MEANINGFUL LEARNIG IN PHYSICS EDUCATION. IS OUR BRAIN PHYSIOLOGICALLY CONSTRUCTIVIST?

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Abstract

About 50 years ago the most widespread method of teaching was purely receptive. Discovery learning (causal or directed) followed afterwards, and now is widely accepted that meaningful learning is the more effective educational system. The question is what will be the preferred pedagogical method in a few years? How many years will last this trend to consider meaningful learning as the best teaching method? In the present work we have constructed a reasoning entitled "Is our brain physiologically constructivist?" in order to highlight the need for meaningful learning in the teaching of physics.

Specifically, we want to show that constructivism is not just another pedagogical trend. Physiologically, our brain is so constituted that works searching for the meaning of the information it receives and, therefore, meaningful learning is not a teaching option, but a physiological requirement of our brain.

Currently, little is known of the influence of the physiology of the brain in its way to conceptualize, but it is widely studied its physiological way to visualize (create visual images) in which the brain function is "to actively construct our visual world". The processes of visualization and conceptualization have many common characteristics. What is done in both is to abstract the constant features of either the "objects" or the "objects or events" and build either a visual world or a cognitive structure. We could therefore "extrapolate" what is known of the brain process of viewing to the brain process of conceptualization.

The brain works very similar when visualizing and when conceptualizing. When the brain visualizes what it does is search for the meaning of the information that reaches it. When the brain conceptualizes what it does is search for the meaning of the information it receives. We conclude, therefore, that meaningful learning is not just a new teaching trend, but the way our brain functions.

Keywords: Meaningful learning, physics, didactics, constructivism.

1 INTRODUCTION

1.1 Learning Theories

Constructivist learning approaches have been established from Piaget's research on the genetic development of intelligence [1, 2]. Piaget's theories indicate the starting point of constructivist learning as a process of internal construction, active and individual. For this author the basic mechanism of knowledge acquisition is a process in which new information is incorporated into pre-existing schemas in the minds of students, which change and reorganize as a mechanism of assimilation and accommodation provided by the activity of the person. Piaget did not claim his research to have educational implications. However, they were inevitable, because the knowledge that is intended to be learned by the student must adapt to their cognitive structure [3].

Piaget's theories were the starting point for further research that questioned behavioral learning approaches. For example, Ausubel [4, 5], with his theory of meaningful learning, and Vygotsky [6], with the integration of psychological and socio-cultural aspects, have had a great impact on psychology, pedagogy and education today, in regard to learning theory. Ausubel coined the terminology "meaningful learning" to distinguish it from repetitive or rote learning, based on the idea of Piaget on the role of prior knowledge in acquiring new information. To Ausubel [5] meaningfulness is only possible if we manage to relate new knowledge with that already owned by the subject. In this sense, Ausubel makes a great critic to learning through discovery and to traditional repetitive

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mechanical teaching, stating that they are not very effective for learning science. For him, learning means understanding, and it is therefore necessary to consider what the student already knows about the subject taught. He proposes the need to design cognitive bridges from which students can build meaningful relationships with the new content. He defends a significant didactic model of transmission-reception to overcome the deficiencies of the traditional model, taking into account the starting point of the students and the structure and hierarchy of concepts.

Novak [7], base don Ausubel's work on the integration of knowledge, states that new learning depends on the quantity and quality of cognitive organization structures in each person. Therefore, for Ausubel and Novak, the key is to know the students' previous ideas [3].

Considering this background, and based on the reflections on the construction of scientific knowledge of many researchers, we can consider that cognitive psychology has allowed us to clarify and understand how our students learn. These contributions necessarily affect cognitive psychology, in the teaching of different disciplines of human knowledge, such as, for instance, our area of expertise: the teaching of physics. Some authors [8] state that constructivism is now the dominant paradigm in cognitive research in education. However, the question we pose in this paper is, is the theory of meaningful learning just another pedagogical paradigm? Or is meaningful learning a physiological requirement of our brain due to its physiological constitution?

Currently there are numerous studies that have explored how the brain acquires information from the outside world when viewing [9,10,11], and yet, how the brain works when it conceptualizes is poorly studied. In this paper, therefore, we try to relate and extrapolate knowledge about the physiology of the brain in the process of viewing to what happens in the process of conceptualization, in order to show that meaningful learning in teaching physics is a physiological need for our brain, rather than just an educational paradigm of the moment.

