Biofeedback as a cognitive research technique for enhancing learning process

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Abstract. The new technologies of measuring the biological indicators and the progress of neuron-communications help to better connect the emotional, intellectual and physiological parameters of the body and brain activity. The emerging research techniques include the biofeedback which enables to define audience's attention, students’ engagement, and offers a more thorough understanding of the learning process. The paper presents the results of the experiments related to the assessment of distance and classroom learning and to the measurement of the consequences for the perceptive, cognitive and volition features of students after both types of work – with physical participation of a teacher and with autonomous studying material through computer. The CMS (Current Mental State) technique in the form of a hardware-software biofeedback complex was used to obtain an unbiased evaluation of the students’ emotional and mental state and well-being. The result of this quantitative research was a set of parameters displaying the current mental state of the participants and showing the students’ reaction to the learning material and environment. The practical significance of the CMS study is to deepen the understanding of the perceptive and cognitive processes through the different forms of educational activity.

1. Introduction

The learning process at universities is organised on the basis of the cognitive processes’ analysis oriented for an “average” student. The modernisation of the society and the industrialisation of economy created the demand for the mass graduates since the middle of 20th century. The high global competition between the higher schools, universities and different education institutions leads to the need for a person-oriented construction of learning process. The digital technologies and the new approaches of cognitive psychology allow scholars and administrators from the education institutions to take into account the finer particular features of the personal cognitive process.

The presented research was aimed to understand, if the psychological traits of students can be taken into account to better build the learning process.

The research questions that are examined in this paper include: the analysis of the change of the current mental state of students during the classroom; the attempt to discover the differences between the impact of an “ordinary” presence learning and of the remote learning on the physiological and psychological state of students; the investigation if the differences can be revealed between the different psychological types of the students.
The results are obtained with the use of specific equipment that permitted to register the biofeedback before and after the classroom on the basis of physiological parameters representing the change of the current mental states of the students involved.

1.1. The purposes and background of the use of cognitive research for the learning improvement

The cognitive research implies the new technologies and multidisciplinary approach for the better understanding of the learning and making decision processes of human beings. The students are involved into the two essential processes of the knowledge economy – creation and transfer of knowledge [1].

The institutional and socio-cultural environment with high-road competition and technological progress required the evolution of the organization of cognitive processes. The digital economy of knowledge presents the new requirements to the labor market [2], the employers today need the graduates who are not only educated and well equipped with information, but who are able to produce and acquire knowledge at work, with the approach of life-long learning that was conceived by scholars but is implemented through the business practices. In this context, the scope of educational process construction challenges has expanded significantly.

The activity of a modern university within the new environment requires constant updating and improvement [3]. As a social institution that plays a core role within the knowledge economy, the university is responsible for both the content of the education, the ambiance and infrastructure, and the communication, from the organization of curriculum and educational program design, of professors and professionals’ contribution, to the educational environment (classroom equipment, lecture halls, etc.) and to the communication (physical and digital library, social media marketing and news publishing of the university, event management, etc.) [4,5,6].

1.2. The environment of tough global high-road competition and customisation strategy of universities

“Student-centered” education [7], based on educational material honing to fit in the learners’ requirements fosters the high-tech and network pedagogy built on the online education, neuro-education and cognitive psychology (“pedagogy of NeuroWeb”). This trend influences on the possibilities to examine and analyze the impact of learning process organization on the students’ cognitive and emotional parameters as a measuring for human capital improvement.

Universities aim to the construction of the cognitive process oriented to the knowledge creation and to build the environment in which the students can acquire and internalize the knowledge [8]. This approach to the universities’ functioning concentrates the attention to the examination of the parameters of different reactions of students during the learning process, including the states of mind and emotional states.

The main research purpose is to reveal the impact of the different works in classroom on the cognitive processes of students with the tools of the measurement of the biofeedback.

The aim of the paper is to present and to discuss the experience of the biofeedback technique implementation and data collection as an option to enhance and support the optimisation of the education process.

1.3. Digital tools and biofeedback for measuring the impact of learning process

Neuro-technologies based on biological feedback are widely used in the modern educational process nowadays [9,10]. The essence of the biofeedback technique is the screen visualization or audio presentation of Current Mental State parameters for the person participating in the test.

