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Design features of the synthetic learning environment

Oleksandr Yu. Burov[1,2]

[1]*Institute for Digitalisation of Education of the NAES of Ukraine, 9 M. Berlynskoho Str., Kyiv, 04060, Ukraine*
[2]*University of Vienna, Liebiggasse 5, 1010 Vienna, Austria*

Abstract. The article considers the features of the learning transformation in the transition from the usual material-object environment to learning in the digital synthetic environment. Attention is drawn to the fact that nowadays' students prefer online and blended learning, in which human interaction with technical learning tools not only creates new opportunities, but also requires coordination of their interaction. A brief description of the main features of learning using new technological capabilities is given, highlighting such aspects as virtual and augmented reality, as well as the use of game-oriented technologies with an emphasis on reflexive games. An analysis was made of changes in the properties of a new learning environment from the standpoint of biotechtonics, which develops the principles of accounting the human factor, i.e. the coordination of human capabilities with technical systems in a digital learning environment in which a person is transferred to a new interactive space using devices that reflect signals in his/her sensory organs and devices, accepting different actions. Variants of teaching technologies based on new principles are proposed, which make it possible to improve the quality of assimilation of educational material. It is noted that the basis for creating complex synthetic learning environments are biotechnical systems, which provide a variety of image content management tools for models of these environments, both for the researcher and the student. It is proposed to expand the concept of "biotechnical system" by including the so-called "biotechnical technologies", which becomes especially relevant in the digital world. The difference between this type of technology lies in the fact that among the technological operations included in them, great importance should be given to operations that are associated with ensuring the safety of work and creating optimal conditions for the resilience and labor activity of a person. At the same time, a person interacts mainly with information technologies, with information and knowledge that affect him/her, but not with material objects, both in the process of management and in the process of studying the outside world to use it effectively.

Keywords: synthetic learning environment, ergonomics, human factors, biotechnical system, principles of harmonization of human and technical characteristics, biotechtonics, learning technologies

1. Introduction

Psychologists and education researchers have developed many theories and concepts over the past century to explain how people learn, how they acquire, organize, and assimilate knowledge and skills, especially in school years [10]. With the emergence and spread of information and communication technologies (ICT), their development and penetration into all spheres of human activity, there is a need and the possibility of their use in education. The need for a wide implementation of innovations in education at all stages and levels of life is caused by the development of new technologies and the transition of mankind to the information society.

burov.alexander@gmail.com (O. Yu. Burov)
https://iitlt.gov.ua/eng/structure/departments/technology/detail.php?ID=281 (O. Yu. Burov)
0000-0003-0733-1120 (O. Yu. Burov)

This trend changes the priorities of society related to:

- development of human capital, taking into account the specific conditions of its functioning in the information environment and the implementation of new forms and means of learning life span [7];
- the increase of requirements to the cognitive capabilities of a person, when the nature of mental activity acquires more and more features of operator work [28];
- the possibility of creating adaptive ergatic systems and the transition to automation of the entire learning process, taking into account the functional capabilities of a human [23];
- creation of effective biotechnical systems [6], including in cyberspace, and, accordingly, ensuring their security [20].

At the same time, it has been theoretically and experimentally proven that the optimal (human-oriented) systems' design creates the prerequisites for effective activity and its control even in difficult conditions [34], especially with an increase in the rate and volume of this activity [11].

The above trends change the requirements for training and retraining, the ability and willingness to move to master new professions that did not yet exist at the initial choice [9]. At the same time, the use of training in a synthetic or combined (artificial and natural) environment is constantly increasing, where modeling and simulation allow the student to explore objects and phenomena that are inaccessible (in the general case) in an ordinary educational institution [17]. This approach allows the student to learn complex concepts more easily and quickly apply them to solving practical problems.

Game technologies are becoming more and more widespread in education [4]. As a result of this process, there is a need for new modeling techniques to describe the behavior of the subjects of the educational process [25]. Such methods arise due to ICT not "in the classroom", but in a digital synthetic environment [3], where the integration of participants in the educational process takes place. At the same time, there is an increasing need to take into account various aspects of the interaction between equipment/technologies and humans, the safety of the latter, which are not limited to physical security problems, but require consideration of the human factor in a broad sense at various stages of life.

Since the trend of using synthetic artificial environment (SAE) in education is quite new, its advantages, disadvantages and consequences remain unpredictable so far. The problem of creating and using the environment in the educational process was primarily dealt with by researchers in the field of emergent technologies, space, and military spheres [5]. Much attention was paid to balancing technologies, the cost of the created environment, trust in it and measuring/evaluating its effectiveness, as well as analyzing the capabilities of SAE for learning in general and in learning modeling systems as such [18]. However, such changes in the means and structure of the learning environment change the teaching load on the pupil/student and actualize the problem of considering the psychological and psychophysiological "cost" of such learning activities [26].