Some authors [12] consider that the most important achievement of cognitive psychology has been to prove the need for mental representation to explain cognitive phenomena, from perception to understanding. It is believed that our mind operates or processes a large number of perceptions, ideas, beliefs, assumptions, thoughts and memories, and that all these realities we perceive are mental representations or symbols of one kind or another. That is, the process begins in the sensory system. When we see something the brain must create symbolic representations of physical information and then operate on those representations. The visual system study involves the investigation of how the brain acquires knowledge of the outside world, approach discussed in recent years in various researches, and not an easy task.

More specifically, neurology clearly establishes symbolic representations as a need to know and understand reality. For example, some authors [13] state that although the main function of the visual system is to perceive objects and events in the world around us, the information available to our eyes is not enough by itself for the brain to make its unique interpretation of the visual world. The brain has to rely on past experience to interpret the information received by the eyes.

This approach is related to the statement made by Ausubel in his book *"Educational Psychology: A Cognitive View," [4], where he states that: "If I had to reduce all of educational psychology to just one principle, I would say this: The most important single factor influencing learning is what the learner already knows. Ascertain this and teach him accordingly".* This principle is now recognized as fundamental to understanding how people learn, specifically how they construct new knowledge by integrating new concepts and propositions to relevant concepts and propositions they already knew. Ausubel's Assimilation Theory explains how humans construct their knowledge or cognitive structures. The challenge for the teacher is to identify with some precision the concepts and propositions that students already know which are relevant to the material to be learned, and then design instruction to facilitate the integration of new concepts and propositions in the knowledge or cognitive structure of that student. Now the question that arises is, is imaging formation is a constructive process? Is vision related to perception?

1.2 The formation of visual images in our brain

The current explanations of the formation of visual images in the brain have been the result of the evolution of numerous research studies in recent years. For example, at the end of the last century, the early neurologists believed that objects transmitted visual codes in the light they emitted or reflected, which led them to believe that the images were printed on the retina, as if it were a photographic plate. The retinal impressions were then passed on to the visual cortex, which analyzed the codes contained in the image. This decoding process led into vision [9, 12].

On the other hand, the understanding of what it is being seen, i.e., the attribution of meaning to the impressions received and their resolution into visual objects, was considered a separate process, emerged from the association of the received impressions with other similar previously experienced. This way of understanding how the brain works created a separation between vision and understanding, between feeling (vision) and perceiving (understanding and meaning), and gave each one of these faculties different locations in the brain. However, the later discovery of parallel systems operating in the vision processes concluded that, although they have autonomy, they are interrelated so that they integrate visual information. This way perception and understanding occur simultaneously [9]. Thus, some ulterior research [10] on the visual association cortex have shown that it is formed by many different areas. These regions are individually specialized to perform different tasks, marking a shift in the way we understand the construction of the visual image in the brain. These findings were discovered after certain studies on brain diseases. They showed that there are discrete cortical areas and subregions of such areas, which are specialized in specific visual functions, so that if one of them is affected, the patient shows inability to acquire knowledge of some aspect of the visual world.

Figure 1 shows the different regions of the visual cortex [9].

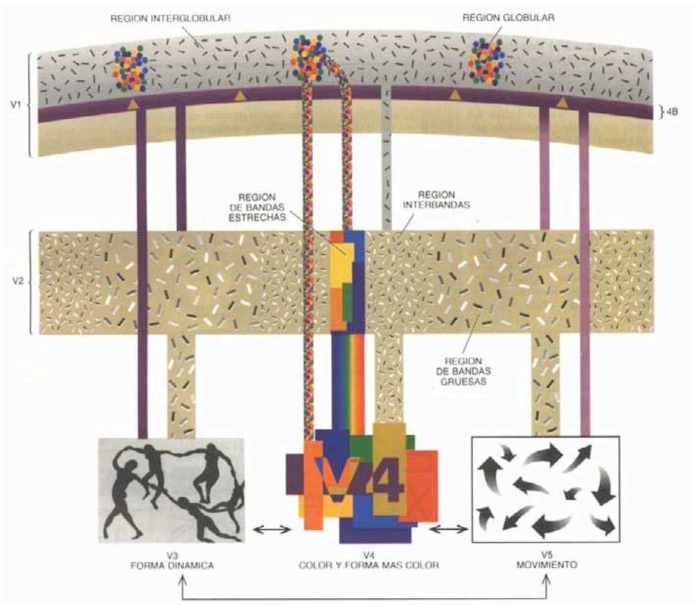


Fig. 1 Perceptual routes identified in the visual cortex. Color is seen when cells sensitive to the wavelength of light, located in globular regions V1, send signals to the V4 specialized area and to the V2 narrow bands, which connect to V4. The form detection associated to color is mediated through connections between V1 interglobular regions, V2 interbands and the V4 area. Certain cells of layer 4B from area V1 send signals to the V3 and V5 specialized regions, both directly and through the V2 area thick bands; these connections enable motion and dynamic form perception.