Currently, biofeedback techniques are used in education in the following cases:

- achieving high functional ability of the learners during the educational process (via studying adaptability of students to the educational process [11], measuring the actual psychological state of high school learners within interactive studying [12], relieving students’ stress during the exams, relaxation and positive attitude, speech correction) [13];
• optimizing physical or mental activity (general improving of health and harmonizing the performance of the nervous and vascular systems), therapy of addictive behavior, treatment of hyperactive schoolchildren [14].

In the foreign literature there is a number of articles describing the use of biofeedback techniques in education [15,16]. According to these sources, some foreign educational organizations, teachers and students offer biofeedback courses for health improving and harmonizing the nervous and vascular systems. For example, in Japanese universities, biofeedback technique is used during exam periods to lower students’ stress and anxiety. In schools of South Dakota (USA), these methods are used within the framework of the program “Self-Awareness through Training with Biofeedback Methods” The Charity fund Melinda & Bill Gates Foundation (specializing in improving the educational system) issued a grant in 2011 for Clemson University (South Carolina, USA) to carry out pilot studies of students’ involvement into the educational process by measuring the galvanic skin response (GSR) [17].

Russian education institutions’ specialists also invest in the projects based on the biofeedback technique. For example, a monitoring research on students’ suitability for studying at Peter the Great Saint-Petersburg Polytechnic University showed that the adaptation process of students for studying at a technical higher school can face difficulties not only due to their personal emotional and communicative features, but also due to various deficiencies in their intellectual capabilities, the most important of which is the logical, abstract and 3D engineering thinking [11]. Within the framework of another project, the actual psychological state of senior high school students was studied in the conditions of interactive teaching. Differences were detected in well-being, activeness and mood in class with interactive methods of introducing new educational material [12].

Biofeedback diagnostics of physiological changes for students in the stress conditions helps to develop methods of stress correction [18] and to find out which time of day and which conditions are the most favorable for studying and then to tune individual regimes of the educational process, as well as efficiently control the well-being of students and teachers. Therefore, biofeedback technique can be used as a tool to improve an individual well-being, and as an efficient method to evaluate actual pedagogical technologies.

1.4. The new techniques and approaches of cognitive research for enhancing learning process at universities

The integration of economics, sociology, psychology on the basis of the cognitive theory and methodology of biological indicators and neuron-technologies helps to improve the research of the educational process and its results [19].

The measurement of the students’ Current Mental States (CMS) gives the information about the essential parameters of the emotional and mental state of students with the psycho-physiological indicators represented with the body’ reactions such as rhythm of the heart rate and the mental and emotional well-being, especially, the spontaneity, productivity of mind, the risk of actualization of psycho-traumatizing emotions, vulnerability and sensitivity, values of specificity, pragmatism. The measuring is realized with the hardware-software biofeedback complex, the original equipment and analysis system are designed and executed in the Peter the Great Saint-Petersburg Polytechnic University by the collaborators of the Institute of Humanities (Advertising and Public Relations Department) and of the Institute of physical culture, sports and tourism (Department of Physical training and adaptation) [20].

The biofeedback method allows educators to evaluate and train students' cognitive abilities. Currently, the method of biofeedback in education is widely used in the following cases:

• the study of students' adaptation to learning, their psychophysiological state in the educational process, the removal of anxiety among students during the session, relaxation and mood for success, correction of speech);

• optimization of physical or mental activity (general recovery and improvement of the nervous and cardiovascular systems);
• consideration of psycho-physiological features of students in the development of training courses and programs [21].

The analysis of CMS helps to better understand the results produced with the learning process (in presence of a teacher and in remote regime) on the rational and emotional parameters of students. The biofeedback helps also to refine the learning process at universities with the understanding of the impact of different classroom work on different types of students according their specific psychological features.

2. Methods

The biofeedback technology is combined with the analysis of the psychological features of the students examined. The investigation of the different psychological features and effects on the CMS is built into the educational process and characterizes the impact of learning process on the cognitive abilities of the students taking part in the study.

