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THE EFFECTIVENESS OF THE BRAIN BASED TEACHING APPROACH IN DEALING WITH PROBLEMS OF FORM FOUR STUDENTS' CONCEPTUAL UNDERSTANDING OF NEWTONIAN PHYSICS

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Abstract: The aim of this study was to assess the effectiveness of the Brain Based Teaching Approach in dealing with problems related to form four students' conceptual understanding of Newtonian Physics, as currently taught in secondary schools. Techniques implemented in this study were based on the Brain Based Learning Principles developed by Caine and Caine (1991, 2003), Jensen (1996) and Sousa (1995). Using a brain compatibility strategy, the study paid specific attention and consideration on seven main areas: (i) activation; (ii) clarification of the outcome and painting the big picture of the lesson; (iii) making the connection; (iv) doing the learning activity; (v) demonstration of student understanding; (vi) review of student recall and retention/ closure; and (vii) previewing the new topic. The effectiveness of this Brain Based Teaching Approach within the targeted context was then assessed in a quasi-experimental research method involving 100 students from two Science Secondary Schools in northern peninsular Malaysia. Data collected from the results, based on the Test of Newtonian Physics Conceptual Understanding, were analysed descriptively and inferentially, using an independent sample *t*-test technique. The findings of the research showed that this teaching approach was effective in dealing with the problems mentioned. It was found that students who followed the Brain Based Teaching Approach possessed a better conceptual understanding of Newtonian Physics compared to students who were exposed to conventional teaching methods.

Keywords: physics education, Brain Based Teaching Approach, conceptual understanding

Abstrak: Tujuan kajian ini dijalankan adalah untuk menentukan keberkesanan Pendekatan Pengajaran Berasaskan Otak dalam menangani masalah berkaitan kefahaman Fizik Newtonian dalam kalangan pelajar tingkatan empat khususnya. Pendekatan ini dilaksanakan berdasarkan Prinsip-prinsip Pembelajaran Berasaskan Otak yang dibangunkan oleh Caine dan Caine (1991, 2003), Jensen (1996) dan Sousa (1995) melalui lima fasa pengajaran serasi otak iaitu: (i) *activation*, (ii) *clarify the outcome and paint big picture of the lesson*, (iii) *making connection*, (iv) *doing the learning activity*, (v) *demonstrate student understanding*, (vi) *review for student recall and retention/closur*e dan (vii) *preview the new topic*. Keberkesanan pendekatan pengajaran ini dalam konteks yang disasarkan kemudiannya dinilai dalam kajian kuasi eksperimen yang melibatkan 100 orang pelajar tingkatan empat di dua buah sekolah di utara Semenanjung Malaysia. Data kajian yang diperolehi melalui pentadbiran Ujian Kefahaman Konseptual Fizik Newton kemudiannya dianalisis secara deskriptif serta inferensi. Hasil kajian menunjukkan bahawa Pendekatan Pengajaran Berasaskan Otak berkesan dalam menangani isu berkenaan. Didapati bahawa kumpulan pelajar yang mengikuti Pendekatan Pengajaran Berasaskan Otak mempunyai kefahaman konseptual Fizik Newton yang lebih baik berbanding dengan kumpulan pelajar yang menerima pengajaran secara konvensional.

Kata kunci: pendidikan fizik, Pendekatan Pengajaran Berasaskan Otak, kefahaman konseptual

INTRODUCTION

In Malaysia, studies have shown that the lack of student interest towards the subject of Physics in schools may well have been caused by ineffective teaching or instructional methods (Sharifah Maimunah & Lewin, 1993). Rote learning methods such as memorising, copying notes, targeting easier topics and predicting, accompanied by teacher-centred strategy and linear instructions, have been identified as the causing factors for the issues concerning conceptual understanding among students (Sharifah Maimunah & Lewin, 1993; Sulaiman, Siow, Wong, Lim, Lew, & Daniel, 1996). Nowadays, the school education process requires more than what was expected before. Latest developments in the field of neuroscience have shown that, in order to ensure the effectiveness of the teaching and learning process, the more significant teaching method would be the Inclusive Approach (Caine & Caine, 1991; Jensen, 1996). These developments have contributed to the exploration of a brain-compatible technique known as the Brain Based Teaching Approach (henceforth, BBTA).