That is, when seeing an image, different areas of the cortex analyze it, searching for different attributes such as shape, color and movement. Thus, "vision" and "understanding" are produced simultaneously, due to the synchronism of activities in these cortical areas. Therefore, the world we see is an invention of the visual brain [9].

On the formation of the visual image in the mind and brain, some authors [9,10] consider that the brain task is to extract constant and invariant features of the objects based on the information it receives from them. Interpretation is an inextricable part of sensation. Therefore, to gain knowledge of what is visible, the brain cannot be limited to a mere analysis of the images that are presented to the retina; it must actively build a visual world. Other authors [13] note that "seeing" is a constructive process, a process in which the brain must perform complex activities to decide which interpretation of an ambiguous visual stimulus is adopting. That is, the brain acts to form a symbolic representation of the visual world.

For authors like Zeki [9], the modern conception of the visual brain has evolved only within the last decades. The processes of vision and understanding cannot be separated, and there is no place to take awareness apart from visual knowledge acquisition. Consciousness is a property of the nervous apparatus that the brain has developed in order to acquire knowledge. Other authors [12] concluded that seeing, understanding, recognizing a familiar face, learning..., requires the brain, the mind, to build precise symbolic representations of what the world provides. Psychology has various concepts coined to refer to these mental representations: sketches, prototypes, regions... and it has tried to explain how we represent what we know.

2 INITIAL APPROACH

Considering the bibliographic references described in the previous section, and since the processes of visualization and conceptualization have many common features (both abstract the constant features of either "objects" or "objects or events", and build either a visual world [9] or a cognitive structure [5]), we will try to "extrapolate" what is known about the visualization visual process to the brain cerebral process of conceptualization. Some authors define the conceptualization as an abstract and simplified view about the knowledge we have of the world that we want to represent. This representation is our knowledge of the world, in which each concept is expressed in terms of verbal relations with other concepts and their real-world examples (attribute relationships, not necessarily hierarchical), and also with multiple hierarchical relationships (categorization, or object allocation to one or more categories). Conceptualizing, therefore, can be considered as "the development or construction of abstract ideas from experience: our conscious understanding of the world" [14].

In this paper, we will focus on the following starting points:

a) When the brain visualizes (when creating visual images), it acts very similar to when it conceptualizes.

b) Because of its physiological constitution, when the brain visualizes, it does so looking up the meaning of the visual information it receives.

c) It is highly probable that when the brain conceptualizes, due to its physiological constitution, it does so looking for the meaning of the information it receives.

The reasoning that underlies our statement has two parts: The first is to accept that the brain does a very similar function during the processes of viewing and conceptualizing .The second is to highlight in this paper that, because of their physiological constitution, when the brain visualizes, it does so searching the meaning of the visual information it receives. If we get both purposes the conclusion is obvious: If the brain visualizes and conceptualizes following very similar processes, and we highlight that when the brain visualizes it looks up the meaning of the information that arrives, we conclude that when the brain conceptualizes it does look up the meaning of the information it receives. Therefore, meaningful learning is not just another pedagogical paradigm, but rather the physiological why of how our brain works.

As noted in the literature review in the previous section, our brain stores the different features of visual images in separate areas, but then coordinates all of them to obtain a coherent world view, i.e., it relates those features to each other to give them meaning, thus creating their visual images [9].

Let's try a little exercise as an example. First, think in our image of chair, and then think of our concept of chair. Aren't we doing the same? In both cases (visualization process [9] and conceptualization process [15]) we are abstracting the constant features that "all" the chairs have. As many authors as Ausubel have analyzed extensively, we can abstract its attributes, properties or characteristics that make them similar to each other, forming a category mentally represented by a concept and denoted by the same word [15].Also, innumerable sets of objects, such as that formed by wooden chairs, plastic chairs, chairs in our work offices or in our homes, with rectangular or round seating, large or small, all the existing chairs in the world, belong or are members of the same category, mentally represented with the same "chair" concept and denoted by the same word: chair.

