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COGNITIVE MECHANISMS IN THE DIDACTICS OF TECHNICAL VOCATIONAL SUBJECTS IN THE LIGHT OF RESEARCH ON BIOELECTRICAL BRAIN ACTIVITY

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Abstract. *The main objective of the paper is to present arguments about the multidimensional character of effectiveness of school education and to discuss a number of factors that influence the outcome of education directly or indirectly. Assessing the effectiveness of school education sheds light on its current problems and indicates directions for future research on innovative approaches to solving such problems. Preliminary assumptions for research based on EEG results concerning cognitive performance during student learning in technical fields will also be presented.*
Keywords: *teaching, effectiveness of education, modern teaching aids, cognitive process, EEG.*

Introduction

The problem of effectiveness as the most sought quality of education can be considered at many levels. Specialists in didactics often assess the effects of education by means of experimental research aimed to evaluate knowledge, skills or social competences. The evaluation is typically carried out by means of selected indicators, defined in research hypotheses, and related to tasks performed by a student. The knowledge and skills at two given stages are evaluated and compared. Measure of association between dependent and independent variables is verified by means of statistical calculations. Rejecting the null hypotheses and adopting alternative ones is the most frequent way to prove the validity of assumptions and solutions proposed for the main research problem (Prauzner, 2013, 2017). However, the question about a source of the dependent variables remains to be answered. The result of human work is analysed in terms of its assessment according to a certain scale. This paper seeks to offer some explanations of the sources of cognitive activity and to answer questions concerning the behaviour of an individual facing a task to be performed. The topic is very broad, transgressing the borders of pedagogy and involving other domains.

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Many years of observations and research form a basis of a reflection combining a theory of general education and cognitive psychology.

Discussion

As a starting point, it is worthwhile to consider the characteristics of cognitive psychology, as a field of science dealing with human cognition of the reality. From a didactic perspective, all human behaviours and responses result from forming mental representations, created by the operation of certain mechanisms. As defined in a dictionary, *„cognitive psychology is a subdiscipline of psychology investigating cognitive processes and structures and the general principles of the functioning of the human mind. Cognitive psychology is an interdisciplinary domain, drawing on research conducted within biology, psychology, linguistics and information science. Its aims include investigating the mechanisms governing thought processes enabling cognition, such as perception, memory, learning, concept construction and logical reasoning"* (Sillamy, 1994). Such mechanisms are described as cognitive processes, which enable the mind to create and transform knowledge structures and skills in response to previous observations and experiences (Nęcka, 2006). The above mentioned cognitive mechanisms exist due to the fact that the mind processes information, creating new associations and concepts. Cognitive psychology is an experimental science, which means that forming and verifying hypothesis is a part of its paradigm. Because of this, when new behaviors are observed in human beings, attempts are made to offer explanations of such behaviours, also in pedagogical terms. Psychology explains human behaviour in terms of the variety of instincts being a driving force behind human activities, including an urge to attain success. In the behaviouristic paradigm human behaviour is accounted for in terms of reinforcing or inhibiting external stimuli affecting human conduct. Cognitive science recognizes this kind of explanation of human behaviour, acknowledging the fact that stimuli directly impinge on human behaviour. In fact, we are all aware of the connection between stimuli encountered in everyday life, work and education, and behaviour. Such stimuli are received via a number of perceptual mechanisms. As cognitive psychology underscores, thought processes are responsible for the human ability to make decisions about one's actions and attitudes (Anderson, 1991, 2007). Because of this, human being is an individual capable of entertaining representations conducive for creative thinking. According to the psychology of creativity, a creative attitude involves an ability to construct something new or an original style of expressing one's ideas. Creativity can also be seen as a result of human abilities, such as abstract and symbolic thinking. Creative thinking is a means to solving problems. An individual way of solving a problem is an example of creativity, since one's work results in constructing an innovative model of a solution. *„All is needed for dormant imagination and thoughts to be motivated for undertaking a creative effort is stimulating conditions. Creativity oriented towards higher values engages not only our reason but also feelings, experience, desires and fear." „The most frequent cause of imagination and creative thinking being inactive is the lack of stimulating condition and the lack of motivation for undertaking effort"* (Madej, 2006). As is often pointed out, motivating a student to work, should be preceded by an assessment of his/her abilities and limitations. Creative activity can be thus understood as individual progress relative to one's interpersonal skills, abilities and intellect. This standpoint will underlie research to be presented in further considerations and publications concerning cognitive processes, based on EEG and QEEG tests.