2.1. The techniques and equipment implemented for the analysis

The use of the biological feedback hardware-software complex needs the preparing of teachers and technical specialists, the researchers directly involved into the survey fulfillment have had the necessary psychological, social-economic and physiological knowledge and scientific degrees that permitted them not only to register the results but also to follow the experiment, to monitor the states of the students involved and to avoid any significant problems. The conception of the indicators to measure and the approach to the analysis of the biofeedback were elaborated by PhD in Medicine B.S. Frolov [22] and updated by PhD in Pedagogy O.E. Piskun [20]. Similar studies on the base of biofeedback technique are conducted regularly by the authors to highlight the problems of cognitive marketing in education [3, 11, 20, 22].

2.2. The sample and procedure description

For the experiment, the groups of students were involved in the classroom work – the lecture within the Business communication course on the “Meeting and Conference Management” topics.

The experiment for the control group (n = 34) included an “traditional” lecture with physical presence of a teacher and interaction between students and professor. The “experimental” group (n=31) was given a classroom work with studying a material with the use of computers and reading a presentation on the same topic.

From these groups involved into the whole survey, two sub-groups of the students were formed, equal in the number (ten persons each), similar in the age and sex and in their psychological structure. The sub-groups participants selected had similar distribution in psychological parameters estimated with the help of a questionnaire to measure such psychological features as psychoticism, extraversion and neuropsychological instability (PEN-model of the dimensions of personality [20]). The examination of the impact on the sub-groups of “psychologically similar” students allowed researchers to reveal the effects proper to the classroom organization type (presence or computer mediated).

These three traits (psychoticism, extraversion and neuropsychological instability) were analyzed in the both whole groups of the students that permitted to compare also the impact of the forms of classroom on the abilities and states of different psychological types of the students.

The students agreed to take part in the experiment, the selected participants have demonstrated the moderate curiosity to the experiment and were explained the details about the content and measuring techniques of the research.

2.3. Organization of the data collection

The current mental states of the students were measured twice - before and after the 30 minutes of a classroom learning process of the same module of learnt material. The measurements were conceived for two types of teaching organization: the interaction with a professor and the work on computer without any participation of teaching personnel, only technical administrators.
Collecting the data on the emotional state of students was based on psycho-physiological methods of CMS (Current Mental State) implemented in the form of a hardware-software complex. This method enables researchers to objectively evaluate the psychological state by the data from cardiorhythmography, as well as monitor the changes in the state during various time periods and gauge the effect of various factors influencing on students’ perception [22]. The hardware-software complex includes a microcardioanalyzer and CMS software.

2.4. Data treatment and analysis

The results of the research are quantitative values for parameters of the current psychological state of the students (in 19 scales) before and after the experiment representing the degree of the feature of the current psychological state. In these scales (in percent) the similarity or difference is determined between the state of the examined person and the reference samples.

The students’ cardiorhythmograms were entered into the computer and processed by the software. The hardware-software complex monitored the data and combined it with a set of 19 parameters presenting the current mental state of the students (figure 1).

![Figure 1. Data screenshot provided by CMS Program.](image)

The average scores for each CMS parameter were obtained and then compared to reference scores. The results were registered and presented in the form of tables and diagrams for each student as well as for the groups (the average data, the analysis of dynamics of the participants CMS indicators, especially, the improvement or the deterioration of parameters).

2.5. The measuring of the categories of states

The CMS hardware-software complex based on measuring the heart rate provides two groups of parameters - nosological and syndromological.

2.5.1. Nosological parameters. These indicators represent the nosological parameters that reflect the level of the general compensation. These indicators describe the psychophysiological reserve for managing the mental activity, the optimal adaptive regulation and adaptation of the psyche. This group includes the following indicators (the names of the scales are based on the medicine nomenclature and taken from the original technique): Af (Affectivity, emotional calmness, balance of emotional state or emotional saturation); E (Epileptoidity, level of mobility – rigidity of mental processes); Ad (Reserve for mental adaptability); N (Neuroticism, neurotic level - hypersensitivity to stimuli, risk of actual psycho-traumatic experiences).
These features reflect the regulatory capacities of persons involved in the interactions or in the learning and professional activities.

2.5.2. Syndromological parameters. State of health and well-being (mental and physical). These indicators reflect the well-being of the participants, their general state.

The group includes the indicators of following features: Is (Scale of hysteria (expressiveness of emotions, balance of mental reactions "Me-Others"); Mn (Mania, excitement of state, degree of revitalization and tension of emotions); PD (Confidence in the correctness (realism, accuracy, infallibility) of one's judgments, certainty in assessments (opposite to self-critics)); OF (Obsession, the appearance of obsessive states, that appear and repeat apart from the person's will); Z (syndromological adaptability scale); AS (Asthenia, fatigue, the need for rest); SC (Reduction of current interest in life situations, vitality in all circumstances); IP (Hypochondria scale (mental and physical well-being)).

