learning levels among primary school students.

1. Introduction

Studying the brain processes of learning and thinking is a contemporary approach in the fields of education and psychology (Goswami, 2008; Jensen, 2005). Cognitive neuroscience assists educators and psychologists in understanding learning, thinking, and behavior mechanisms by investigating the functions of brain structures and the organization of nervous systems (Blakemore & Frith, 2005). These are normally done through several neuro-imaging scan techniques (Jong et al., 2009; Wolfe, 2001). However, according to many researchers, only a few studies have attempted to bridge the gap between the outcome of the suggestive scientific findings or theories and classroom applications (Blakemore & Frith, 2005; Goswami, 2008; Jensen, 2005; Jong et al., 2009; Katzir & Parè-Blagoev, 2006; Purves, et. al., 2004; Zull, 2002). This study attempts to fill the gap between neuroscience and education by using a thinking strategy based on the principles of neuroscience and examines its effectiveness when implemented in the classroom. In other words, it tries to answer the following question: What are the effects of neuroscience-based-thinking (NBT) and non-neuroscience-based thinking (NNBT) strategies on creative thinking and the performance of thinking in science tasks among the participating primary schools students?

2. Neuroscience and the brain

The results of many neuro-imaging scan studies have consistently uncovered the fact that the human brain includes neurons that are responsible for sending and receiving information through specific transmission processes...
when they are connected through the synaptic mechanism (Carey, 1990; Purves, et al., 2004). In order to receive incoming information, the dendritic fibers increase the surface area of neurons to increase the capacity of information in several brain lobes (Fiala, & Harris, 1999), and this may encode learning and thinking through certain activities (Dolcos & Cabeza, 2002; Leff et al., 2002). The frontal lobe is responsible to executive the functions related to cognitive ability and behavior, such as thinking (Andreason, 2005). In particular, the neocortex of the frontal lobe performs the higher mental functions that enable humans to use higher cognitive skills and abilities (Dietrich, 2004) by making strong connectivity among specific cortex regions to produce thinking processes (Stuss & Knight, 2002). Specifically, the long-term potentiation (LTP) causes synaptic connections within the hippocampus (O'Keefe & Nadel, 1978).

3. Applying neuroscience in education

The functions of brain structures are of interest to neuroscientists and psychologists as they suggest some principles of learning and behaviors from a neuroscience perspective to develop and support the improvement of students’ learning, thinking, and behavior (Caine, Caine, McClintic & Klimek, 2005; Goswami, 2008). One theoretical example that used the biological perspective is Piaget’s learning theory. It is a constructivism theory but is not based on the functions of brain structures (Lawson, 2003). According to Lawson (2003) studied children’s mentality through Piaget’s four stages of cognitive development. He stated that children between ages of seven and twelve can use logical thinking better and acquire new information by constructing and redefining knowledge to make experiences (Feldman, 2007; Lawson, 2000). However, Hebb was able to merge neuroscience and psychology in order to understand learning and thinking; he proposed the Hebbian synapse hypothesis to explain the mechanism of interaction between neurons based on stimulation to produce thought synthesis (Brown & Milner, 2002).

Moreover, the branch of neuroscience that investigates brain mechanisms supports neuro-linguistics (Arbib, 2003). One neuro-linguistic application is neuro-linguistic programming (NLP), which is directly related to education (Norman, 2000). It is a model of human behaviors and thinking processes that are related to the brain and the nervous system, which help one work effectively with others (Bandler & Grinder, 1979). It is noteworthy that neuroscience (Brown & Milner, 2002; Goswami, 2008; Hebb, 1945) and neurolinguistics (Bandler & Grinder, 1979; Gow, Reupert, & Maybert, 2006; Robbins, 1986; Tosey & Mathison, 2003) highlighted brain processes and behaviors, such as thinking and learning.

4. Interpenetration of neuroscience and thinking

Several scholars have spent a lifetime and invested great efforts studying the essence of thinking and learning, as well as the relationship between the two, to provide learners with opportunities to use their mind and apply their knowledge to everyday life (Guilford 1950; Hebb, 1945; Piaget, 1963; Torrance, 1963). The foremost example of these efforts is their attempt to explore both creative and critical thinking. “Creative” is understood as producing new and unique things (Torrance, 1963), while “Critical” implies the use of logical thinking (Dixon, Prater, & Vine, 2004). The two have an intimate relationship and reciprocate with each other (Paul, 1993). According to Paul (1993), creative and critical thinking processes are closely related to imagining skills. Thus, Lawson (2001) suggested a model of creative and critical thinking because these thinking types are correlated. Other instances of scholarly efforts include various studies emphasizing that creativity is related to thought and feeling and might also increase the interactions between them (Aldous, 2007). Thus, Dietrich’s (2004) framework suggested that creative insights can appear in a spontaneous and deliberate fashion, because both thought and feeling interact with cognition and emotion.
5. Integrating the principles of neuroscience in the curriculum