The BBTA is a strategy implemented based on the Brain Based Learning Principles developed by Caine and Caine (1991, 2003), Jensen (1996) and Sousa (1995) through related brain research. This teaching approach was designed in such a way so as to be compatible to the structure, tendency and optimum function of the human brain, to ensure the effectiveness of the individual learning process (Caine & Caine, 1991, 2003; Jensen, 1996; Sousa, 1995). Although all teaching processes are essentially brain based, compared to other methods, the BBTA is a strategy specifically created to value the true potential of the brain in a learning process (Caine & Caine, 1991). Unlike traditional methods, this approach is based on the theory that everyone keeps on learning as long as the human brain is not prohibited from undergoing its routine processes (Caine & Caine, 1991; Jensen, 1996). The assumption is made based on the fact that the human brain is an organ of extremely high potential and that every student is able to learn effectively if his or her brain is given the opportunity to function in an optimum manner. Children of all learning styles will benefit from this kind of teaching approach.

The BBTA advocates three instructional techniques: Orchestrated Immersion creates a learning environment that fully immerses students in many educational experiences; Relaxed Alertness eliminates fear in the learners while maintaining highly challenging environments; and Active Processing allows the learner to consolidate and internalise information by actively processing it (Caine & Caine, 1991). The integration of these learning optimum state elements is believed to be able to fulfil various learning requirements whilst fostering interest among students. Based on these characteristics, the BBTA is expected to be a new breakthrough in dealing with the issues related to students' conceptual understanding of Newtonian Physics.

BRAIN BASED LEARNING PRINCIPLES

According to the theory of Brain Based Learning Principles (Caine & Caine, 1991, 2003; Jensen, 1996; Sousa, 1995), every teaching and learning process should integrate all of the following elements:

Relaxed Alertness – emotional climate

1. The brain learns best in its optimal state.
2. The brain's bio-cognitive cycle influences the learning process.
3. Emotions are critical to the brain's patterning process.
4. Learning is enhanced by challenge and inhibited by threat.
5. Positive climate stimulates brain function.
6. Appropriate environment, music and aroma excite brain activity.

Orchestrated Immersion – instruction

1. The brain is unique and is a parallel processor (able to perform several activities at the same time).
2. Search for meaning comes through brain patterning process.
3. The brain processor works in wholes and parts simultaneously.

4. Complex and active experiences involving movements stimulate the brain development.
5. Learning engages the whole physiology.

Active Processing – strengthening

1. Learning involves both focused attention and peripheral perception.
2. Learning involves both conscious and unconscious processes.
3. Learning always takes place in two memory approaches – retaining facts, skills and procedures; and/or making sense of experience.
4. The brain can easily grasp and remember facts and skills embedded in its memory space.

IMPLEMENTATION OF BRAIN BASED TEACHING APPROACH

The Brain Based Teaching Approach (BBTA) in this research was generally implemented based on the integration of "Brain Based Learning Principles" (Caine & Caine, 1991, Sousa, 1995; Jensen, 1996) through seven brain-compatible instructional phases (Sousa, 1995; Smith, 2003): (i) activation; (ii) clarification of the outcome and painting the big picture of the lesson; (iii) making the connection; (iv) doing the learning activity; (v) demonstration of student understanding; (vi) review of student recall and retention/closure; and (vii) previewing the new topic. The optimal learning state is the main feature of this approach.

A. Instructional Phase

Phase	Features	Brain Based Learning Principles
(i) Activation	Activate the memory processor system and student's prior knowledge to stimulate the transfer process.	i. Brain learns best in its optimal state ii. Learning is enhanced by challenge and inhibited by threat. iii. Brain processor works in wholes and parts simultaneously

(*continued*)

(continued)

