

The Use of Brain Based Learning Elements in a Teaching Approach for Scientific Understanding of Biology Concepts

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Abstract The attempt of a functional conflation of the knowledge originated from neuroscientific research with the educational practices has been supported by many researchers in the fields of education and neuroscience. Brain-Based Learning (BBL) encompasses teaching techniques that leverage neuroscience in designing educational methodologies. Regarded as a holistic approach to education, its defining traits are rooted in pivotal insights and extensive research findings. The aim of this study was to assess the effectiveness of a teaching approach based on BBL elements in improving secondary students' conceptual apprehension of common biology concepts. A quasi-experimental design with two comparable groups (treatment group and comparison group) of seventh grade students, using pretest and posttest, was implemented so as to examine the extent to which the BBL teaching technique was effective enough for the learners' understanding of the biology concepts and their conceptual change. The results revealed that the students of the treatment group displayed a statistically significant better conceptual understanding about conceptions concerning Biology than the students of the comparison group. These results are discussed in the context of supporting the use of BBL elements in constructing more efficient teaching practices for Biology courses.

Keywords: brain based learning, instructional practice, conceptual understanding, biology teaching, biology concepts

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1. Introduction

Over the last decades there has been a special interest in the study of human brain from neuroscientists and psychologists. The various findings, stemming from continuous research efforts, succeeded by means of new high-tech neuro-imaging technologies, have crucially contributed to the study of the brain changes which take place both at brain structure and function level during the learning process [1].

As a consequence, many researchers in the fields of education and neuroscience have claimed the attempt of a functional conflation of the knowledge originated from neuroscientific research with the educational practices [2,3,4]. The aforementioned idea has led to the creation of a new interdisciplinary field which aims to propose research based ways of the effective application of the contemporary knowledge about the physiology and function of the human brain to the education process.

However, some researchers have expressed skepticism about the successful cooperation between neuroscience and education, mainly because they consider that there is a tremendous difficulty for the two different disciplinary fields to be bridged in a practical level [5,6]. Difficulties that emerge from the cooperation between education and neuroscience have been attributed to factors such as: (i) the use of different scientific language and terminology that is typical for the two scientific fields, (ii) the inadequate communication between the neuroscientific researchers and the educational community, (iii) the philosophical and epistemological differences that by definition exist between scientific research and practical implementation [7,8].

Despite the various concerns that have been expressed, there is a vivid interest in seeking appropriate ways that could enable the effective and fruitful implementation of neuroscientific findings into the classroom. Some researchers and specialists have proceeded to the formulation of a core set of neuroscience concepts which could enrich and support teachers' understanding about

the learning process, enabling them to tap into pedagogical choices [3,4,9]. This could be feasible through: a) continuous research and trial in practical level under school conditions and b) the concurrent provision of support to the teachers with more practical proposals. This could provide them with sufficient background and clarification about neuroscientific findings, as well as with specific practices that could be implemented in the educational act [10,11].

The BBL consists an integrated educational and instructional context appropriate for the designation of effective student-centered didactical approaches which attempts the synthesis of a holistic simplified scientific knowledge about the human brain with the teaching practices [12,13]. It was originally founded on twelve principles which have been formed from various findings derived from the intensive biology and neuroscientific research about the structure and function of the brain [14,15]. This will lead to the enhancement of students' inherent cognitive abilities by optimizing the natural mechanisms of brain function. Moreover, BBL fosters a rich learning atmosphere conducive to natural learning processes. Simultaneously, it facilitates each student's engagement in the learning process according to their individual style [12,14,16]. The aforementioned principles are incorporated into three pedagogical and didactical axes that are used as a guidance for designing learning environments. The first axis refers to the relaxed alertness and is related to the need for balance in the learning environment in which students have a calm state of mind, a calm learning environment and do not feel threatened or challenged. The second one is called orchestrated immersion and concerns the need to have a learning environment that introduces students to multiple techniques, actions and ways of mastering it mainly through interaction, integration and communication. The third axis concerns active processing where, through practices and appropriate materials, students are given the opportunity to reflect so that their learning displays meaning and leads to constructive learning experiences [14].