Creativity can be useful not only for the environment. It can also be a mechanism for developing personality and social aptitude. Kozielecki rightly observes that "*creativity can be seen as transgressing the limits of one's possibilities* (1980)." The nature of creativity was also discussed by such classical philosophers as Plato, Aristotle, Kant, Schopenhauer and Nietzsche. Similarities and differences between problem solving and creative thinking were also dealt with in a number of works by other thinkers and philosophers, including Dewey (1967), Wallas (1926), Stróżewski (2007) and many others. From a didactic perspective, the education process is based in a correlation of subjects participating in it.

In the era dominated by modern technologies aiding the education process, the model of relationship among didactic activities is aptly represented by a didactic tetrahedron, formed on the basis of two dimensional relations between S (Student), I (Instructor), DM (Didactic Material) and DCS (Didactic Computer System) (Fig.1).

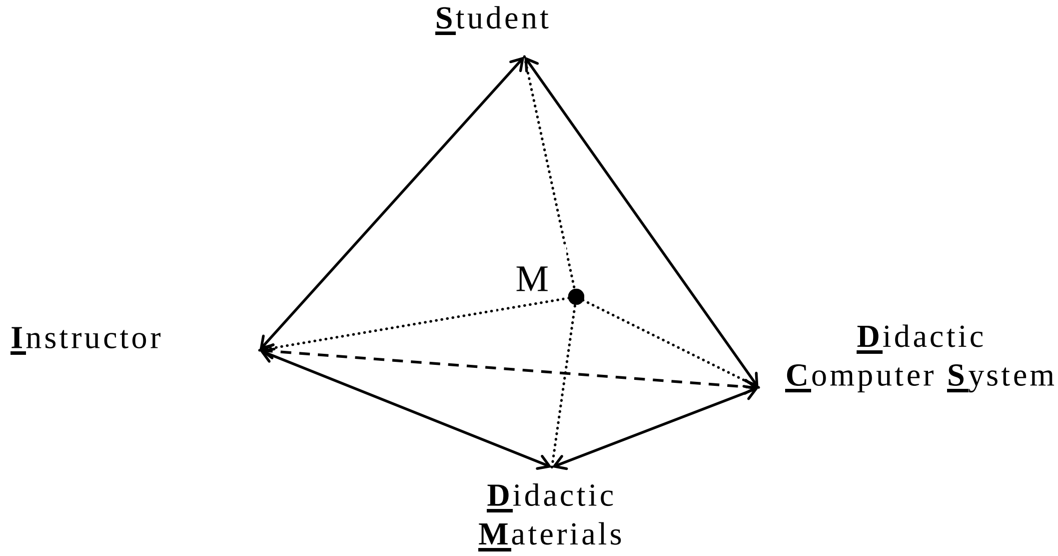

Fig. 1. **Model of relationships between didactic activities** (Barski, 1998, p. 85)

The above-presented model of the didactic process can be modified, depending on the subject, topic of the class, age of students, conditions of providing instruction, etc. The model may not be ideal, as it does not include of the elements of the teaching process, however it is sufficient for the current purposes of discussing effectiveness of education since it provides space for modern teaching aids. Such aids are useful both for the teacher and the student, so their function cannot be overestimated. They include simple teaching aids or didactic materials enabling or facilitating the teaching process. The model represents both one-dimensional and two-dimensional relations. The former are visualised as axes connecting the two extreme apexes of the model: S-DM, I-DM, I-S, S-DCS, I-DCS, DM-DCS. In a simplified way, they capture relationships between two subjects, connecting the three apexes of the solid figure. Naturally, the fourth element is never beyond the didactic space. A randomly chosen point M determines the strength of the connection between the elements of the cognitive process. Its location within the confined space determines the adopted form and method of education, as well as preference for some elements. The didactic computer system can be thus treated as an auxiliary means for raising the effectiveness of the teaching process. Examples of implementations of such as system include simulation software recommended in technical and vocational training (Ptak, 2015, 2016). The model presented above can be considered traditional, since in the era of the development of information technology, didactic computer systems tend to occupy increasingly important place. Their role as aids supporting the traditional learning is continuously loosing significance, as they are being replaced by integrated complex virtual learning environments. The role of the other elements of the tetrahedron is also diminishing or at least changing. Didactic materials are becoming a part of computer software and the role of the instructor is that of a coordinator of the whole process. Even though the role of the instructor is still crucial, it is the one-dimensional relationship S-DCS that is gaining the greatest importance.

