Brain-Science-Based Teaching Method for Natural Science Education

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ABSTRACT

With the development of the society and the extensive studies of brain sciences, teaching adolescents according to their brain development characteristics has become particularly important to the improvement of their intelligence level and the cultivation of their overall quality. This paper develops inquiry-based teaching programs and conducts inquiry-based teaching in natural science classes for one year, hoping to understand the effects of inquiry-based teaching on the brain development of adolescent students and provide a certain reference for the selection of teaching models in the future. The results show that inquiry-based teaching can significantly improve students' academic performance and enhance their right-brain tendency; and that at the same time such kind of teaching has positive effects on the students' imagery thinking and right-brain development. Therefore, in teaching practice, teachers should provide students with a suitable learning environment and pay attention to students' abilities to observe, think and solve problems. At the same time, considering the importance of the theoretical brain science research, brain science education should also be incorporated into the occupational training of teachers to improve their scientific literacy.

Key Words: Brain Science, Education, Inquiry-Based Teaching, Quality

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Introduction

The brain, as an important organ of the human body, plays an important role in an individual's growth and ability development (Maguire *et al*., 2000; Dehaene *et al*., 1999; Bengtsson *et al.,* 2005). In recent years, researchers all over the world have attached great importance to human brain research and achieved a large number of results (Pantev *et al*., 1998; Temple *et al*., 2003), which has laid a solid foundation for the mankind to understand themselves, treat brain diseases and develop brain potentials (Goswami, 2006; Callan *et al*., 2003). At the same time, brain science research can also serve as guidance in education and teaching activities (Mysterud, 2003). The development of human brain and the improvement of teaching quality complement and promote each other. Therefore, it is very necessary to carry out the course design for school education based on brain science to improve educational effects.

At present, many schools and teachers are still keen on "knowledge dissemination", that is, they devote themselves mostly to the dissemination of known knowledge. Although some educators are also using courses developed based on brain science, they do not really understand why these courses can improve their academic performance (Barrós-Loscertales *et al*., 2006). Adolescence is a golden period for individuals' intellectual development. So, when promoting quality education, schools also need to apply the theories of brain science research in education to improve students' learning efficiency and promote their ability development.

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Therefore, this paper applies relevant research on brain science in specific school education activities and explores the effects of the inquiry-based teaching method on the brain development of students by developing inquiry-based teaching programs for natural science course. This research is of great importance to the brain development and quality improvement of adolescent students and the training of teachers.

Brain structure and education

The human brain is a nervous tissue consisting of nerve cells, protected by a hard skull. It is one of the most important organs in the human body. Its main components are cerebrum, cerebellum, and brain stem (You *et al*., 2012; Krištofiková *et al*., 2005) (see Figure 1). The cerebrum occupies 80% of the brain volume and is divided into two hemispheres. The left cerebral hemisphere is mainly responsible for rational and logical thinking, and the right brain for abstract art and senses, etc. (Spitzer, 2000; Abe, 2014; Ladd *et al*., 2000).

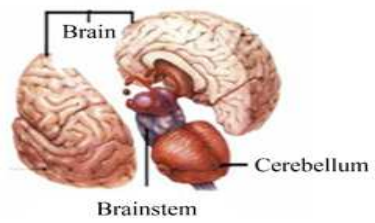

Figure 1. Structure of the brain

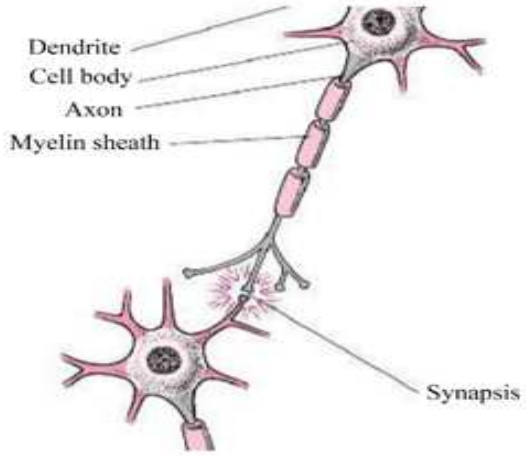

Figure 2. Structure of the synapsis

The nerve cells in the brain are composed of cell bodies and processes, the latter of which are called synapses, used for signalling (Steinheuser *et al*., 2014) (see Figure 2). Education is just to control the external stimuli to allow the brain's nervous system to signal accordingly (Cunningham, 2015); in other words, it is a process of inputting and storing external information and then enhancing, consolidating and memorizing such information within the brain nervous system, so that all the stored information can be automatically extracted when needed.

Development characteristics of the human brain

Nerve cells in the human brain grow and trim with the learning process. Frequently used nerve cells will survive and strengthen, while less frequently used ones will be eliminated. Therefore, the critical period of brain development is closely related to intellectual development.

