

Investigating children's conceptions of the brain: First steps

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This paper reports data, part of a cross-sectional study about the use of pupil's drawings as a means of probing the development of 195 Brazilian pre-school children (4 to 6 year-olds) and 681 primary school pupils 1st Grade through 4th Grade (7 to 10 years of age) conceptions of the human brain. The aims of the present study is to analyze how the conception of the brain develops, how they represent their brains, and whether it is based on historical models or current scientific knowledge, in their interaction with school and society at large. The methodology involved the presentation of a contour of the head and neck drawn on the blackboard in the classroom, and children were asked to draw what they think they have inside their heads. After the drawings were collected some pupils were interviewed to explain their drawings. Classification of the collected drawings were interpreted on the perspective of historical models of the brain and scored following a 6 level rating scale depicting degrees of neuroanatomical resemblance. Gender and age were taken into consideration. The results show that younger pupils are adepts of mental ideas in their representations of the brain, i. e. what the brain does, but progressively as they get older, start to develop a more morphological representation of the brain. Knowledge obstacles for learning about the nervous system and elementary neuroscience implications are discussed.

Keywords: biological conceptions, mental images, historical brain representations, children, kindergarten and primary school.

Introduction

Basic Biology

All living systems share a common ancestry of organic structure (El-Hani & Videira, 2000). Organisms basically orient their existence at absorbing nutrients to secure survival, develop mechanisms controlled by genes to evolve and to avoid predators or environmental perils. Thus, a communication program evolved randomly inside organisms to detect and integrate incoming information to face a changing world, which may be observed, for example, in very simple animals as the protozoa *Paramecium sp.* (Capra, 1996). Its cell membrane possesses ion channels that allow one to register a membrane potential close to that as is obtained in a common neuron (Hille, 1994; Loewenstein, 1999; Cotterill, 2001). Eventually cells gathered together to develop an information network subjected to evolution pressures which in the end originated an elemen-

tary neuronal net, later a complex nervous structure in other more advanced animals, and ultimately the brain of vertebrates capable of dynamic adaptive behavioral responses to a variety of environmental stimuli (Allman, 2000; McCrone, 2002).

Historical brain representations

The creationist model of the world (the religious belief that life, the planet Earth and the universe are the creation of a supernatural being) started to be replaced by a new hypothesis stating that the universe is often changing and does not follow a pre-established plan due in part to science development in the 18th-19th Century period (Scott, 2004). Knowledge in organisms started to be studied on the approach that mind and brain function are related and work together. The Cartesian dualism which was a current explanation of the brain, involving the complex “mind-soul and body”, was put aside as a valid model of investigation (Edelman, 1992). Another tenet is that the brain is the product of neural Darwinian evolution which selected the living systems according to their ability to adapt to the environment where they are supposed to live (Edelman, 1987). The brain by itself favors the capacity of adaptation of the organism, turning it more independent of genetics and more subject to experience and learning opportunities. In spite of these scientific advances and findings amongst pupils and teachers still persists the Cartesian dualism reflected by means of historical models of the brain instead of an understanding of biological mechanism patterns responsible by thinking and learning (Clément & Mein, 1987).

Thus, historically the organ of the brain (cerebrum) went through a long path to find its way as a structure responsible for human thinking and behavior. From Ancient times to the Renaissance the problem was to specify and to locate the site of the psychic phenomena. For instance, in the Greek thinking the heart was the place for the sensations, passion and intelligence asserted by Aristotle in the 5th Century before Christ, according to the cardiocentric thesis (Frampton, 1991). However, even before Aristotle, Democritus had proposed a cephalocentric thesis for a material basis by means of a circulating liquid involved with sensations and thinking (Changeux, 1991; Dolan, 2007). The theme of the three ventricles advanced to the 18th Century on the concept of a “hydraulic model” with circulating fluids and even Descartes accepted this model for muscle contraction and the “seat of the soul”. More recently, the brain was represented by a model of phrenology in the 19th Century by Gall. Nowadays, contributions by Ramon y Cajal on the theory of neurone and contemporary studies by Donald Hebb, (1949/2002) Sperry & Sperry, (1983) and John Eccles, (1994) on synapses and technical advances in brain imaging brought new light for a better understanding of the brain (Brazier, 1959; Johnson, 2004; Parent, 2009).