According to cognitivists, a student can initiate and exercise cognitive activities and also decide about its results. By processing information, he/she develops new and creative ways of defining a stimulus, in this way choosing a response to that stimulus. Such responses are created on the basis of individual learning within associative memory, combining declarative and procedural memory. Creativity is also affected by abilities and motivation of an individual, which in turn depends on the physical and social environment surrounding that individual. Declarative memory is defined as a relationship between an object of cognition and an event, whereas procedural memory refers to the ability to make use an object’s functions. Patterns for reference are stored in long-term memory (in the form of a code), which provides a basis for meta-cognitive knowledge, such as observations, comments, memories, thoughts and decision-making. New information is confronted in the brain with known information and on the basis of the comparison conclusions are drawn in an attempt to answer questions constituting a part of the task.

Constructivist point out that the effect of the newly constructed knowledge is influenced not only by the magnitude of previously stored knowledge, but also the environmental conditions in which the cognitive process is taking place. The point in question is not only the atmosphere or the number of classmates but most importantly the quality of communication and the source of information. Cognitive theories of learning and teaching play a major role in computer-aided education. Besides, in accordance with constructivists assumptions, the teacher is only a person fostering the learning process, so the educational methods employing modern information technology are gaining significance. Creating new knowledge structures results from, among other factors, using appropriately selected didactic aids. The structures can be remembered for a short time if a situation so requires, but they can also become stored in long-term memory. From the viewpoint of didactic effectiveness, acquiring new knowledge and storing it in the long-term memory is the most desirable. Such knowledge provides a permanent basis for solving problems which may appear in new situations. Thanks to the constructional activity of the mind a new internal cognitive representation of the world is created. Didactic aids in question include computer programmes, especially those offering deterministic computer simulations conducive to technical and vocational learning. Learning then involves creating new knowledge resources by means of modern tools of cognition, representing a complex graphic interpretation of reality. Visualisation, degree of detail in a picture, colours and dynamics of motion are perceived through the sense of sight. In a medical sense, this process can be described in a simplified way as follows:

- an object observed reflects optical waves, which are perceived as a stimulus by the sight organ;
- subsequently, photochemical reactions occur in the retina (coding information), electrical nerve impulses are produced and conducted to the appropriate areas of the visual cortex;
- the newly perceived stimuli are associated with other stimuli originating from other brain areas. Information is encoded and sent to the motor cortex (this is known as programming the response), and subsequently to other parts of the body.

Teaching can be described as polysensory when beside the dominant sense of sight other senses, such as hearing and kinaesthetic experience are involved. As postulated by the Multiple Intelligences Theory by Howard Gardner, teaching methods should be selected accordingly to the polysensory preferences of a student (Gerring & Zimbardo, 2008).

Methodology

The main objective of this paper is to present the results of a preliminary stage of investigations on the cognitive activity assessed on the basis of bioelectrical brain activity in student of technical programmes. The first stage of research on the brain activity assessment will be carried out on the basis of EEG and QEEG tests performed in the Biofeedback Experimental Laboratory at Jan Długosz University in the academic year 2017/18. It is assumed that the final results will prove a significant correlation between the cognitive activity and the use of deterministic simulation programmes in technical education. The research is a follow-up to the results obtained in 2013/14in an EEG laboratory (Prauzner, 2015). Medical equipment for analyzing brain waves in EEG and QEEG will be using in the study (Fig.2). The presence of an QEEG rhythm indicates activity of neural cells at a certain location and corresponds to electrical pulses forming rhythmic patterns of brain waves. For each band of waves generated by the brain, a specific type of neurotransmitters is produced, which affect the functioning of the organism. The best known neurotransmitters include adrenaline, noradrenaline, dopamine, serotonin and endorphins. All the brain wave components are generated all the time but some of them can be fostered at will and by systematic training. By increasing the share of the desired wave bands, we automatically increase the production of the neurotransmitters and affect the functioning of our organism, boosting the activity of the brain regions which are the most important for learning. The following wave bands will be recording and analyzing in the future research: theta, beta1 and gamma. Electromagnetic signals will be recording from electrodes located at various places of the scalp and body such that they show the highest degree of activity: the occipital lobe (responsible for analyzing colours, motion, shape, depth, visual associations, assessment and making decisions and other tasks), the temporal lobe (responsible for the sense of musical and phonemic hearing, auditory perception, speech comprehension, object recognition, object categorization, verbal memory and memorizing); the parietal lobe (responsible for understanding symbols, abstract notions and geometrical relations) and the frontal lobe (responsible for understanding the meaning of words, identifying situations, working memory, volition, temporal relations, control over a sequence of events, planning, responses to external stimuli and simulations in the model of the world) and over.