Syndromological scales mainly characterize a cross section of the mental state of the experiment participants. These indicators include the spring problems with health that are typical for northern regions (deficit of solar illumination, vitamins etc.).

2.5.3. Emotional sphere indicators and qualities of perception. These indicators reflect the nature of the emotional attitude to the experiences or emotional coloring of the experiences (includes balance and intensity of emotions). The group includes the indicators of following features: S (Sensibility, concrete and practical thinking); TR (Caution, prudence, property of anxiety); AG (Active strategy aimed at achieving one's interests, the property of aggression); DP (Depression of the mental state); RZ (Sensitivity to external stimuli, irritability); SL (Limitations of the current emotional spontaneity, differentiation and productivity of the psyche); IZ (Psychic rigidity scale, level of mental rigidity); DF (Dysphoric property).

The qualities of emotional and volitional states of students relate to the perceptive and cognitive processes and reflect the results of the experience during the lesson with or without a teacher from the point of view of the impact on the possibilities and capacities to face different kind of phenomena of the reality [22].

3. Results and Discussion
The summary of the experiments results is analysed directly with the registered levels of indicators according the equipment used (in per cent of the scale of measurement of the parameter).

The average indicators for the both control and experimental groups are measured before and after the experiment in pretest and posttest series (Table 1), the analysis of the covariance and correlation is fulfilled for the dynamics of the change of the parameters in the groups (Table 2).

3.1. Evaluations obtained in the experiments
The essential measurements resulted from the experiments are presented in the Table 1, the indicators represent the features of the students of both groups as well as the reference values for each indicator that represent the etalon rate of the psychic norm. After obtaining the data before and after the class, a comparison was made of the improved, worsened and unchanged indicators on average for the group and for each student as a result of the experiment.

| Indicators                                      | Control group, pretest | Control group, posttest | Experimental group, pretest | Experimental group, posttest | Reference value |
|------------------------------------------------|------------------------|-------------------------|-----------------------------|------------------------------|-----------------|
| Affectivity, balance of emotional state         | Af                     | 6.53                    | 14.53                       | 29.22                        | 35.89           | 4.8             |
The collected data from both surveys were tabulated and processed in MS Excel. The obtained results were examined with the covariance and correlation analysis for both research parts – the comparative analysis of the impact of the classroom work forms on the psychologically similar students (see Table 2 at the Appendix A) and the investigation of the different influence of the forms of classroom work on the psychologically different students’ cognitive abilities and mental states.

The significant levels of the positive correlation between the CMS parameters and the form of learning process (with or without teacher) is fixed for the parameter of the Reserve for Mental adaptability (Ad), the Pearson correlation is 0.808; for the Syndromological Adaptability Scale (Z) with the ratio of 0.612; the Active strategy aimed at achieving their interests, aggression (AG), with the level of correlation 0.525; and the Depression of the mental state (the opposite of cheerfulness) (DP), 0.626.

The negative correlation is fixed for the parameters of the Concreteness, sensibility, practical thinking (S), with the Pearson correlation at -0.425; the current reduction in overall mental tone, fatigue, the need for rest, property of asthenia (AS), with the ratio 0.541; and the Sensitivity to external stimuli, irritability (RZ) with the correlation level at -0.465. The other parameters did not present the significant correlation. The analysis of the covariance and correlation between the CMS and the classroom work form (with teacher presence and with computer’s mediation) is presented in Table 2.