Organ and organ systems in school

Therefore, when the human body is being taught concerning organs and organs systems, teachers make use of analogies between the human body and machines expecting that the comparison will help in the understanding of its organization and function. Generally speaking analogies simplify the processes and in the end might turn into obstacles to scientific learning (Duit, 1991; Andrade et al., 2002; Giraldo & Souza, 2006; Glynn, 2007). As an alternative to the use of analogies investigations over the spontaneous conceptions of the students by means of collecting drawings and interviews may bring the developing of efficient teaching strategies (Steward & Furuya, 1982; MacPhail & Kinchin, 2004; Hall, 2007). Probing the ideas which pupils have about brain representations may reveal what are the common sense ideas that act as hindrances to an understanding of scientific concept, in this case the form and functioning of the brain.

Several studies have investigated the spontaneous development of students' conceptions of the human organism. Conceptions may be considered as structures of knowledge through

which one constructs new information that later, after some reflection, might be converted in knowledge (Pines & West, 1986). Some pioneering studies were carried by Nagy (1953), who looked at what Hungary children from Budapest, 4 to 11 year-olds thought as revealed by drawings and interviews, was the functioning of the brain, lungs and stomach. Her findings indicated that children from her sample, had difficulties to tell the mechanism of the functioning of the organs, but rather defined the role of the organ, for instance “the brain is for thinking”, lungs are for air”. On the other hand, Tait and Ascher (1955), asked adults and a few sixth-graders “draw the inside the body, including all the organs” and got as a response from the students that the “the brain is inside the head”. However, it was a limited sample (N=22).

Adults agree the brain is crucial for life, whereas children recognize Gottfried et al., (1999) that it is an important biological organ (Crider, 1981; Gellert, 1962; Johnson & Wellman, 1982; Nagy, 1953). Several studies have investigated the spontaneous development of students’ conceptions about the human organism (Amann-Gainotti & Antenore, 1990; Flear, 1994, Reiss & Tunnicliffe, 2001; Reiss & Tunnicliffe et al., 2002; Manokore & Reiss, 2003; Frändberg et al., 2004). A general trend emerged from these findings i. e. very young children (aged 4 to 5 and 5 to 6 years old) have little knowledge about the human organism including the brain (Mintzes, 1984; Carey, 1985; Osborne et al., 1992).

According to Carey (1985), when referring to the nervous system and the brain, 2nd graders know that thought is needed for different kinds of activities, for instance to start walking. Upper elementary school students attribute to nerves the function of conducting messages and controlling activity of the body (Gellert, 1962). However, 5th graders appear not to understand that the brain controls involuntary activities, like breathing and heart beat (Johnson & Wellman, 1982). Learning how human organs and organ systems of the human body are structured and function which seems to be a mere descriptive issue is full of difficulties as noticed for Brazilian children (Rabello, 1994).

Teaching how the human body works, especially the nervous system involving the brain and thoughts demands a detailed planning. Society is facing a huge growth of neuroscience research and an explosion of information through the Internet and other popular media, influencing the school and in a way, how students learn in the classroom (Goswami & Szűcs, 2011; Battro et al., 2011).

Children’s conceptions of the brain were examined under the approach of explanations of mental phenomena, for example, remembering, thinking, dreaming as located in the head, in the brain (Johnson and Wellman, 1982; Johnson, 1990; Watson et al., 1998), brain imaging in medical situations Wilf et al., (1983), understanding of cerebral computed tomography scan procedure (Hellier et al., 1986), perception of organ and function before a pre-operative event (van Koot, 1990), usage of drawings to diagnose headaches (Stafstrom et al., 2002), and safety measures adopted when wearing helmets (Cynkar & Rutledge-Gorman, 2004). However, fewer studies looked at what children think is inside their heads, expressing their opinions by means of drawings, thus revealing their thoughts, dreams, and potential models of what they imagine the brain is and does (Savy and Clément, 2002, 2003; Bartoszeck and Bartoszeck, 2006). Thus, it is the goal of biology education researchers to identify the starting points for teaching from children and then find ways to add new knowledge to that which the pupil already possesses (Tunnicliffe, 2006).

The objective of the present study is to analyze qualitatively and quantitatively how the conception of the brain develops, whether there is a historical representation of the brain from pre-school pupils up to 4th graders, in their interaction with school and society at large (Lawson, 1988) in a Brazilian sample. This exploratory study, by means of drawings (Cox, 1992, 1997), aims to capture what the pupils think he/she has inside his/her head and the amount of

knowledge related to the brain and mental images or thoughts children have. The authors are unaware of any other study carried out with the same focus in Brazil.