The effect of various teaching approaches, that have been organized based on the principles of BBL on various academic features, has been the subject of active research during the last decade. According to literature, BBL displays many advantages and supports students' retention of knowledge and school achievement [17,18,19]. It was also found that selected units in Biology, with learning activities based on the principles of BBL, augmented eleven to fourteen-year-old learners' cognitive performance age [13,20,21]. Also, the positive effect on the adequate degree of conceptual understanding and conceptual change achievement was found in a small number of studies [22,23].

The difficulties confronted by the students in dealing with major concepts at learning physical sciences, consists of a crucial factor for their school performance [23]. Additionally, in their attempt to interpret various natural phenomena in their everyday lives or to give explanations about procedures using the appropriate conceptions that pertain to sciences, students result in creating various alternative conceptions [24,25,26,27,28,29].

In the field of biology, a large body of research has dealt with the detection and the record of students'

alternative conceptions about various biology phenomena and procedures and how these alternative conceptions affect students' ability in the deeper understanding of the proper scientific concepts [30,31,32].

In particular, as far as the human digestive system, the procedures of organisms' food intake, nourishment and the concept of energy are concerned, various alternative conceptions have been documented. Students at different school grades have expressed various alternative views regarding the structure and organization of the digestive system in relation to its constituent organs and how it works [33]. They struggle with comprehending that starch is finally broken down into glucose molecules which in their turn are absorbed and are transferred into the circulatory system [33]. Many students believe that digestion and absorption take place only in the stomach whereas the processes of foods' chemical digestion comprise also a difficult point in their understanding of digestion generally [34]. Although they are aware of the fact that plants need water, air, sun for living, they hardly understand that these materials are used by plants in order to make their food, thus, resulting in the misunderstanding of autotrophic organism and photosynthesis concepts [35]. Many students believe that during photosynthesis, plants use both sun light and heat or only heat [36] or absorb organic material and food components from the soil for their living [37].

Students' difficulties in accurate comprehension of various scientific concepts consists of a crucial factor for their school performance in the subject of biology. It is crucial for the instructional process to facilitate the brain in forming appropriate connections among the various pieces of information it receives, ultimately fostering meaningful learning.

This study aimed to assess the effectiveness of a teaching approach based on BBL elements in improving secondary students' conceptual apprehension of common biology concepts. These concepts concern the procedures of organisms' food intake and nourishment and the humans' digestive system structure and function. It was assumed that students exposed to a BBL designed instruction would have a better learning outcome as far as their conceptual understanding is concerned compared to the students' that were instructed with a conventional way of teaching.

2. Method

A quasi-experimental research method with two comparable groups (treatment group TG and comparison group CG) was employed so as to examine the extent to which the BBL teaching technique was effective enough for the learners' understanding of the biology concepts and their conceptual change.

2.1. Participants

The participants, deriving from public schools, were 97 seventh grade students, 53 male and 44 female (age range 12-13 years, $M = 12.47$ years, $SD = 0.30$ years). The treatment group (TG) consisted of 48 students ($M = 12.43$ years, $SD = 0.29$ years) assigned to two intact

classes and the other two intact classes consisting of 49 ($M = 12.51$ years, $SD = 0.31$ years) students served as the comparison group (CG). A statistical analysis using an independent samples t-test revealed no significant difference in the mean age between the two groups ($t = 1.28$, $p > .05$, 2-tailed).

2.2. Instrument and Data Collection

Students' accurate conceptual comprehension of biology concepts and processes during the pretest and posttest phase was evaluated by a properly structured test consisting at its final form of a total of 12 items. There were nine items in multiple-choice format, while three were open-ended questions requiring brief student responses. Each multiple choice item consisted of one statement that was the correct answer and three distractor statements [38]. The distractors were based on students' common alternative conceptions about biology concepts and procedures according to the results of previous studies concerning photosynthesis, food, energy, and human digestive system [33,34,36,37,39,40] [41,42,43,44,45] [46,47,48,49,50].