This means that the influence of the choice of the presence form or remote form (classroom work at computers without a teacher’ assistance) has influenced on the current mental states of students in the different directions, for the group of parameters with positive correlation the impact of the classroom work was similar, without influence of the learning form; for the groups of parameters with the negative ratio of the correlation the results were significantly depending on the form of the classroom work with the preference for the physical presence of a teacher.
Table 2. Covariance and correlation analysis of the data collected.

| Experiment                        | Covariance $^1$ | Pearson correlation $^1$ |
|-----------------------------------|-----------------|-------------------------|
| Affectivity, balance of emotional state | Af 28.395       | 0.085                   |
| Epileptoidity, level of mobility – rigidity of mental processes | E 3.522         | 0.024                   |
| Sensibility                       | S -65.714       | -0.425                  |
| Reserve for mental adaptability   | Ad 294.452      | 0.808                   |
| Neuroticism, neurotic level       | N -5.754        | -0.043                  |
| Scale of hysteria (balance of mental reactions "Me-Others") | IS 6.264        | 0.274                   |
| Mania, excitement                | MN -52.401      | -0.183                  |
| Confidence in the correctness of judgments, certainty in assessments | PD 2.691        | 0.079                   |
| Obsession                         | OF -5.758       | -0.177                  |
| Syndromological adaptability scale | Z 267.803       | 0.612                   |
| Caution, prudence, property of anxiety | TR 4.311       | 0.101                   |
| Asthenia, fatigue                 | AS -22.521      | -0.541                  |
| Property of aggression            | AG 32.295       | 0.525                   |
| Depression of the mental state    | DP 0.967        | 0.626                   |
| Reduction of vitality             | SC -0.495       | -0.013                  |
| Hypochondria scale                | IP -6.706       | -0.114                  |
| Sensitivity to external stimuli   | RZ -29.225      | -0.465                  |
| Limitations of the current emotional spontaneity | SL -0.669 | -0.257                  |
| Scale of mental rigidity          | IZ 2.459        | 0.129                   |
| Dysphoric property                | DF 0.345        | 0.047                   |

$^1$ Ratio of the covariance and the Pearson correlation are calculated with the MS Excel.

It is worth to mention that the level of the correlation of the parameters’ groups (nosological, syndromological, perception and balance of emotions) is not significant and does not exceed 0.227 (the highest level for the syndromological scale – 0.227, a similar level for the nosological group – 0.221, null correlation for the perceptional and emotional group – 0.009).

At the same time, the correlations were calculated for the whole groups, the control one with professor’ teaching (n=34) and the experimental one with autonomous work on computers without human assistance (n=31). The groups examined included persons with different personality structure, which are presented as their characteristics of PEN (Psychoticism, Extraversion and Neurotism). We have revealed the statistically significant correlation for the parameter of the Extraversion, the parameters of the Psychoticsim and Neurotism did not demonstrate significant levels of the correlation with the majority of the measured parameters. The results obtained demonstrate the negative correlation between the parameters of the Reserve for Mental adaptability and the Extraversion, the Pearson correlation is -0.573 between the personal feature of extraversion of a student and her/his change of the mental adaptability, the lower ratio of the correlation is obtained for the Syndromological Adaptability (-0.340 – close to the limit of statistical significance). This means that the introverts seem to be more efficient than extraverts at the classroom with computer without a teaching person.

The traits of the psychoticism and neuroticism have demonstrated the slight positive Pearson correlation ratios but lower than 0.3. If the correlation ratios were higher, we could suppose that the interaction with professor has the higher emotional influence on the students and helps both to express the feelings and to calm the anxiety.

3.2. The changes of the indicators

The changes of the indicators measured after the experiments witness of a significant impact that both kinds of the lessons’ organization have on the mental and emotional states of learners.
The analysis of the dynamics of the indicators demonstrate that the most apprehensive impact is registered for the indicators of nosological scale and emotional features, the significant advantage is fixed in the experimental group, where the first five indicators have been improved for 55.6% of students, while only 35.6% of students of the control group have experienced the improvement of these indicators.

The results demonstrate that in the control group as a result of the experiment, indicators related to affectivity (Af), nosological adaptability (Ad), agitation, mania property (MN), syndromological adaptability (Z), anxiety (TR), fatigue, need for rest (AS), a decrease in the productivity of current mental activity (SL). Such indicators as mental mobility (E), external expressiveness of emotions (Is), aggression property (AG), rigidity (Iz), reduction of current interest in life situations (SC) improved as a result of the experiment.

The final level assessment of the current mental state, taking into account the values of all scales in the control group before the experiment was 3.18, after the experiment 3.62, which corresponds to a slight deviation from the standard etalon norm, but close to the limits of a moderate deviation from the norm level.