Theoretical background

The concept of “science literacy” seems to include a view that a close observation of the natural world and what neuroscientists do is poorly known to the general public. One of the goals of Biology education, by means of neuroscience education, is to provide ways to teach how the brain works and what it does from very early, starting in the pre-school years (Zardetto-Smith et al., 2000; 2002). Children recognize that the brain is a very important biological organ (Gottfried et al., 1999).

However, very few studies looked at what children think is inside their heads (Savy and Clément, 2002, 2003), or inside themselves (Reiss et al., 2002). Thus, drawing is a tool that might reveal what is the mental model of the brain they may have on the perspective of “intellectual realism” (Luquet, 1927/1969; Cox, 1992). In this study, drawing of the contour of the head was adopted to probe the mental model of the brain which is hard to explore. Instead, an expressed model is expected, would bring to the surface, the mental models the pupil has of this biological organ (Gilbert & Boulter, 2000). Therefore, researchers could identify the starting points for teaching early year children, avoiding misconceptions on what the brain looks like and does, and devise ways to add new knowledge to that which the student already possesses (Tunnicliffe, 2006). Biological concept in this study is considered as a mental construct created by the learner in the cognitive structure of his mind and is supported by ideas, images, and tentative explanations to cope with a new problem in his environment (Giordan & de Vecchi, 1996; Clément, 1998; Reiss & Tunnicliffe, 1999).

Key objectives and research questions

- Investigate the structure & function of the brain (as a mental model) pupils may have manifested by means of a drawing depicted as the expressed model;
- Evaluate whether historical models of the brain are still depicted;
- Indicate if there is a development understanding of the brain by age and gender;
- Interview a few pupils to explain what they drew and how they think brain works

Participants, methods and data sources

The participants are grouped on kindergarten II (4 to 5 year-olds), kindergarten III (5 to 6 year-olds) [106 boys and 89 girls] pre-school, and as primary school, 1st through 4th graders [331 boys and 350 girls] (Table 1). The fieldwork was carried out at 8 Schools of Infancy Education (6 non fee paying and 2 private schools) and 8 Primary Schools (6 state funded and 2 private). The schools which agreed to participate were located downtown and in suburban areas in the cities of Curitiba and Foz do Iguaçu, Paraná State, Brazil as to reflect the availability of resources and social and cultural strata of the population sampled in southern Brazil. All subjects from this study were attending schools in classes corresponding to their ages.

Procedure

The researchers told the pupils that today they would perform a different kind of activity. They were asked to write down their first names, age on the top of a blank A4 sheet of paper with a black pencil. Next, pupils were asked to draw in pencil “what they think they have inside their head”. An outline of the head and a portion of the neck were drawn on the blackboard of the classroom to serve as a model. Alternatively, some pupils preferred to use the profile of a head, which was also accepted. The drawings were created under normal classroom conditions and pupils sat in desks no so close to each other, and asked not to copy from the drawings of the neighbors sitting nearby.

Table 1. Number (n) of pupils whose drawings representing the brain was collected in this sample

Grade	n	boys	girls
Kindergarten II (5 year-olds)	98	52	46
Kindergarten III (6 year-olds)	84	49	35
First (F)	154	71	83
Second (S)	161	93	68
Third (T)	187	72	115
Fourth (Fo)	227	117	110

Pupils were given 10 to 15 minutes to complete their drawing. Many pupils spontaneously labeled the internal biological structures on the outlines. The teacher wrote labels to the younger pupils (4 to 6 years old) for the biological structures when requested, but only the exact words in places on the outline pointed by the children. The field work was conducted in whole class settings.

Drawing analysis

A total of 1151 drawings were collected. Pupils’ distribution by grade level is indicated on Table 1. Classification of the drawings was done independently by the authors adapting the method of Savy and Clément, (2002) and depicted on Table 2. The authors by analyzing the drawings developed a classification, that in their view, there are representations of mental images, hydraulic, dog bone, “enteroid”, epithelial, “callote”, as well as neuroanatomical models. Few disagreements occurred in classifying the drawings according to models which were resolved between the authors before data processing.