If you made this little exercise and you thought both on the image of a chair and on the concept of a chair, consider the following question: Don't you think that the brain acts very similarly when it visualizes and when it conceptualizes? If we conclude that it is very likely, we can extrapolate what we know about the physiology of the visualization process (which is a great amount) to the field of the conceptualization process (where very little is known). In the following sections we highlight that when the brain visualizes, it looks for the meaning of the information received through the retina, and that can be generalized to the conceptualization process and conclude accordingly.

3 OUR VISION IS MEANINGFUL

Consider the following example using the illusory figure of a duck or a rabbit by Jatrow [16,17]. If you were asked what do you see in Figure 2, you will find that you are looking at your "database" of visual images to see which of them you can relate to what you are seeing. The result is that there are two possibilities; you can relate it to a duck looking to the left side or a rabbit facing the right side. In the process we have been relating what we're seeing (what we are learning) with what already exists in our brain (what we already know). That is exactly what is stated in the meaningful learning theory [5].

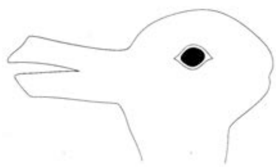


Fig. 2 Jatrow's duck-rabbit

Now look at the image in Figure 3. Could describe it? Is it even possible? What is happening in your brain? You will find out that your brain is not able to find a visual image in your memory to associate to what you are viewing. That is, your brain is not able to find any meaning for the image (just as it often happens to our students when they are attempting to learn a concept). The image shows a three-pronged fork (circular section), which parts fit together in an impossible way as two connected rectangular branches.

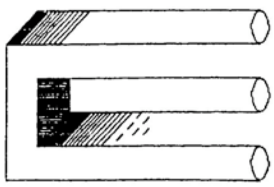


Fig. 3 Example of a blivet or impossible object [18]

This image has no "logical significance" [5]. This situation is unprecedented in our brain, which is unable to relate the visual information to anything. Therefore, if we want to remember that image, we'd have to "memorize it" side to side, segment by segment, and soon it will disappear from our memory. We can relate what happens when viewing figure 3 to Ausubel's meaningful learning theory, which stresses the need of a "logical significance of the material", i.e., that the material presented has an organized internal structure, that is likely to result in the construction of meaning. Let's do a test: try to reproduce the image in Figure 2 and in Figure 3. Without much effort you can reproduce an image similar to that seen in the Fig. 2, but you will feel a great discomfort when trying to draw Fig. 3. The reason is because in the first figure you found meaning, and that meaning is now what you intend to reproduce. But in the second figure, you fail to find a meaning; you do not know what features are really important to appear on the drawing.

Now look at the picture in Figure 4, taken from the book "Recreational Physics" [19]. If we look closely we can see that the perception of it changes and alternates between seeing a cube located over three other cubes, and seeing a cube below other three cubes. This figure shows that, sometimes, the same information can be interpreted by our brain in different ways, and associate it with different prior knowledge existing in the "visual structure" of the individual.

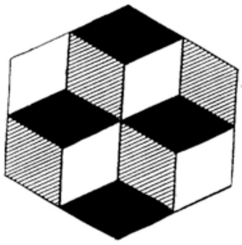


Fig. 4 Cubes

Consider the example of Figure 5 [20]. We must look at the image with just one eye (covering the other) in front of the black point and looking away to the squares at the right side. In some moment the top and bottom lines will be seen as continuous, without discontinuities in them. This is due to the fact that the brain is so used to working with the information received from the retina that it "knows" that there is a zone in which there are no photoreceptors (the blind spot). If no information is received from that area of the retina, the brain expects it to be caused to this lack of photoreceptors, and not because there is no real information. Consequently, the brain "reconstructs" the image including the missing visual information that supposedly exists.

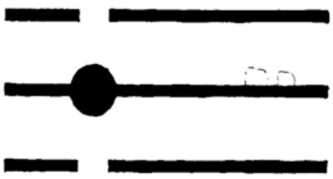


Fig. 5 Example of image recomposition. This optical illusion devised by Vilayanur S. Ramachandran illustrates the ability of the brain to supply, complete or build the visual information that is missing because it falls within the blind spot.