The final assessment of the current mental state taking into account the values of all scales for the experimental group before the experiment was 3.45, after the experiment 3.23, which corresponds to the population norm, but approaches the limits of a light deviation from the etalon of the psychic norm and is a better indicator than the control groups.

Thus, as a result of the experiment, the control group had improved indicators epileptoidity (E), reflecting the level of mobility-rigidity of mental processes, degree of external restraint – expressiveness of emotions, balance of mental reactions “Me-Others” (IS), syndromological adaptability scale (Z).

The experimental group changed for the better the following indicators: affectivity (Af), level of emotional calm, mobility-rigidity of mental processes (E), level of concreteness, earthiness, practicality of thinking (S), mental adaptability reserve, adaptive reserve (Ad), state agitation, property of mania (MN), obsessions property (OF), range of syndromological adaptability (Z).

4. Conclusions
The research results showed the high dependence of the indicators of psychological and physical state of the students’ health and mental state on the form of learning process. Both similar and opposite dynamics were registered in the groups, that witnesses of the sophisticated processes that are resulting in the mental state transformation, that, in its turn, relates to the complexity of the cognitive processes, to the diversity of the endogenous and exogenous factors that influence it, to the uniqueness of the individual conscience and of the personal reactions determined by the experience accumulated and patterns acquired for adaptation.

The hypothesis of the research was that the efforts necessary for the knowledge production and assimilation would lead to the decrease of emotional state, would use the reserve of adaptability and the resources of psychic control.

The increase of the affectivity significantly over the reference value of etalon norm is revealed in both groups, this change is higher for the lesson based on the interaction with teacher than for the computers’ classroom work, but the whole affectivity rate is much higher in the experimental group, that can be explained with the curiosity and the interest of students towards the experiment.

The both groups showed the similar slight improvement (decrease) of the indicator of reduction of current interest in life situations, decrease of vitality in all circumstances: in the both groups the high level of current spontaneity, differentiation and productivity of thinking in reflecting reality was established before the experiment, and the minor change toward the normalization of this indicator is fixed with the posttest. This normalizing change reflects the decrease of the vitality that can be related to both the fatigue after the lesson and to the mental work which has been fulfilled during the lesson.
These results can be considered in the favor of the hypothesis that any form of learning activity leads to the use of the mental and emotional reserve, in any form of organization of the learning process.

The changes of the indicator of the reserve for Mental adaptability and of the integrated parameter of syndromological adaptability scale show the different direction of the impact: the interaction with professor has led to the decrease of the both capacities of adaptability, while the learning process through the interaction with machine has been followed with a slight increase of the adaptive abilities of the students in the experimental group approximating the etalon norm’ reference value. These results demonstrate that the presence of the teacher requires more efforts and mental resources from students than the autonomous learning of the material through the computer.

At the same time the confidence in judgments and assessments is decreasing due to the impossibility to check the correctness of the assimilated nuances of the material learnt.

Independent work on the educational material contributes to the improvement of emotional calm, mobility of mental processes, practical thinking and helps to strengthen the reserve of mental and syndromological adaptability, removes the state of excitement.

Work on the study of new theoretical material under the guidance also contributes to strengthening the reserve of syndromological adaptability, increases the level of mobility of mental processes, the balance of mental reactions “Me-Others”.

The sample was insufficient (total N=65) to measure the impact of the learning process form on the students with different PEN traits, but it allows us to conclude about the existence and the direction of such impact. The statistically significant correlation shows the higher efficiency of the autonomous work with computer for the students with higher level on introversion, and of the work with a person (teacher) – for the students with higher degree of extraversion.

The low correlation ratios permit to raise question of the further and finer research to prove or deny the real influence of the characteristics of psychoticism and neuroticism for choosing the better learning process organization for the students with higher and lower degrees of these two traits in the personality of students.

It may be postulated that the learning process must be carried out as an optimal adaptation of students, whereby the proper development of the students’ emotional and cognitive sphere is ensured. There is also a growing need for interdisciplinary cooperation between such modern sciences as neurobiology, psychology, pedagogy and didactics, as such studies help to answer important questions for the issues of the learning process.

The adaptive concept of cognitive research takes into account the existing needs and lifestyle of students involved into the learning process. The new paradigm of education as a process of knowledge production and transfer focuses on the study of perceptive and cognitive processes of individuals, especially the perception of students, e.g., in the form of cognitive maps [23]. The learning process includes the acquaintance with a new context and familiarization with new information and fostering the inquiry abilities of students, their competences to “observe, think, generalize, and create like a scientist” [24], that help to comprehend scientific concepts through cognitive processes [25, 26].