Table 2. Kinds of models of the brain descriptive characteristics

Type	characteristics
Hydraulic model	Brain represented by lines as the flow of a small brook
Dog bone model	Brain represented as dog bone distributed all over the skull
Enteric model	Brain represented by tubes or thick threads similar to the intestine, on the top of the skull.
Epithelial model	Brain represented as patches of epithelial tissue on the top of the skull.
Neuroanatomical model	Brain roughly represented by right & left hemispheres.

Results

Our data revealed that children from pre-school through 4th graders are adepts of historical models of the brain, i. e. depicted as hydraulic, “dog bone”, enteric, epithelial, and finally a few neuro-anatomical models on their drawings (Fig. 1).

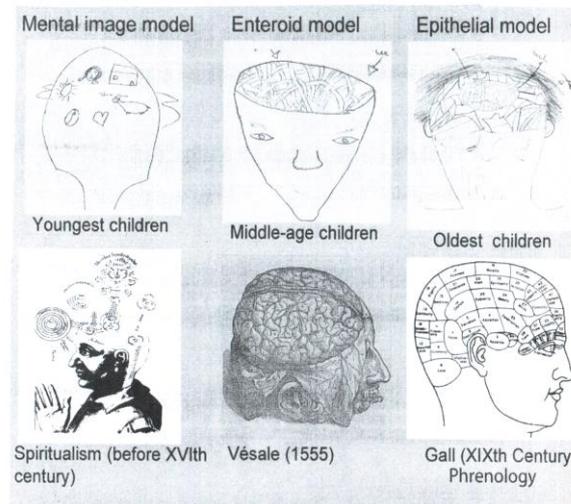


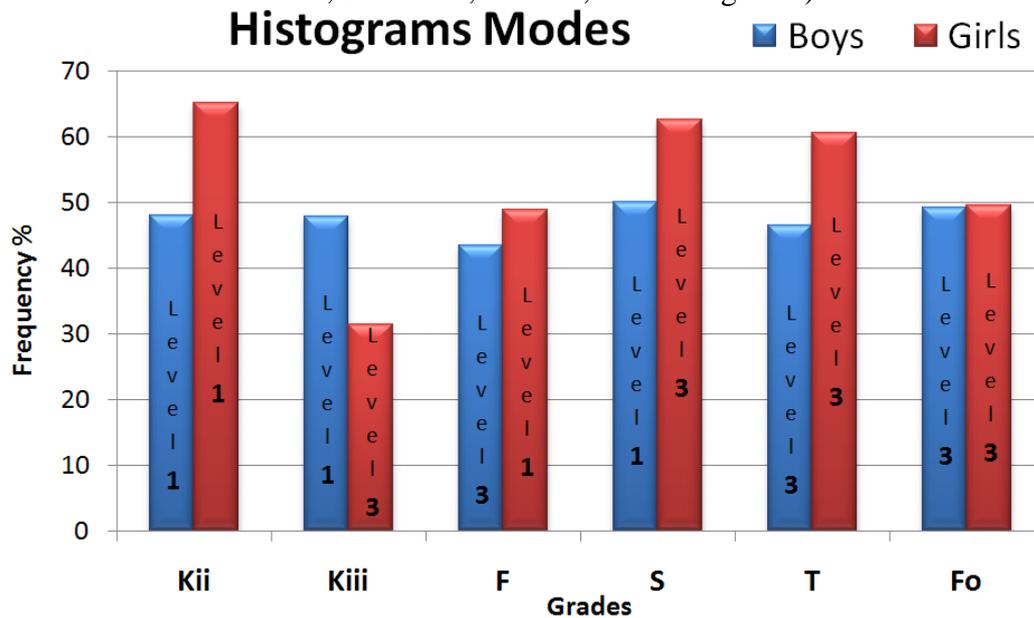
Figure 1. Examples of children’s conceptions of the brain corresponding to historical models (after Brazier, 1959; Edelman, 1992; Parent, 2009)

Not many students scored level 6 as the rubric used (Table 3). Most of them did not achieve higher levels (Table 4).

Table 3. The rubric used to allocating a grade to the drawings.

Level	Criteria
1	Do not attend the criteria.
2	Lines, entangling of threads spread all over the skull.
3	Amoeboid shape sphere with stripes or spokes or spiral lines.
4	Connecting tubes spread all over the skull.
5	Sphere-like or cranial “callote” shaped brain, connected or not to sense organs.
6	Roughly cerebral hemispheres with cerebral circumvolutions at approximate position, gross anatomical brain structure.