All questions were in accordance with the learning goals outlined in the National Greek Curriculum for Biology, tailored for first-grade middle school students. Additionally, the items evaluated for content validity by a panel of experts. A preliminary trial of the tool with a group of 22 students from the same grade in the preceding school year, indicated an internal consistency factor Cronbach's alpha value of 0.695. Each correct multiple-choice answer was awarded one point, while open-ended questions could receive up to three points based on the thoroughness of the response. The total possible score for the assessment was 18 points. The documentation of low score indicates few correct answers resulting thus in many alternative conceptions, while achieving a high score indicates quite the opposite.

2.3. Procedure

All treatment and comparison group students were delivered, as a pretest, the conceptual test that was implemented during a single class session prior to the teaching intervention phase. After changing the pretests question order, so as to diminish possible recollection effects, it was administered as a posttest to both groups (TG, CG) two months after the completion of the intervention period. The duration of the actual research was seven weeks (with one intervention every week, according to the biology program for first Junior High School graders). To this end, the biology chapter called 'Intake of Substances and Digestion' was taught in seven consequent 45 min. class meetings. According to the National Curriculum, we aimed for the instruction of the aforementioned chapter to conclude within the first semester for both approaches (the conventional method and the BBL one). Both the implementation of the BBL instructional approach to the treatment group and the conventional instructional approach to the comparison group were carried out by the same teacher.

The particular BBL sessions [12,13,14,16,23,51] were implemented in seven consecutive meetings. Each session comprised seven instructional stages (Table 1) progressing through three time periods (prime time 1 - downtime - prime time 2), with consideration given to students' attentional abilities in accordance with the principles of the serial position effect (first/middle/last) as outlined by Sousa [16].

The period of optimum attention with a duration of approximately 19 minutes was named prime time 1. Initiating learning sessions with activities like brief experiments or displaying relevant cartoons and images related to the lesson's topic served as catalysts to spark curiosity and anticipation for the upcoming presentation of new material. Additionally, incorporating occasional light-hearted jokes and witty remarks, combined with the teacher's calm voice and friendly smile, fostered a positive and enjoyable environment, reducing stress throughout the learning process. Participants engaged in either completing a concise questionnaire or crafting a brief paragraph detailing their existing knowledge of the subject matter slated for instruction, facilitating the formation of fresh connections with the forthcoming learning content. The delivery of novel information incorporated suitable audiovisual aids, models, and interactive worksheets, along with simulations, aiming to stimulate both hemispheres of the brain evenly for comprehensive engagement.

Table 1. Instructional stages of BBL teaching approach

Time zone	Phase	Characteristics
Prime time 1 period of optimum attention	1. Introduction, Activation	Curiosity and enthusiasm inducement with anticipation for something new. Brain exposure to an overview of the new learning material for students' access facilitation with preference to the right hemisphere.
	2. Preparation	Activation of memory system by connecting old knowledge to the new one for better student preparation.
	3. Exposure, Immersion, Meaning creation,	Immersion in the learning material. Provision of essential information and basic concepts with the usage of audiovisual means. The multiple-way approach of the new learning material contributes to stress reduction. Information organized and classified for searching personal meaning.
Downtime period of reduced attention	4. Process, Application of instructional activities	Processing, thought and reflection stage. Mental feeling of learning along with kinesthetic approach and experience. Left and right brain activation.
	5. Incubation, Memory encoding.	Focus on relaxation and reflection time. The brain learns more effectively mainly in the course of time and not always immediately.
Prime time 2 period of good attention	6. Corroboration, Self-confidence check	Students feel the need of their learning self-confirmation. The possession of a model associated with the new concepts and the learning material by knowledge transfer to daily situations helps better to remember it.
	7. Integration, Digestion	Creation of positive and satisfactory atmosphere with the ascertainment of personal meaning through prior knowledge retrospection and connection of learning material to the next courses.