This article proposes the results of a research that has revealed several aspects of the impact of the digitizing of education on the mental state of students, that witness the complexity of the cognitive processes, especially, of the learning process. Using biofeedback as a tool, the academia and educational practitioners are prepared to test the teaching materials and handouts, compare the alternative pedagogical methods and techniques. Further investigations using the biological feedback technique can help answering the questions about students’ emotional state and involvement; about the optimal time-schedule of classes, alternating between “active” and “passive” hours (for example, between physical training and lectures); about the time required for restoration (relaxation) after difficult classes and exams.
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References
[1] Pokrovskaia N N, Trostinskaia I R, and Safonova A S 2017 Professionalization of education within the digital economy and communicative competencies Proc. of the IEEE VI Forum Strategic Partnership of Universities and Enterprises of Hi-Tech Branches (Science. Education. Innovations) (SPUE) pp 29-32
[2] Brusakova I A 2017 About problems of management of knowledge of the digital enterprise in fuzzy topological space Proc. of 2017 20th IEEE Int. Conf. on Soft Computing and Measurements, SCM 2017 (St-Petersburg) pp 792-795. DOI 710/1109/SCM.2017.79707269210
[3] Ababkova M Yu and Leontieva V L 2018 Neuromarketing for education: rethinking frameworks for marketing activities. The European Proc. of Social & Behavioural Sciences EpSBS XXXV 1-9 Doi http://dx.doi.org/10.15405/epsbs.2018.02.1
[4] Glukhov V V and Vasetskaya N O 2017 Improving the teaching quality with a smart-education system Proc. of the 2017 IEEE VI Forum Strategic Partnership of Universities and Enterprises of Hi-Tech Branches (Science. Education. Innovations) (SPUE) (St. Petersburg; Russian Federation, IEEE: N.Y.) pp 17–21
[5] Almazova N, Baranova T and Khalyapina L 2019 Development of Students’ Polycultural and Ethnocultural Competences in the System of Language Education as a Demand of Globalizing World Advances in Intelligent Systems and Computing (vol. 907 Going Global through Social Sciences and Humanities: A Systems and ICT Perspective. GGSSH 2019), ed Anikina Z (Switzerland: Springer) pp 145–156
[6] Almazova N, Andreeva S and Khalyapina L 2018 The Integration of Online and Offline Education in the System of Students’ Preparation for Global Academic Mobility Communications in Computer and Information Science 859 pp 162–174
[7] Razinkina E, Pankova L, Trostinskaya I, Pozdeeva E, Evseeva L and Tanova A 2018 Student satisfaction as an element of education quality monitoring in innovative higher education institution E3S Web of Conf. 33 03043. https://doi.org/10.1051/e3sconf/20183303043
[8] Necheukhina N S, Matveeva V S, Babkin I A and Makarova E N 2017 Modern approaches to the educational process aimed at improving the quality of highly qualified personnel training. Proc. of the 2017 IEEE VI Forum Strategic Partnership of Universities and Enterprises of Hi-Tech Branches (Science. Education. Innovations) (SPUE) ed Shaposhnikov S (St. Petersburg, Russian Federation) pp 192–195.
[9] de Bruin E I, van der Zwan J E and Bögels S M 2016 A RCT Comparing Daily Mindfulness Meditations, Biofeedback Exercises, and Daily Physical Exercise on Attention Control, Executive Functioning, Mindful Awareness, Self-Compassion, and Worrying in Stressed Young Adults. Mindfulness 7 pp 1182–1192. doi:10.1007/s12671-016-0561-5
[10] Peper E 1979 The Possible Uses of Biofeedback in Education Mind/Body Integration ed E Peper, S Ancoli, M Quinn (Springer US) pp 111-117
[11] Piskun O E 2011 The influence of intelligence features on the adaptation of students to study at a technical college. The scientific-theoretical journal “Uchenye zapiski” 11 (81) pp 123-126. (In Russian)
[12] Kovaletskaya E V 2015 The current mental state of high school students in an interactive learning environment Psiholohicheskaya nauka i obrazovanie [Psychological Science and Education] 7 pp 48-58. (In Russian)
[13] Velichko T I 2017 Assessment of the functional state of the body using the APC "AMSAT-COVERT" (hardware-software complex of an analytical medical system of automatic testing) during the session for students Zhivaya psihologiya (Living psychology) 4 pp 285-294. DOI: 10.18334/lp.4.4.38654 (In Russian)