Phase	Features	Brain Based Learning Principles
(ii) Clarify the outcomes and paint the big picture	• Have the students affirm for themselves personal performance target'. • Activate the right brain processor prior to the left brain. • Alleviate anxieties over the accessibility and relevance of the material. (Smith, 2003; Sousa, 1995)	i. The brain is unique and a parallel processor (able to perform several activities at the same time). ii. Brain processor works in wholes and parts simultaneously
(iii) Making connection and develop meaning	The stage where the topic or unit of work about to be completed is connected with what has gone before and what is to come. It builds on what the learners already know and understand and helps them assimilate and integrate new information. (Caine & Caine, 1991; Smith, 2003)	i. Learning involves both focused attention and peripheral perception. ii. Learning involves both conscious and unconscious processes. iii. Learning always takes place in two memory approaches, retaining facts, skills and procedures or making sense of experience. iv. Brain can easily grasp and remember facts and skills embedded in its memory space.
(iv) Doing the learning activity	• The stage for digesting, thinking about, reflecting on and making sense of experience utilising visualisation, auditory, kinaesthetic in multiple contexts. • Access all of the multiple intelligences. (Jensen, 1996; Smith, 2003)	i. The brain is unique and a parallel processor (able to perform several activities at the same time). ii. The search for meaning comes through brain patterning process. iii. Brain processor works in wholes and parts simultaneously iv. Learning involves both conscious and unconscious processes. v. Complex and active experience involving movement stimulate brain development. vi. Learning engages whole physiology.
(v) Application and integration / Demonstrate tudents' understanding	The stage for brain active processing (Caine & Caine, 1991; Smith, 2003)	i. The brain is unique and a parallel processor (able to perform several activities at the same time). ii. Learning always takes place in two memory approaches, retaining facts, skills and procedures or making sense of experience

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(continued)

Phase	Features	Brain Based Learning Principles
(vi) Review for students' retention / Closure	The activity stimulates working memory to summarise the lesson (Sousa, 1995)	Learning involves both conscious and unconscious processes.
(vii) Preview the next topic	The experience helps brain pre-processor and reptilian brain to focus on the new lesson (Shaw & Hawes, 1998)	Learning involves both focused attention and peripheral perception.

B. Optimal Learning State

Strategy	Brain Based Learning Principles
Pulse learning episode. Theory/concept development (prime time) alternately with learning activity (down time) (Sousa, 1995)	i. Brain learns best in its optimal state. ii. Brain bio-cognitive cycle influence learning process.
The use of appropriate aroma and music (Jensen, 1996)	i. Positive climate stimulates brain function. ii. Appropriate environment, music and aroma excite brain activity. iii. Emotions are critical to brain patterning process.
Active learning and student-centred strategies (Caine & Caine, 1991, 2003; Jensen, 1996; Sousa, 1995)	i. Learning involves both focused attention and peripheral perception. ii. Learning involves both conscious and unconscious processes. iii. Learning always takes place in two memory approaches, retaining facts, skills and procedures or making sense of experience. iv. Brain can easily grasp and remember facts and skills embedded in its memory space.
Emotion in learning experience (Caine & Caine, 1991, 2003; Jensen, 1996; Sousa 1995)	i. Positive climate stimulates brain function. ii. Learning is enhanced by challenge and inhibited by threat.
Real-life experience (Caine & Caine, 1991; Jensen, 1996; Sousa, 1995)	i. Learning involves both focused attention and peripheral perception. ii. Learning involves both conscious and unconscious processes. iii. Learning always takes place in two memory approaches, retaining facts, skills and procedures or making sense of experience. iv. Search for meaning comes through brain patterning process. v. Brain processor works in wholes and parts simultaneously.

RESEARCH METHODOLOGY

The aim of this study was to assess the effectiveness of BBTA in dealing with the issues related to students' conceptual understanding of Newtonian Physics in the context of form four Physics instruction in our schools. The research was conducted using the design of a quasi-experimental approach involving 100 students: 50 were in an experimental group and the other 50 were in a control group. These students were randomly selected from two equivalent schools to represent the population of Science secondary school students in northern peninsular Malaysia. The experimental group was then given the BBTA whereas the control group followed the conventional method to learn the topic of Force and Motion, according to the current form four Physics syllabus. The attainment of Newtonian Physics conceptual understanding among students was measured before and after the intervention through the Test of Newtonian Physics Conceptual Understanding, which consists of 30 respective items, in order to determine the effectiveness of the implemented BBTA (Refer Appendix for sample questions of the test). Data collected were then analysed descriptively and inferentially using independent sample *t*-test and paired sample *t*-test techniques.