Many neuroscientists and psychologists appeal for the implementation of neuroscience principles in the education and psychology domains by integrating neuroscience with the psychological theories of education in an attempt to bridge the gap between them (Howard-Jones, 2005; Jong et al., 2009; Zull, 2002). They call for the integration of the principles of neuroscience in the curriculum and their application in the classroom as well as in the education processes because, according to Hale and Fiorello (2004), integrating such principles in the curriculum helps educators understand the biological needs of students. However, the neuroscientists and psychologists called upon educators to avoid a strict adherence to the scholasticism of traditional education. In other words, not understanding the process of how the brain works would be an obstacle in the teaching and learning process (Ward, 2007).

Likewise, many studies maintained that integrating neuroscience-based thinking skills in the curriculum by using appropriate strategies, approaches, methods, techniques, or activities would help students to enhance their higher-order thinking skills (Beyer & Backes, 1990; Kozlovsky, 1990; Lopez, & Sanchez, 1992; Shaw, 1986; Weinstein, 1988; Westwood, 1993). This is especially true of science subjects, which constitute an essential part of the school curriculum (Cassel, 1999). Thus, several neuroscience studies found that children combine scientific activities with daily life when their thinking is driven by the science curriculum (Ward, 2007).

6. Employing neuroscience principles in NBT

This study seeks a neuroscience orientation in education by investigating the effects of integrating neuroscience principles into the science curriculum of Malaysia’s primary schools. Although the Malaysian Ministry of Education desires that students should receive quality learning and master higher-order thinking skills, there are no ongoing proposals for the implementation of neuroscience in the school curriculum.

6.1. Integrating principles of neuroscience through NBT

According to Arbib (2003), neuroscientific brain studies improve neuro-linguistics. In addition, neuroscience and neuro-linguistics consider language and the processes of the brain (Lakoff & Johnson, 1999). Hence, both cognitive neuroscience and neurolinguistics are integrated into an NBT strategy. The present study attempts to combine them using partially and/or wholly relevant major principles that can be incorporated in the NBT strategy. The major principles of NBT strategy is deduced from the principles of cognitive neuroscience and neuro-linguistics, which interact in the relevant areas. The major principles are as follows:

1- **Learning results from a complex process of the brain and multisensory systems.** This cognitive neuroscience principle of the NBT strategy underlines the processes and sensory systems of the brain.
2- **Learning is produced by the brain mechanisms and its memory through a special system.** This cognitive neuroscience principle emphasizes the mechanisms and the memory of the brain.
3- **Learning is possible for anyone within the unique features of each brain.** The brain is innate and inherent, and unique to each individual; its capacities are available to everyone.
4- **Learning is a patterning process of the positive intentions of the brain map, produced by emotional information and thoughts of the brain.** This principle underlines the area of emotions and thoughts concerned with patterning, brain maps, and positive intentions.
5- **Current learning is the best choice available, where the brain interacts with communications, the environment, and the surroundings.** This principle considers the social environment, the physical surroundings, the best choices available, and communications.
6- Learning is developmental and results from the brain processes through conscious and unconscious experiences. This final principle emphasizes experiences, consciousness, and the interaction between the brain and the body.

6.2. Implementing neuroscience principles in the NBT strategy

This study proposes a framework of the NBT strategy showing the creative and critical thinking skills that are controlled by cognitive skills. The NBT strategy attempts to integrate the creative and critical thinking skills together as interactive elements. Each of them is controlled and influenced by two types of neuroscience principles (cognitive and linguistic) merged together. These skills do not function separately but interact with one another in four main stages: brain excitement, conceiving an idea, using thinking skills, and developing the idea in a dynamic, alternative, and reciprocal mode. This kind of interpenetration and interaction between the NBT elements to make thinking more teachable and learnable as well as to engage the individual’s thinking during the activity in order to maximize the person’s thinking performance. However, the NNBT strategy includes only those thinking skills that improve one's thinking achievement. Therefore, the students’ performances depend on the teacher and a syllabus based on NBT and NNBT strategy components. Hence, the current study attempts to measure the effectiveness of the NBT strategy of the science curriculum in Malaysia in year 5 (see Figure 1).