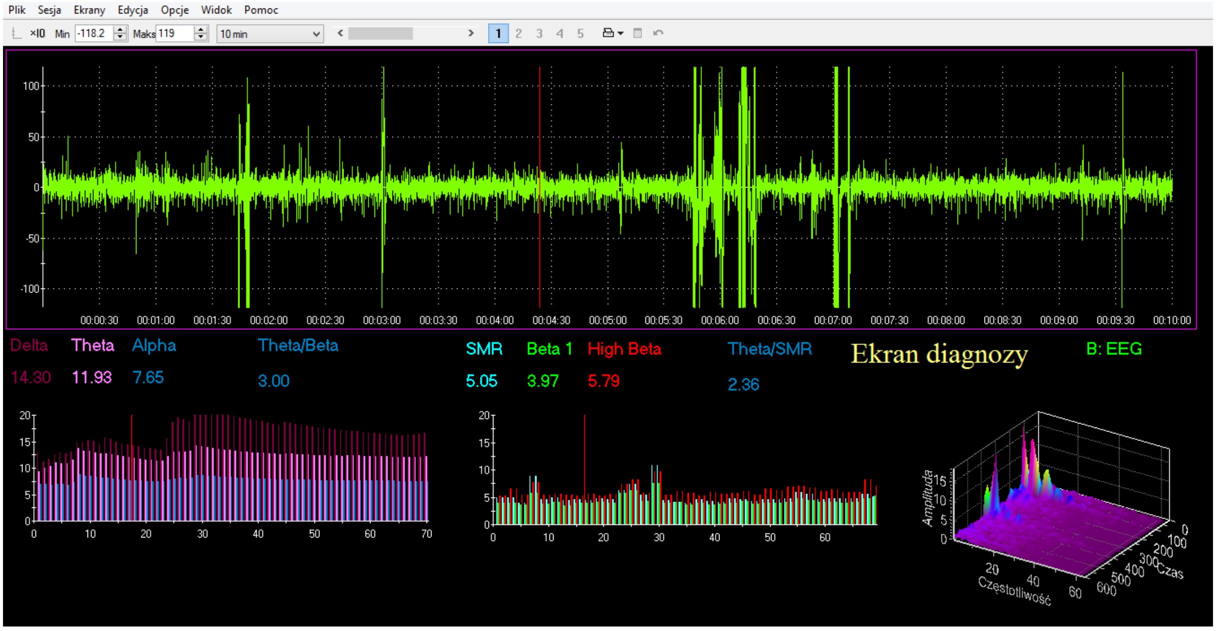

Fig. 2. **Sample (preliminary) EEG research**

The author intends to complement the existing results with new findings obtained by means of more advances software and laboratory equipment. To this end, it is necessary to subject the population examined to preliminary assessment. Because of that, assessing the group under scrutiny with respect to polysensory preferences is justified. The assessment test was based on a questionnaire developed by Kozielska (2012). Students were asked to rate the following statements from *1* (most preferred) to *3*:

- I learn by looking: I have to see the teacher, I prefer to observe a phenomenon directly or a demonstration/visual presentation thereof, such as text, illustrations, graphs, schemata, etc. The information acquired aurally becomes meaningful after it is illustrated and ordered. I construct images on the basis of my thoughts.
- I learn by listening: I listen carefully to what the teacher says, I pay attention to the details of the tone of voice, rate of speech and other vocal features of the messages, the information which is written becomes meaningful to me only when I hear it, I learn by listening to lectures, discussing things, reading aloud or talking to others.
- I learn by touching objects, movement and action: I need to be active, I learn most effectively by examining the physical environment, e.g. by touching, manipulating, constructing, experimenting, or checking the operation of a device.