This "search for meaning" is seen not only in the formation of static visual images, but also can be seen when moving images are perceived. We all know from experience what will we perceive if we successively see the sequence of images appearing in each one of the columns of Figure 6,. In the case of the left column we will perceive the correct rotation of the wheel. In the middle column the wheel will appear motionless. Lastly, in the right column the sense of rotation will seem the opposite to the real movement. We could think of the figures as frames from a movie. If one of the spokes is painted black to differentiate it from the others, we note that in the case of the left column, from one frame to the next, to the wheel turns 45°. In the center column the wheel spins exactly one turn, and the right column it spins around minus 45° (315°). Thus the sequence of images we receive is the one corresponding to the interpretation of the movement that the brain makes, acting properly according to its experience. The brain is used to verify that, when you receive an image sequence, the motion of the object is the way he interprets. That is, visual information is associated with what comes from previous experience.

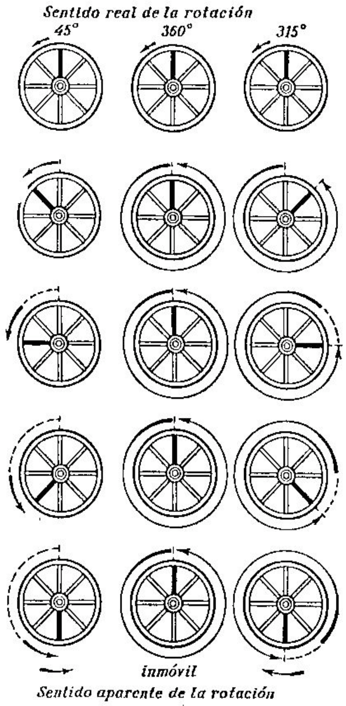


Fig. 6 Mysterious movements on the wheels on a movie screen [19]

4 READING IS ALSO MEANINGFUL

We may continue our reasoning with a vision application so common as reading. How does our brain work when reading? If you look at the image in Figure 7, we find that we can read it until the end, even though the three bottom lines feature only one half of each letter and, moreover, some letters are wrong.

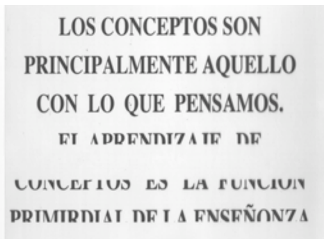
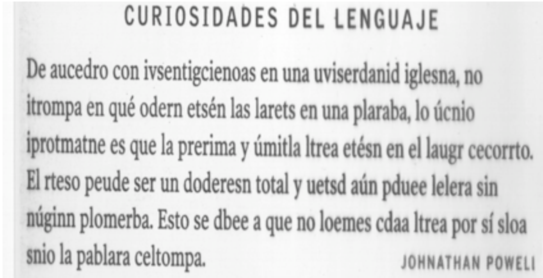


Fig. 7 Example of incomplete text

Our brain is getting enough visual information to find the meaning of the sentence, which is what really interests us. Moreover, if we try to read the fourth and fifth line, we find that the fourth is read better. This is because the top half of the letters is better identified because we read from top to bottom. Our eyes start scanning the top of the letters and when we recognize them (when we find its meaning), they move into the next line without reaching the bottom. We really do not read letter by letter. We are looking for meaning, so we look at more letters (even whole words) at a time, and when we find the meaning we continue to the next group. This is the main reason for newspapers to be written in short rows columns. The width in those rows is appropriate for us to find meaning at a glance. That is, we read looking at an entire row, and when we obtain its meaning we move to the next row. We do not read all the letters. Hence, to find spell mistakes in a document is very convenient to hand it over to a person other than the author, because the author may "read" several times what he really wanted to write without appreciating the mistakes. We do not even see the whole letters, as we stop looking at them once we capture the information needed to get the meaning (which is what we really want) and move on. Whenever our brain receives the minimum necessary information, its work will focus on finding the meaning of what is written, and thus it can successfully complete its task.



CURIOSIDADES DEL LENGUAJE

De aucedro con ivsentigcienoas en una uviserdanid iglesna, no itrompa en qué odern etsén las larets en una plaraba, lo úcnio iprotmatne es que la prerima y úmitla ltrea etésn en el laugr cecorrto. El rteso peude ser un doderesn total y uetsd aún pduee lelera sin núginn plomerba. Esto se dbee a que no loemes cdaa ltrea por sí sloa snio la pablara celtompa.