FINDINGS

Table 1(a) shows the findings on students' conceptual understanding of Newtonian Physics before the intervention. Generally it was found that students from both groups (experimental and control) obtained almost equivalent conceptual understanding mean scores in the pre-test administered. The scores were 6.42 for experimental group and 6.52 for control group. Consequently, the standard deviation of the mean scores for students in the experimental group was slightly smaller than the control group students.

Table 1(b) shows the Levene test for homogeneity and *t*-test analysis of the results obtained. The Levene test indicates that variants in the dependent variables are homogeneous towards all independent variables involved. The *t*-test analysis shows that there is no statistical significant difference amongst the students that compose the selected study sample in terms of the level of the students' conceptual understanding of Newtonian Physics. This means that the sample is homogeneous and suitable to serve as research subjects. Thus, it is assumed that the findings can be the basis for any decisions made against the effects of the treatment on the groups concerned. Furthermore, the results explained that before the intervention, the conceptual understanding of Newtonian Physics of students in both the control and experimental groups was still vague because they had yet to be exposed to the respective instructional methods.

Table 1(a). Mean scores of the pre-test of Newtonian physics conceptual understanding between experimental and control groups of students

Group	Mean score	Standard deviation	Standard error
Experimental ($N = 50$)	6.42	1.486	0.210
Control ($N = 50$)	6.52	1.798	0.254

Table 1(b). Independent sample *t*-test of the mean scores of the pre-Test of Newtonian Physics Conceptual Understanding between experimental and control groups of students

Levene test of homogeneity		t-test						
F	Sig.	t	df	Sig. (2-tailed)	Mean difference	Standard error difference	95 % confidence interval of difference	
							Lower	Upper
2.674	0.105	0.303	98	0.762	0.100	0.330	–0.555	0.755

Significant level, $p = 0.05$

After two and half months of intervention, during which the experimental group was exposed to the BBTA and the control group was presented with the conventional teaching method to learn the topic of Force and Motion, students' conceptual understanding of Newtonian Physics was found to become clearer than ever before. Table 2(a) indicated that both groups had higher scores in the post-test administered compared to the pre-test. However, compared to the control group, results obtained showed that the experimental group demonstrated a better conceptual understanding. Students from the experimental group obtained a higher mean score than that of the students from the control group, with the score of 19.62 compared to only 14.48. The standard deviation of the mean scores for students in the experimental group was slightly higher than that of the control group.

Table 2(b) shows the independent sample *t*-test analysis between the scores obtained from these two groups. It is found that there is a significant difference between the scores obtained by the students in the experimental group (M = 19.62, SL = 3.827) and those in the control group (M = 14.48, SL = 3.092), with $t = -7.387$ and $p = 0.0.00$, $p < 0.05$. Based on these findings, it can be concluded that BBTA is more effective than conventional teaching methods in stimulating students' conceptual understanding of taught physics concepts. This factor may be due to characteristics of the BBTA, which provides more consideration to the optimum potential of the brain in order to boost learning.

Table 2(a). Mean scores of the post-Test of Newtonian Physics Conceptual Understanding between experimental and control groups of students

Group	Mean score	Standard deviation	Standard error
Experimental (N = 50)	19.62	3.827	0.541
Control (N = 50)	14.48	3.092	0.437

Table 2(b). Independent sample *t*-test of the mean scores of the post-Test of Newtonian Physics Conceptual Understanding between experimental and control groups of students

Levene test of homogeneity		t-test						
F	Sig.	t	df	Sig. (2-tailed)	Mean difference	Standard error difference	95 % confidence interval of difference	
							Lower	Upper
3.44	0.07	–7.387	98	0.000	–5.140	0.696	–6.521	–3.759

Significant level, $p = 0.05$

Table 3(a) and 3(b) shows further analysis of students' achievement on the subscales of the Test of Newtonian Physics Conceptual Understanding that concur with the results obtained. With the exception of inertia, there were significant differences between scores obtained by these two groups in each subscale tested. This is probably due to the fact that the concept of inertia is perhaps the easiest concept to be understood within the topic of Force and Motion. Therefore, students were generally found to have no problems in understanding the idea conceptually. Other concepts that are more abstract than inertia require a variety of learning experiences, such as those provided by the Brain Based Teaching Approach. This explains the higher mean scores obtained by the students in the experimental group, who received the Brain Based Teaching Approach.