7. Methodology

Gay and Airasian (2003) stated that experimental study involves steps such as choosing the groups, applying the treatment to each group, and measuring the influence of the treatment at the end of study. Data were collected from 62 standard five students enrolled in school during the period May through July 2010. A total of 30 students were placed in the NBT group and the remaining 32 students in the NNBT group. They were selected randomly from two primary schools.

In the study, the researcher prepared the test of creative thinking (TCT) and the science task of thinking (STT). These were administered to determine the thinking skills of students before and after the intervention. In order to acquire the reliability between study instruments, Cronbach alpha and Pearson correlation were used at the.05 level. The Cronbach alpha value of all tests and tasks were significant. The TCT coefficient was 0.79, the STT (form A) 0.81, and the STT (form B) 0.86. The reliability between forms A and B of the thinking tasks was significant according to Pearson’s correlation test. The reliability of the two instruments used in the present study was checked through a test-retest method for one month. All the correlations were significant.
8. Results

In order to determine if the NBT and NNBT groups’ creative thinking and thinking of science task before and after the treatment were significantly different, we used descriptive statistics such as means, standard deviations, the two-way analysis of covariance (ANCOVA), the two-way multivariate analysis of covariance (MANCOVA) test, and the least significant difference (LSD) statistical method at the .05 alpha level.

8.1. The creative thinking results

The average mean of the posttest creative thinking scores for students in the NBT strategy group (N= 30, M= 13.56, SD= 4.43) is higher than that of the NNBT group (N= 32, M= 11.34, SD= 3.92). The result of ANCOVA revealed a significant difference between the groups’ total posttest creative thinking scores (F = 4.057; ρ<.05 = 0.049), but Levene’s test does not show a significant difference (F = .438; ρ>.05 = .511). This result proves that the assumption of homogeneity of variances has not been violated. The results of all the tests are reported in Table 1.

Table 1. ANCOVA results for the difference between students’ performances in creative thinking tests

<table>
<thead>
<tr>
<th>Source</th>
<th>Type III Sum of Squares of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
<th>Partial Eta Squared</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corrected Model</td>
<td>78.185a</td>
<td>2</td>
<td>39.092</td>
<td>2.211</td>
<td>0.119</td>
<td>0.351</td>
</tr>
<tr>
<td>Intercept</td>
<td>1121.271</td>
<td>1</td>
<td>1121.270</td>
<td>63.421</td>
<td>0.000</td>
<td>0.432</td>
</tr>
<tr>
<td>Group</td>
<td>71.732</td>
<td>1</td>
<td>71.732</td>
<td>4.057</td>
<td>0.049</td>
<td>0.233</td>
</tr>
<tr>
<td>Pre Creative</td>
<td>2.328</td>
<td>1</td>
<td>2.328</td>
<td>0.132</td>
<td>0.718</td>
<td>0.055</td>
</tr>
<tr>
<td>Error</td>
<td>1043.110</td>
<td>59</td>
<td>17.680</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>10677.102</td>
<td>62</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corrected Total</td>
<td>1121.294</td>
<td>61</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Since the total scores of the two groups in the creative thinking tests were significantly different, the LSD post hoc test was used to determine the actual pairs. The finding indicated a significant difference (ρ<.05 = 0.049) between the NBT and NNBT groups in favor of the NBT group (mean difference = 2.167, std. error = 1.076). Therefore, the NBT students were classified as the higher-performance group in the post TCT.

On the other hand, the present study used the means of the posttest scores of three dependent variables (fluency, flexibility, and originality) in the MANCOVA test to compare the two groups (NBT and NNBT) (see Table 2).

Table 2. Mean and standard deviation of creative thinking skills of the post test in each group

<table>
<thead>
<tr>
<th>Test Type</th>
<th>Variables</th>
<th>Group</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Posttest</td>
<td>Fluency</td>
<td>NBT</td>
<td>5.1143</td>
<td>1.6863</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>Fluency</td>
<td>TS</td>
<td>6.3884</td>
<td>2.4512</td>
<td>32</td>
</tr>
<tr>
<td></td>
<td>Flexibility</td>
<td>NBT</td>
<td>2.8381</td>
<td>0.4916</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>Flexibility</td>
<td>TS</td>
<td>2.3661</td>
<td>0.7063</td>
<td>32</td>
</tr>
<tr>
<td></td>
<td>Originality</td>
<td>NBT</td>
<td>5.6048</td>
<td>2.6838</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>Originality</td>
<td>TS</td>
<td>2.6295</td>
<td>1.6328</td>
<td>32</td>
</tr>
</tbody>
</table>