JOHNATHAN POWELI

Fig. 8 Language curiosities

A prove of the correctness of our theory may be found on the book "Emotional Intelligence" [21]. Figure 8 shows an illustration from the book that schematically illustrates the process of cerebral vision. It indicates that visual information reaches the thalamus and from there the majority goes to the brain which "analyzes it and evaluates it in search of meaning." A small fraction of the output signal goes from the thalamus directly to the amygdala, without going through the visual cortex. This is done to not waste time finding its meaning in case we need a very fast reaction, which sometimes happens when we see a coiled rope and we jumped in fright, thinking that it was a snake. The meaningless part of the visual information that reaches the amygdala from the thalamus makes us jump, but when the bulk of the information goes through the visual cortex its meaning is determined, and the misunderstanding is cleared up.

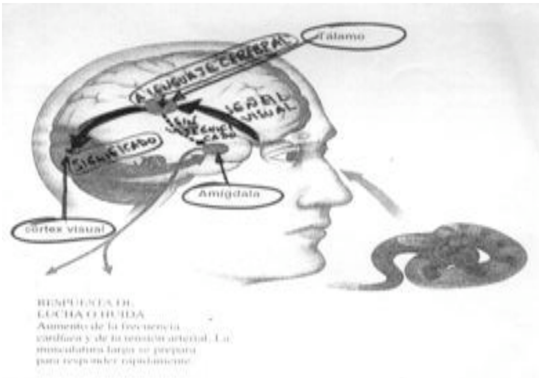


Fig. 9 Schematic illustration of the overall view process

Another example that clearly shows that when we visualize what we do is to look up the meaning of the information that reaches our retinas and from there to our brain are stereograms. Figure 9 shows one of them that hosted at https://plus.google.com/photos/111374320213520522218/albums/5725753581183666225?banner=pwa&gpsrc=pwrd1#photos/111374320213520522218/albums/5725753581183666225/5725755351426067570. This drawing contains visual information that initially is not significant for our brains, but if we work hard at it and apply the appropriate technique (look at a point a few inches behind the paper) and some patience, after a certain time an image of a skull will be revealed. Those who have made through this experience confesses unanimously to feel a kind of joy and serenity sensation to get it. This also happens to our students when they get to find the meaning of a concept that we are explaining, which also need all that was noted a few lines above about applying the right technique and have patience.

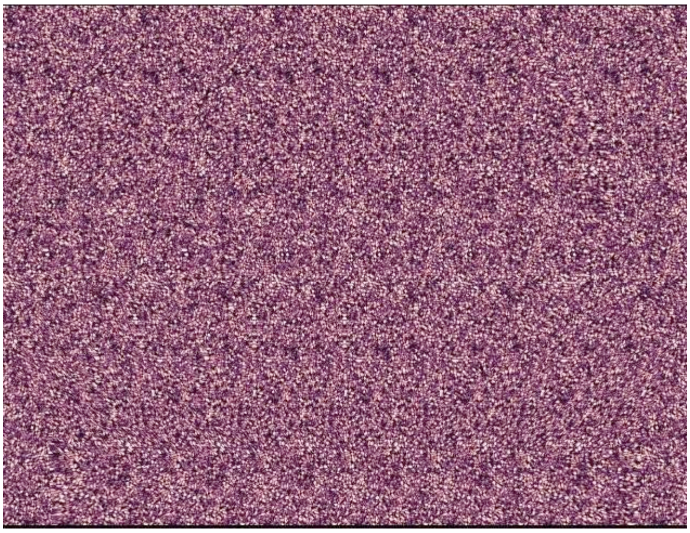


Fig. 10 Stereogram example

But we not only seek meaning in the visualization process, the search for meaning is a necessary condition for the survival of the species. If we imagine an small animal which receives a series of information (such as a visual image, a smell, a roar, etc.) from a wolf, and it is not able to determine that its meaning is "a predator is going to attack me", it won't be able to act accordingly, and its species will disappear in a few generations. Or if it sees a fruit of a certain color and it is not capable of appreciating that it means that the fruit is mature and can be eaten, the same thing would happen.

5 CONCLUSIONS

At the beginning this communication we accepted that the brain process of conceptualization is very similar to that of visualization. Due to their physiological constitution, during the visualization process, the function of our brain is to seek the meaning of the visual information that arrives. We must then conclude that, because of their physiological constitution, also during the conceptualization process the mission of the brain is to seek the meaning of the information that arrives. Therefore, meaningful learning theory is not just the pedagogical paradigm of the moment; our brain is physiologically constituted so its function, when forming concepts, is to look up the meaning of the information it receives. This finding is of great significance, because it is a key motivation for our students during the study of the Constructivist Theory of Learning.

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