Table 4. Frequency in percentage achieved by boys and girls from the rubric used in Table 3. Notice that higher levels are not depicted as they reached very low frequencies. (Legend reads: kindergarten II,III=pre-school II [5 year olds], preschool III [6 year olds]; F=first, S=second, T=third, Fo=forth grades)



Some of them do not make a clear distinction between the biological structure of the brain and mental images i. e. their imagination as depicted in Fig.2.



Figure 2. A drawing by a 10 years-old boy, 4th grade representing a mental image (imagination, memory) model of the brain (caption reads: uma vaca=a cow).

During interviews to explain the children drawings and what the brain they think it does, younger pupils mention that: it is a place with pipes where blood and ideas circulate; where happiness lives; a place (organ) that helps see, sleep, dream and sometimes aches. Only in the higher grades (7 to 10 year olds) children drew pictures resembling the brain structures and how it works, as for example, they said in the interview, ideas are recorded and move in the inner lines; feel pain; gives will power; remember things, make eyes and ears, arms and legs work; control hunger and thirst, helps pay attention and think (Fig. 3).

Brazilian children's results from the present sample are very close to those found by (Savy & Clément, 2002) and (Savy, 2005) from 800 French pupils 6 to 11 year-olds. A low percentage of the students scored level 5 in the rating scale (1: lines all over the skull, to 6: cerebral hemispheres or cerebral circumvolutions at approximate position (see Table 4). Pupils from this sample do not make a clear distinction between the biological structures of the brain from thoughts represented as mental images of everyday experiences, their memories. When prompted to say something about their drawings, they mentioned that ideas circulate inside the brain and skull, the road is the tubing system. Progressively pupils draw pictures trying to explain what the organ is and its function, but still as with the French sample, the pupils do not separate thoughts completely from the biological structure that creates them. Organizing curricula contemplating nervous system issues would bring meaningful improvement in the learning of elementary neuroscience.



Figure 3. A drawing by a 7 years-old boy, 1st grade representing a hydraulic model of the brain

Evolution in drawings from per-school to 1st grade

Mental images defined here as an experience that , on most occasions, resembles the actual experience of perceiving some object, event or scene that occurs even when not present to the senses , tend to be reduced in percentage of the total drawings in this sample from pre-school to 4th grade. Apparently children do not separate memories, recalling of situations or mental images from the biological structure that generate them. The “ hydraulic model” (Fig. 3) still persists at the 1st grade but the “dog bone model” as depicted in Fig.4, which is an assembly the bones forming the skull is reduced as children get older, although about 50% of the drawings were considered unidentifiable (scribbling) according to the rubric used to allocating a grade to the drawings (Table 3).

“However, there is a progressive complexity improvement in the representation of the brain shaped as an epithelial, calotte and hemispheres (neuroanatomical) models as illustrated on Table 2.

Evolution in drawings from 2nd to the 4th grade

Although mental image drawings still persist in this range of grades, we observed a drop on the percentage for the hydraulic model, for the bone model and a meaningful increase in the elaboration of the brain shaped as a calotte located on the top of the head. Another point is that there is a decrease in the proportion of the unidentifiable drawings from 54 % at the kindergarten III pupils to 18.3% at the 4th grade. However, even at the 4th grade the brain is poorly represented (only 7.8% of the total sample) as distinguishable brain hemispheres (Fig. 6).

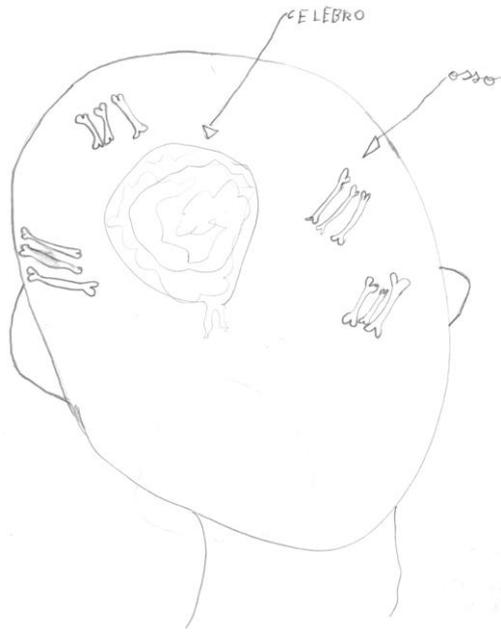


Figure 4. A drawing by a 6 years-old girl, representing a dog bone model of the skull and brain [kindergarten III] (captions read: cérebro=brain, osso= dog bones).