2.3.1. Brain Based Learning Intervention Approach

4. Discussion

This research aimed at investigating the extent to which a BBL instructive intervention on Junior High School learners had positive effects on the learning of biology concepts. Results revealed that students who received instruction utilizing BBL elements exhibited significantly enhanced conceptual understanding of topics related to the Biology unit "Intake of Substances and Digestion" compared to those subjected to conventional teaching methods. These findings corroborate prior research indicating that the adoption of a teaching approach based on BBL principles yielded superior outcomes in students' conceptual comprehension across various subjects, such as physics topics like force and motion [23] and electricity [22].

Although there was an improvement in conceptual comprehension to the students of both groups, the treatment group showed a significant better understanding a fact that might be owed to various reasons. The organization, the course and the variety of learning practices during the BBL teaching approach seemed to ensure the multifaceted student involvement with the learning material, enabling thus a more individualized approach to the learning process [12,14]. The allocation of the instruction phases in three attentional time zones, contributed to the learning process harmonization with the brain physiological rhythms. This could reinforce important factors that affect students' performance and play a pivotal role in implicitly influencing the engagement of various brain regions by facilitating memory distribution and training neuronal circuits [9,14]. The ability of the BBL approach to allow learners time to relax results into a better delivery, processing and understanding of new knowledge [14]. More particularly, the intermediary time of the downtime phase helped learners feel less anxious, comfortable, relaxed, sentimentally and psychologically content in order to proceed with their learning.

As Ausubel [54] has supported, the inner cognitive conceptual structures that are being possessed by an individual, consist of a crucial factor that contributes to the achievement of the connection with the learning material or in other words with meaningful learning. The amount and the kind of conceptual structures determines the extent of how the various information and facts can be retrievable and useful in learning [55]. Documentation of students' prior knowledge, which was relative to the new learning subject, had been a permanent element in the structure of every BBL instructional session. It has been shown that this personal knowledge, stemmed from either daily experience or previous lessons, consists of one of the most important presuppositions of learning [56]. The recollection of previous knowledge and experiences enable students to make connections and associations with the new learning information. In addition, it determines to a great extent the understanding of the learning material, facilitating the integration of new knowledge to the students' cognitive schemata, making it meaningful and important to them [57]. Hence, the new information has a personal relevance for the students leading to its individualization, which in parallel subserves to the construction of mnemonic processes that are more powerful contributing to memories formation [58].

All the above procedures took place into the framework of relaxed alertness and orchestrated immersion, characterized by students' reflection and internalization upon the new learning material. This was accomplished by means of appropriate instructional activities as they had been designed according to the BBL teaching approach. The whole procedure had a significant effect on students' better performance as it was demonstrated at the results of the conceptual understanding posttest.

As it was mentioned, students' prior knowledge comprises the frame of the new knowledge construction. However, in other cases it might conflict with the new knowledge scientific conceptual framework, resulting thus in a process of learning as a product of conceptual change [59]. This implies that students' attempts to assimilate the new scientific knowledge into their theoretical contexts might lead to the creation of misconceptions [29]. Moreover, students are able to possess both misconceptions and scientific acceptable concepts so that they might use them differently depending on the different problem and context that are facing each time [60]. This might be a reason why students, who attended the BBL instructional approach, failed to achieve a high score in the posttest despite the fact that they displayed a significant improvement in their conceptual understanding.

5. Conclusion

Students alternative concepts about processes and phenomena concerning Biology field consist of a crucial learning factor since they strongly affect students' correct scientific conceptual understanding, showing in parallel a notable persistence even after the instructional intervention. The research reveals that it is possible to have better cognitive results when using a number of instructive methods and learning tasks, even in the traditional classroom. Nevertheless, it seems important that interventions are planned and implemented in a particular sequence so as to allow a balance in students' disposition and ability to attend and concentrate. The BBL approach is an instructive method that may allow learners' better conceptual understanding and expansion of their learning capacity. Further studies could investigate the effectiveness of the BBL teaching approach in other grades of the secondary education level including various biological concepts and processing concerning different biology topics.

Statement of Competing Interests

The authors report there are no competing interests to declare.

Ethical Considerations

The study was approved by the research ethics committee which conforms to the declaration of Helsinki. Participation in the study was based on informed consent. All tests were anonymously completed by the students and appropriate codes were used for the data processing.

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