According to relevant studies, a fetus in the mother's womb already contains a large number of nerve cells; the brain capacity of a newborn infant is about 350cm3; the brain capacity of a four-year-old child is comparable to that of an adult, while the number of synapses is about 1.5 times that of an adult; during adolescence, due to the trimming effect, the number of synapses begins to gradually decrease until it reaches the adult level (see Figure 3 for details). From this, it can be seen that in the critical periods of brain development, such as the age of 8 months, 4 years and adolescence, the brain structure and functions are most plastic and can be easily affected by the external environment, so during these periods, proper stimulation can effectively improve brain functions.

Figure 3. Formation and trim of cynapse

Inquiry-based teaching

At present, the research on inquiry-based teaching in China is still at the initial stage. Although many researchers are working on inquiry-based teaching, there is not yet a system in place and few studies have explored the effects

of inquiry-based teaching on students from the perspective of brain science. This paper develops inquiry-based teaching programs for the natural science course and conducts a one-year teaching experiment to study the effects of inquiry-based teaching in improving students' academic performance, intelligence, and right brain development.

Methods

Subjects

The experiment selected second-grade students from a secondary school as the subjects. In this grade, there are four classes. The scores of each class in the last school year are shown in Table 1. It can be seen that the scores of theses class were very close. In this experiment, Class 3 and 4 were selected as the experimental classes where inquiry-based teaching would be adopted, and Class 1 and 2 are control classes, where the traditional teaching method would still be used.

Table 1. Scores of different subjects in various classes

Subjects\Class	1	2	3	4
Chinese	59.8	57.2	60.4	59.5
Math	60.2	58.4	61.6	57.3
English	58.0	60.1	64.2	63.6
Politics	72.5	71.0	60.0	58.4
History	54.9	58.0	57.1	54.5
Geography	60.2	58.6	68.4	70.0
Biology	62.2	66.7	61.5	71.4
Average	61.1	61.4	61.9	62.1

Teaching programs

According to the teaching content of the natural science course for the second grade in this school, the author developed 10 inquiry-based teaching programs and implemented them in the natural course class. Some of the contents are shown in Table 2 and 3.

Experimental process

Before the experiment, based on the final exam scores of the 4 classes in the last school year, simulation test 1 was developed and carried out to test the academic performance of the 4 classes in the natural science course; then inquiry-based teaching was adopted in the experimental classes and the traditional teaching model was adopted in the control classes. After the end of the teaching, simulated test 2 with the same degree of difficulty was developed and carried out to test the students. The scores of the two tests were compared to check their academic performance.

Questionnaire

"Questionnaire for Intelligence of Primary and Secondary School Students" (prepared by Zhang Liwei) and the "Questionnaire for Left and Right Brain Tendencies" (prepared by Brown) were used as the questionnaires to evaluate the intelligence and left and right brain tendencies of the subjects. Through the statistical analysis of the questionnaire results, the author obtained the students' IQ and distribution of left and right brain tendencies. After the teaching experiment, the questionnaire survey was conducted among the students. See Figure 4 for details.

Table 2. Part of inquiry teaching programs

No.	Title	Analysis of teaching material	Teaching procedures
1	To investigate the comsumption plastic bags	To probe the enverionmental problemes caused by using placstic bags.	See table 3
2	To observe plant movement	Design an experiment of plant movement, in order to experience the procedure and method of an experiment.	Create a sistuation; inquiry project,Experimental Hypothesis, design, probe the outcome of experiment, summarize and communication.
3	To probe into the calculation method of protein peptide bond number	Grasp the structural characteristics of protein, found out the relationship between amino acids polypeptide chain protein in the number and the number of peptide bonds	Create a sistuation; explore, create another sistuation, explore, make a concluction, consolidate

Table 3. Design and time arrangement of the teaching program "To investigate the consumption of plastic bags"

Step	Students	Teachers	Arrangment
1	Put forward a question	Create an sistuation	first class
2	Determine the subject of investigation	Guide inquiry	
3	Design the investigation plan		
4	Investigation procedure		After-school activities
5	Make a conclusion		
6	Summarize and conmucation	Evaluation feedback	Second class

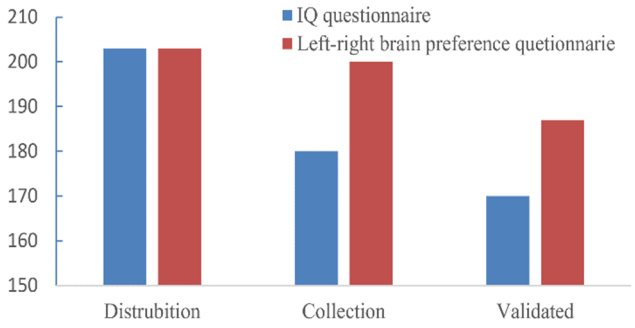

Figure 4. Collection and distribution of questionnaire results

Results

Scores

The scores of the 4 classes in simulation test 1 were distributed as follows (out of 100 points):

Before conducting the inquiry-based teaching experiment, the scores of the control classes and the experimental classes were mainly distributed between 30-70 points, and scores within this range accounted for 72.1% and 75.9%, respectively. Students could only answer about half of the inquiry-based questions, indicating that they were in urgent need to improve their inquiry skills.