Results of Research

The research was conducted on 181 students of such programmes as Forensics and Safety Systems, Innovative Technologies and Modern Materials, and Safety Engineering carried by the Institute of Technology and Safety Systems at Jan Długosz University in Częstochowa, in the academic year 2017/18 (Fig.3).[1]

Table 1 **Polysensory preferences of the population under scrutiny**

Preferred option	**I learn through sight**		**I learn through touch**		**I learn through listening**	
	number of answers	*%*	*number of answers*	*%*	*number of answers*	*%*
First	132	73	31	17	18	10
Second	40	22	57	31	84	46
Third	9	5	93	51	79	44
Total	*181*	*100*	*181*	*100*	*181*	*100*

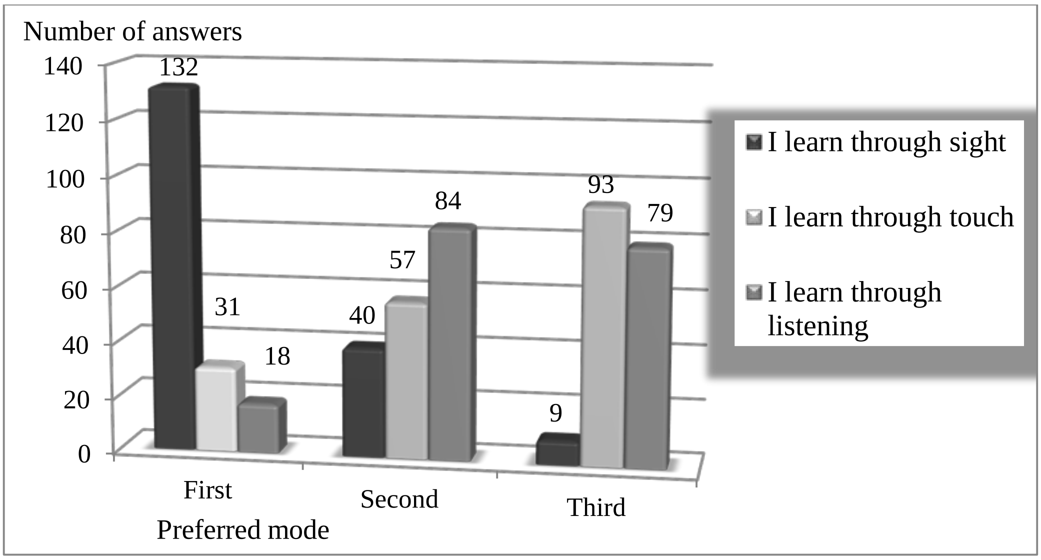

Fig. 3. **Polysensory preferences of the population under scrutiny**

Concluding remarks

The dominant learning mode relies on the sense of sight. The second most preferred mode is learning through the sense of touch (kinaesthetic preferences) and the third one through the sense of hearing. The second position is taken by

[1]Institute of Technology and Safety Systems, Jan Dlugosz University in Czestochowa, Poland, www.iet.ajd.czest.pl [access 22.11.2017]

the preference ordered as listening, touch and sight. The third combination of preferences is learning though touch, listening and sight. 73 % students indicated that sight is the most important sense in the learning process. The sense of sight is then the dominant path of information transmission from the environment to the brain. It is supported by the sense of hearing, and to the least extent by the sense of touch. Visual presentation of contents is therefore essential as it fosters constructing knowledge though images. Of crucial importance is the graphic form of presenting materials, the quality of representation, as well as the dynamic of motion and colour. A picture itself is not however a sufficient source of information, and as the results show, it should be supported by aural information. It can be concluded that using pictures (animations) aided by sound (such as verbal narration provided by the teacher or a computer) caters to the needs of students in the didactic process. To verify the preliminary results, at the next stage of research other methods of diagnosing abilities and limitations of students will be employed, including EEG tests describing brain activity by recording selected frequencies of impulses generated by the activated parts of the neural system. The one dimensional relationship S-DCS appears to be highly significant, which encourages further investigations of the role of modern didactic aids in the learning process.

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