Table 3(a). Mean scores of the subscales of the post-test of Newtonian Physics Conceptual Understanding between experimental and control groups of students

Subscale	Group	N	Mean	Std. deviation	Std. error
Linear motion	Experimental	50	.55	.290	.041
	Control	50	.32	.277	.039
Motion graph	Experimental	50	.75	.274	.039
	Control	50	.56	.389	.036
Inertia	Experimental	50	.81	.224	.032
	Control	50	.71	.341	.048
Momentum	Experimental	50	.49	.234	.033
	Control	50	.19	.194	.027
Impulse	Experimental	50	.67	.198	.028
	Control	50	.47	.299	.048
Effect of force	Experimental	50	.74	.247	.034
	Control	50	.42	.228	.032
Gravity	Experimental	50	.67	.305	.043
	Control	50	.55	.328	.046
Forces in equilibrium	Experimental	50	.62	.219	.031
	Control	50	.45	.248	.035

Table 3(b). Independent sample *t*-test for the mean scores of the subscales of the post-test of Newtonian Physics Conceptual Understanding between experimental and control groups of students

Independent sample t-test							
Subscale	t	df	Sig. (2-tailed)	Mean difference	Std. error difference	95% confidence interval of difference	
						Lower	Upper
Linear motion	4.11	98	.000	.233	.346	.121	.346
Motion graph	2.77	87.973	.007	.187	.321	.053	.321
Inertia	1.73	84.708	.087	.100	.215	.015	.215
Momentum	6.98	98	.000	.300	.385	.215	.385
Impulse	4.04	85.182	.000	.205	.306	.104	.306
Effect of force	6.72	98	.000	.320	.414	.226	.414
Gravity	1.10	98	.048	.127	.252	.001	.252

(*continued*)

Table 3(b) (*continued*)

Independent sample t-test							
Subscale	t	df	Sig. (2-tailed)	Mean difference	Std. error difference	95% confidence interval of difference	
						Lower	Upper
Forces in equilibrium	3.56	98	.001	.167	.260	.074	.260

Significant level, $p = 0.05$

In addition, a paired sample *t*-test analysis conducted to evaluate the impact of the intervention on students' score on the test of Newtonian Physics Conceptual Understanding before and after the treatment also indicated that there was a statistically significant increase from the pre-test to post-test in both research groups. However, it was found that the gain score for the experimental group was higher than that of the control group. The gain score for the experimental group was 13.20 whereas for control group, the gain was 7.96. The results are shown in Table 4(a) and 4(b).

On the whole, based on the findings obtained, it can be concluded that the Brain Based Teaching Approach was more effective in developing students' conceptual understanding as compared to the conventional method.

Table 4(a). The mean score, standard deviation, standard error and gain score in pre- and post-test of Newtonian Physics Conceptual Understanding of the experimental and control groups of students

Group	Test	Mean score	Standard deviation	Standard error	Gain score
Brain Based Teaching Approach (experimental)	Pre-test ($N = 50$)	6.42	1.486	0.210	
	Post-test ($N = 50$)	19.62	3.827	0.541	13.20
Conventional teaching method (control)	Pre-test ($N = 50$)	6.52	1.798	0.254	
	Post-test ($N = 50$)	14.48	3.092	0.437	7.76

Table 4(b). Paired sample *t*-test for pre- and post-Test of Newtonian Physics Conceptual Understanding of the experimental and control groups of students

	Paired sample t-test							
	Mean	Standard deviation	Standard error	95% confidence interval of difference		T	df	Sig. (2-tailed)
				Lower	Upper			
Brain Based Teaching Approach (experimental)	–13.200	4.050	0.573	–14.351	–12.049	–23.042	49	0.000
Conventional teaching method (control)	–7.96	3.200	0.453	–8.870	–7.050	–17.586	49	0.000

Significant level, $p = 0.050$

DISCUSSION

These research findings have shown that the Brain Based Teaching Approach is effective in developing Newtonian Physics conceptual understanding among students. Besides being applicable to the Malaysian secondary school situation, the results obtained also confirmed previous related findings which have found that brain-compatible teaching and learning approaches were effective in improving students' achievement cognitively and affectively (Goh, 1997; Shamsun Nisa, 2005). Brain-compatible elements are believed to be able to lighten the concept learning process, as well as to stimulate motivation among students.