The result showed that Levene’s test of equality of error variances was significant for all creative thinking skills (fluency: F= 5.521, ρ<.05 = 0.022; flexibility: F= 4.068, ρ<.05 = 0.048; originality: F= 7.887, ρ<.05= 0.007). This result shows that the skill levels among students are not equal. Box’s test is also significant (Box’s M = 29.588, F = 4.663, ρ > .05 = 0.000). This finding is finally determined by the tests of between-subject effects (fluency: F= 3.086,
The result of Wilks’ Lambda $\lambda$ of the (MANCOVA) test indicated significant differences ($\rho<.05 = 0.000$) between the two groups in post-TCT skills ($\lambda = 0.472$, $F = 20.517$, $\rho = 0.000$). This result proves that the scores of the study groups were different (see Table 8.3). Multivariate $\eta^2 = .460$ indicates the effect size, meaning that most of the 46% variation in pre-test creative thinking skills is attributed to the differences between the students’ groups. To determine the direction of the significant differences between the groups, the LSD test was used.

The LSD test indicated no significant difference ($\rho >.05 = 0.084$) in fluency skills between the NBT (M = 5.11, SD = 1.69) and NNBT (M = 6.39, SD = 2.45) groups but showed a significant difference ($\rho<.05 = 0.003$) in flexibility between the NBT (M= 2.84, SD= 0.49) and NNBT (M= 2.37, SD= 0.71) groups with gains for the former (NBT group), as well as in originality ($\rho<.05 = 0.000$; NBT: M = 13.56, SD = 4.43; NNBT: M= 8.31, SD= 3.41), also benefiting the NBT group. Thus, the NBT group showed higher performance in posttest flexibility and originality but no difference in fluency.

### 8.2. Thinking results of science tasks

The average mean scores of the NBT strategy group in post-task thinking in science (N= 30, M = 1.73, SD = 0.27) were higher than those of the NNBT strategy group (N = 32, M = 1.44, SD = 0.31). The results of ANCOVA showed a significant difference between the groups in posttest general thinking in science tasks ($F = 16.612$, $\rho<.05 = 0.000$), and Levene’s test ($F = 0.142$, $\rho<.05 = 0.707$) showed that the scores of the studied groups were different (see Table 4).
Since there was a significant difference between the groups, the LSD test was used. The finding indicated that there was a significant difference ($p < .05 = 0.000$) between the NBT and NNBT groups in favor of the NBT group (mean difference $= 0.282$, std. error $= 0.069$). Thus, the students of the NBT group were better in the post STT. In other words, most of the NBT students showed higher responses to creative pictures in science tasks, while the NNBT students chose critical pictures.

9. Discussion

The results show that the main objective of the study - to improve students’ learning by enhancing their creative thinking and performances of science task (thinking) - is met. The results revealed that there was a significant difference between the NBT and NNBT groups with an advantage for the NBT strategy except in fluency. One interpretation of the fluency result is that ordinary thinking is not a very complicated ability and all teachers in both groups encouraged the students to offer more ideas. It is well known that in the thinking process the brain automatically triggers its action through a special mechanism. Consequently, the NBT strategy stimulates the brain to increase the students’ creativity. This is consistent with the neuroscience principle that learning is produced by the brain mechanisms and its memory through a special system. The activities that were done for the NBT strategy students may have increased the synaptic activity of the students’ brain by repeating the previous processes of synaptic cells and by persistently stimulating the subsequent synaptic cell (Hebb, 1945) because long-term potentiating (LTP) might produce thinking (O’Keefe & Nadel, 1978). Another possible explanation is that this is consistent with another neuroscience principle that current learning is the best choice available, where the brain interacts with communication, the environment, and the surroundings. Thus, the different learning environments of the NBT and NNBT strategies might have allowed NBT students to be more focused on new idea as compared to NNBT students. As a result, there were also some differences in terms of instructions, the syllabus, and thinking strategies. Therefore, the learning environment could have affected the students’ thinking style and science thinking. Hence, students in the NBT group may have been prompted to concentrate more on pictures that stimulate new ideas related to science subjects. This theory is actually consistent with Ward’s (2007) study, which found that the participating children had combined their scientific knowledge with what they experienced in their thought processes.

10. Conclusion

This study has contributed to the body of knowledge in neuroscience and educational psychology as part of the efforts to bridge the two fields. It managed to support the thinking and learning of primary students by drawing upon the principles of neuroscience in a proposed strategy that focuses on thinking skills. It was made to suit all levels of students. In short, the study was able to (i) identify accurate information on the students’ thinking levels, (ii) suggest an effective design of the syllabus for standard 5 science subjects to be used in primary schools, and (iii) provide information regarding the advantage of NBT in enhancing students’ learning and thinking skills.

References


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