[14] Ratanasiripong P, Ratanasiripong N, and Kathalae D 2012 Biofeedback Intervention for Stress and Anxiety among Nursing Students: A Randomized Controlled Trial. ISRN Nursing doi: http://dx.doi.org/10.5402/2012/827972

[15] Chaló P, Pereira A, Batista P and Sancho L 2017 Brief Biofeedback Intervention on Anxious Freshman University Student. Appl Psychophysiological Biofeedback 42(3) pp 163-168

[16] Oman D, Shapiro S L, Thoresen C E, Plante T G and Flinders T 2008 Meditation Lowers Stress and Supports Forgiveness Among College Students: A Randomized Controlled Trial. Journal of American college. Health 56 pp. 569-578.

[17] Strauss V 2012 $1.1 million-plus Gates grants: “Galvanic” bracelets that measure student engagement. The Washington Post, 2012, June 11, [online], Available at: http://www.washingtonpost.com/blogs/answer-sheet/post/11-million-plus-gates-grants-galvanic-bracelets-that-measure-student-engagement/2012/06/10/gJQAgAUbTV_blog.html (accessed on 21 June 2019)].

[18] Yumatova Yu V 2015 Studying the correlations of psycho-physiological characteristics of the students in stress. Nauka i obrazovanie: novoe vremya [Science and Education: Modern Times] 5 (10) pp 62-65 (In Russian)

[19] Kalmykova S V, Pustylnik P N and Razinkina E M 2016 Role of Scientometric Researches’ Results in Management of Forming the Educational Trajectories in the Electronic Educational Environments Advances in Intelligent Systems and Computing vol. 545 ed M E Auer, J Uhomoihbi, D Guralnick 19th Int. Conf. on Interactive Collaborative Learning, ICL (Belfast; United Kingdom; 21 - 23 September 2016) (Springer Verlag: Cham, Switzerland) pp 427–432.

[20] Piskun O E, Ababkova M Y and Leontyeva V L 2018 Biological feedback method to facilitate academic progress Teoriya i Praktika Fizicheskoy Kultury 10 pp 45-47

[21] Houston J B, First J, Spialek M L, Sorenson M E, Mills-Sandoval T, Lockett M, First N L, Nitiéma P, Allen S F and Pefferbaum B. 2017 Randomized controlled trial of the Resilience and Coping Intervention (RCI) with undergraduate university students. Journal of American College Health vol 65 pp 1-9

[22] Piskun O E, Petrova N N, Frolov B S, Ovechkina I V and Bondarchuk I L 2016 Technique for objective assessment of current mental state and personality traits to determine adaptation level of students SPbGTU Krisiznye sostoyaniya: sovremenny podhody k okazaniyu specializirovannoj medicinskoy pomoshchi [Crisis States: modern approaches to the provision of specialized medical care] pp 84-93. (In Russian)

[23] Wei F and Pokrovskaya N N 2017 Digitizing of regulative mechanisms on the masterchain platform for the individualized competence portfolio IEEE VI Forum Strategic Partnership of Universities and Enterprises of Hi-Tech Branches (Science. Education. Innovations) (SPUE) pp 73-76

[24] Hsiao H S, Chen J C, Hong J C, Lu C C and Chen S Y 2017 A five-stage prediction-observation-explanation inquiry-based learning model to improve students' learning performance in science courses EURASIA J. Math., Sci Tech. Ed vol 13 (7) pp. 3393–3416

[25] Baranova T, Khalyapina L, Kobicheva A, Tokareva E. 2019 Evaluation of students’ engagement in integrated learning model in a blended environment Education Sciences 9 (2), 138. DOI: 10.3390/educsci9020138

[26] Hong J C, Hwang M Y, Liu M C, Ho H Y and Chen Y L 2014 Using a “prediction-observation- explanation” inquiry model to enhance student interest and intention to continue science learning predicted by their Internet cognitive failure Computers & Education vol 72 pp 110–120