In this research, students' conceptual understanding of the subject matter was formed based on the implementation of a brain-compatible strategy. The exposure of students to the phases of activation, the clarification of the outcomes and the painting of the big picture, enabled them to be more focused and gave them a better ability to confront the learning process. These factors indirectly contributed to the students' optimal learning state. This teaching approach, which focuses on the activity of "making connections", heightened students' awareness of their learning process (White & Gunstone, 1992). Various learning experiences, inputs (visualisation, auditory, kinaesthetic) contexts which involved emotion and physiology aspects in the optimal state of doing the learning activity phase, encouraged students to make connections for the development of the accepted pattern. The acquired meaning was then strengthened with the active processing based strategy via inductive techniques, discussions, evaluations and problem solving activities (Caine & Caine, 1991; Jensen, 1996). These teaching and learning activities have been shown to enhance information transferring process among students (Sousa, 1995).

For example, to teach the concept of impulse force, students initially were given a big picture of the surrounding phenomena that applies the idea, such as why the front or rear part of a car crumpled easily during an accident. Based on the image given, students were guided to develop the concept of impulse force, defined as the force acting on objects in collision or explosion whereby $F = (mv - mu)/t$. Then students were encouraged to make the connection between the learned concept and their own daily experience activities, such as why they have to move back their hand to catch a ball flying towards them at high speed in order to reduce the impact of the impulsive force. The phase of orchestrated immersion in the BBTA provided an opportunity for students to experience various learning activities related to the concept of impulse force. Here students were provided with a variety of visualisation, auditory and kinaesthetic learning activities based on their preferred learning style. Among the activities that students conducted during this phase were analysing the related video or simulated material, carrying out experiments to explore the concept of impulse force, solving the related problems, and listing and discussing in depth phenomena related to impulse force. This active learning strategy, supported with a good rapport between teacher-student and student-student, indirectly stimulated students' active processing to assimilate and process the information effectively and develop their conceptual understanding.

The application of a pulse learning style, active learning and a student-centred strategy, emotions and real life experiences, and the use of aroma and music, were also found very effective in ensuring the optimum brain state of students. It was also observed that by practicing these types of techniques, students seemed to enjoy their learning process even more. The variety of choices provided by this teaching method made concept learning much more assessable and easier for students to grasp.

Evidently, through the brain based teaching technique, students were exposed to various concrete learning experiences to explore the abstract concept learned. According to Brain Neuroplasticity (Diamond, 1988; Jacobs, Schall, & Scheibel, 1993) and Proster Theory (Hart, 1983), these learning experiences indirectly increase synapse connections and neuron complexities to help form the right connection for internalising concepts. The process eventually encouraged students' conceptual understanding of the matter and the right pattern of meaning was then formed.

In contrast, students' readiness, focus on making the connection process, various learning experiences and active processing, are not really considered in classrooms that follow the conventional teaching method. A teacher-centred teaching and learning process has always been the norm. The teacher often focuses his or her teaching towards concept exposure, drilling and lab activity. Traditionally, conceptual understanding is not the aim of the teaching and learning process. The most vital component of the learning process is the ability of the students to answer exam questions.

CONCLUSION

In conclusion, it has been found and proven that the Brain Based Teaching Approach is effective in encouraging conceptual understanding of Physics among students. Results obtained have shown that there was a significant difference between the achievements of conceptual understanding for students that followed the Brain Based Teaching Approach as compared to those who followed the conventional teaching method. The brain based learning group obtained a significantly higher Newtonian Physics conceptual understanding score as compared to the conventional group. Therefore, it is concluded that the Brain Based Teaching method is effective in dealing with students' conceptual understanding of the subject of Physics in schools.

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APPENDIX

Sample questions of the Test of Newtonian Physics Conceptual Understanding:

1. Why does a child in a wagon seem to fall backward when you give the wagon a sharp pull?

2. A car hitting a brick wall will experience more damage than a car hitting a haystack because...

3. A woman exerts a constant horizontal force on a large box. As a result, the box moves across a horizontal floor at a constant speed v_0. The constant horizontal force applied by the woman is…