After the one-year experiment, the scores of the students in simulation test 2 are as follows:

After the experiment, the academic performance of the students in both the experimental classes and the control classes improved significantly. The scores of the control classes were distributed between 70-100 points, while those of the experimental classes were mainly distributed between 90-100 points. The scores within this 90-100 range accounted for as high as 73.5% in the experimental classes, while those only accounted for 47.7% in the control classes. After analysis of the test content, it is found that students in the low-score section of the experimental classes progressed faster than those in the control classes. The students in the experimental classes grasped the inquiry-based knowledge better, understood the basic inquiry-based learning method, and were familiar with the inquiry process. Their comprehensive analysis abilities were greatly improved. In terms of systematic and theoretical knowledge, the students in the control classes were better than those in the experimental classes.

In the teaching process, the inquiry-based teaching can enhance the interest and initiative of the students in classroom learning and inspire their curiosity, which helps students improve their learning level and academic progress.

Intelligence level

Before and after the experiment, the intelligence test results of the students in the experimental classes and the control classes were as follows:

Before the experiment, no intelligence test was conducted on the students in the experimental classes and the control classes. Moreover, the development of intelligence was a long-term and progressive process. It is unlikely to improve the students' intelligence level through one course within one year. This is also verified in Table 6.

Right brain development

The left and right brain tendencies of the students in the control and experimental classes are shown in Table 7. As can be seen, the students tended to be generally balanced between the left and right brains, with no obvious tendency. After the experiment, students in the experimental classes tended to be more balanced between the left and right brains. Therefore, it can be concluded that inquiry-based teaching has a certain effect in promoting students' whole brain development.

Table 4. Results of simulation test 1

Class\ score	<10	20-29	30-39	40-49	50-59	60-69	70-79	80-89	>90
Class for compariion	—	2	13	12	17	23	11	5	4
Percentage(%)	—	2.30	0.15	13.79	0.20	26.44	12.60	5.75	4.60
Experimental class	—	2	15	14	16	22	13	6	3
Percentage(%)	—	2.20	16.50	15.39	17.58	24.18	14.30	6.59	3.30

Table 5. Results of simulation test 2

Class\ score	<10	20-29	30-39	40-49	50-59	60-69	70-79	80-89	>90
Class for compariion	—	—	—	—	—	7	18	21	41
Percentage(%)	—	—	—	—	—	0.08046	0.21	0.24138	0.471264
Experimental class	—	—	—	—	—	3	11	12	65
Percentage(%)	—	—	—	—	—	0.03297	0.12	0.13187	0.714286

Table 6. Results of intelligence test (pr=percentage)

Unit	statics	IQ≥130		120-129		110-119		90-109		80-89		IQ≤80		$\bar{X}_{IQ}$	P	mode	degree of association (R)
		No.	Pr (%)	No.	Pr (%)	No.	Pr (%)	No.	Pr (%)	No.	Pr (%)	No.	Pr (%)	—	—	—	—
Experimental class	91	3	3.30	5	5.49	13	14.29	59	64.84	6	6.59	5	5.49	96.4	> 0.05	5	0.427
Class for comparision	87	2	2.30	3	3.45	11	12.64	48	55.17	16	18.39	7	8.05	95.1	—	5	0.403
Boys in experimental class	54	2	3.70	3	5.56	9	16.67	35	64.81	3	5.56	2	3.70	97.3	> 0.05	5	0.451
Boys in Class for comparision	48	1	2.08	1	2.08	5	10.42	34	70.83	4	8.33	3	6.25	92.8	—	5	0.432
Girls in in experimental class	37	1	2.70	2	5.41	4	10.81	24	64.86	3	8.11	3	8.11	95.9	> 0.05	5	0.411
Girls in Class for comparision	39	1	2.56	1	2.56	5	12.82	27	69.23	2	5.13	3	7.69	95.7	—	5	0.409

Table 7. Results of the left and right brain tendency

Class\Left-right brain preference	Left brain	Left brain tendency	Medium	Right brain tendency	Right brain
Experimental class	4.1	11.7	64.5	15.3	4.4
Class for comparision	6.8	17.3	62.1	9.7	4.1

People cannot conduct daily activities without the cooperation of the left and right brains. In the course of school teaching, developing a teaching system that is helpful to the whole brain development will be of great significance to improving the students' cooperation, observation, and creativity.

Conclusions

This paper applies the results of brain science research in the teaching of second-grade students at a secondary school. By developing the inquiry-based teaching programs and comparing the results with those of the traditional teaching method, this paper obtains the following conclusions:

(1) Inquiry-based teaching can significantly increase students' interest in learning, and effectively improve their academic performance. After one year of inquiry-based teaching, the scores of the experimental classes were mainly distributed between 90-100 points, and scores within this range accounted for up to 73.5%, while such percentage in the control classes was only 47.7%, which was 25.8% lower.

(2) Short-term inquiry-based teaching has no obvious effect in improving the students' intelligence.

(3) Inquiry-based teaching can promote both the brain development and comprehensive ability cultivation of the students.

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