Figure 5. A drawing by a 6 years-old boy, kindergarten III, representing the brain in the shape of a “calotte” model (misspelled “selebro”=brain).



Figure 6. A drawing by a 10 years-old girl, 4th grade representing the brain hemispheres model and sensory organs (eyes)

Discussion and Educational Implications

There is a scarcity of studies concerning the development of the conception of brain in children and adult human beings (Clément, 1984, 1994, 1997; Mein & Clément, 1988; Kochkar et al., 2002). Young children build and developed their own models of the world and they become frameworks as how the world is progressively understood. Pupils from the early years try to understand and explain the brain's function and seem to succeed, but have a poor idea of its shape. Thus, they use their limited experience in other domains seeking for meaning, and only around 10 years old, similar to the French children sample, the brain hemispheres are more realistic depicted, but even so, evoking conceptions of historical models (Fig. 1). It seems from our data that children do not make a clear distinction between the biological structure of the human brain from thoughts represented as mental images, i. e. pictures of their thoughts as happy memories of vacations, parties and members of the family. Concerning the hydraulic model it may suggest for the youngest children, that thoughts circulate inside the skull and brain, the callote model may refer to the position of the brain on the top of the skull and may otherwise be shaped as an enteric gastric tubing, or as type epithelial tissue, where ideas circulate. These depictions may be viewed as representatives of the stage of "realism intellectual" (Luquet, 1927/1996; Bourassa, 1999). Organizing "hands-on" practices modeling the brain, spinal cord and sense organs activities would bring meaningful improvement in the learning of elementary neuroscience earlier starting in the pre-school years (Moreno et al., 1997; Gelman et al., 2010).

Implications

Pupils should be subjected to practical classes on the following topics:

- Create models depicting the human brain with clay or styro-foam;

- Practice in assembling brain parts into a skull plastic case;
- Use sandpaper pieces and wooden shaped small objects to identify tactile stimuli;
- Use flowers, perfume, and kitchen seasonings (e. g. cinnamon, clover) to identify scent stimuli;
- Visits to Natural Science Museum to watch and manipulate with care preserved fish, rat, bird, toad, primate and human brains in jars.

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Çocukların beyine ilişkin kavramalarını araştırma: İlk adımlar

Bu makale insan beyni kavramı ile ilgili olarak, birinci sınıftan dördüncü sınıfa kadar olan 7-10 yaş aralığında 681 ilköğretim öğrencisi ve 195 Brezilyalı okul öncesi çocuklarını (4-6 yaş aralığı) çizimlerinin kullanımını içeren değişimli bir çalışmayı rapor etmektedir. Bu çalışmada beyin kavramının nasıl geliştiğini, çocukların beyinlerini nasıl temsil ettiklerini, bunun tarihsel modellere mi? yoksa günümüzdeki bilimsel bilgiye mi? dayandığını, bu bağlamda okul ve toplumun etkileşimini analiz etmek amaçlanmıştır. Metot, baş ve boyun çevresinin sınıftaki tahtada çizimini içermektedir ve çocuklara başlarının içinde ne bulunduğu sorulmuştur. Çizimden sonra bazı öğrencilerin yaptıkları çizimleri açıklamak amacı ile görüşmeler yapılmıştır. Toplanan çizimlerin sınıflandırması için beynin tarihsel modellerinin perspektifi yorumlanmış, nöroanatomik benzerlik derecesindeki tanımlanan altılı bir likert tipi ölçek ile puanlanmıştır. Cinsiyet ve yaş dikkate alınmıştır. Sonuçlar, daha genç öğrencilerin beyinlerinin betimlemesinde zihinsel fikirlerin uzmanı olduklarını, başka bir ifade ile beyin ne yapar? Fakat yaşları arttıkça beynin daha morfolojik bir betimlemesini geliştirmeye başladılar. Erken nörobilim ve sinir sistemi ile ilgili olarak öğrenme için bilgi engelleri olası etkileri tartışılır.

Anahtar kavramlar: biyolojik kavramlar, zihinsel imajlar, tarihsel beyin betimlemeleri, çocuklar, okul öncesi&ilköğretim okulu