According to research results [13], online learning is today the preferred form (89% of respondents indicated this), but the mixed form is even more interesting (93%). The emergence of new learning tools is generating new trends in digital education (eLearning) that expand the range of ergonomics/human factors problems formulated just a few years ago [15]. Of note, it is the growing interest in the use of virtual (VR) and augmented (AR) reality in education [22]. However, these new technologies also give rise to new problems: deterioration in the interaction of students; emergence of dependence on mixed reality; hardware and software deficiencies; high costs (today); limited content [21]. In addition, it should be considered that, for psychophysiological reasons, the use of these technologies is recommended for children at least 12 years old.

The article *purpose* is to analyze the features and to develop a model of interaction between a human and technical means in a synthetic learning environment.

2. Results and discussion

Synthetic learning environment (SLE) require the attention of ergonomics and human factors specialists to a much greater extent than traditional approaches, since a human, technical means and a learning environment are explicitly integrated in their interaction. The activity of a person (both a teacher and a student) is acquiring more and more features of operator work [2]. For operators included in the production process control system, a methodology and method for assessing the level of their training have been developed [19]. The system methodology is also known for biomedical research [12], methods for training and predicting the performance of an operator have been developed (at least for process operators, dispatchers, and manipulators). However, for a group of research operators, to which students can be assigned (in accordance with the classification of types of operator work adopted in ergonomics), many design and analysis issues require considering human activity in an environment that can be simultaneously characterized as technical and technological with an emphasis on the use of information technology. It is advisable to dwell on the main aspects of this problem – the features of the SLE, learning technologies in it and the problems of coordinating a human with technical systems in such a learning environment.

2.1. Synthetic artificial learning environment

As Cook and Palmer [13] point out, the known data indicate a tendency to enrich learning opportunities by transferring learning and development activities to a synthetic environment, where the content of learning is shifting towards self-learning and project-oriented activities. At the same time, Cannon-Bowers and Bowers [12] note that: “a synthetic environment is a reconstructed multifunctional system with a mixture of real and computer synthesized (simulated) objects under control of a computer that provides interaction between combinations of real and synthesized objects. SLE consists of a digital and analog representation of the physical environment with a given accuracy and complexity; it scales to any size and complexity. At the same time, “the subject of the educational process actually functions as an operator-researcher, using auxiliary intermediate means (technical, informational, organizational, etc.) to achieve the ultimate goal (acquisition of knowledge, skills, competencies)” [26]. In addition, it should be considered that in the SLE “a human-operator is transferred to a new interactive environment with the help of devices that reflect signals in human sensory organs and devices that perceive various actions of the operator." Therefore, it is advisable to use the following principles for designing a multimedia learning environment when creating it: consistency, signaling, spatial adjacency, and temporal suggestion.

The concept of an immersive and virtual environment is related to the concept of SLE. According to Sergeev [31], in terms of content, a learning environment always appears as "a dynamic process of forming a network of relations in the subject of education, to which a wide variety of elements of the external and/or internal environment are selectively involved in order to ensure the autopoiesis of the organism, the stability of the personality and the continuity of its history" [32].

The main properties of an immersive learning environment are as follows: redundancy; the possibility of observation; accessibility to cognitive experience; saturation; plasticity; posture-subjective spatial localization; autonomy of existence; possibility of synchronization; vector; integrity; motivation; presence and interactivity.

Virtual learning environment and augmented reality. According to a report by Digi Capital [16], approximately 3.5 billion AR devices will be issued by 2023 and it will become a $90 billion industry. VR may grow more slowly, to 60 million devices and $15 billion in revenue over the same time period. Naturally, large tech companies are already taking steps to expand their services, such as Snapchat and Facebook recently introduced enhanced AR and VR features for both entertainment and education. The prospect of using AR and VR in education is also considered at the level of state programs. Thus, the United States held a 2-year competition for the best development of AR for medicine; more than 170 companies and institutions in China have united in the Virtual Reality Industry Alliance to accelerate the development of AR/VR; the French Ministry of Education introduced AR into the secondary school curricula; in the OAE, 17 schools have joined the pilot project to integrate VR into the curriculum.

Progress in this area will cover in the nearest future, apparently, most countries. However, it is important to understand the difference between AR and VR to optimize the implementation of such innovative technologies into the educational process. Smart, Cascio and Paffendorf [32] offer such an interpretation of the connection between the knowledge of the world and the means of AR/VR in the SLE (figure 1). One considers it expedient to supplement the scheme with the resulting product from the modeling side as "New Possibilities of Cognition" (in the original, the authors of [29] did not consider the result of the SLE in this direction).

The prevalence of the term "synthetic learning environment" (SLE) in the English-language literature is associated with the emergence and rapid development of electronic learning tools. At the same time, new opportunities appear for the formation and development of new forms of human socialization, various approaches to understanding the "syntheticity" of the educational environment, the place and "presence" of the subjects of the educational environment in the educational process. The "synthetic experience" acquired by the student has a unique potential for interaction with the structures of the mind and acquires the functions of a kind of thinking exoskeleton [1].

New technical and technological solutions for the creation of the SLE require the development of pedagogical systems and their methodological foundations. According to the author, the main pedagogical elements in SLE should include: provision of sufficient reference information/resources built into the simulation, preparation of training settings, diagnostic interactions, collaboration, dynamic and context-sensitive assistance, reflective strategies, student-controlled

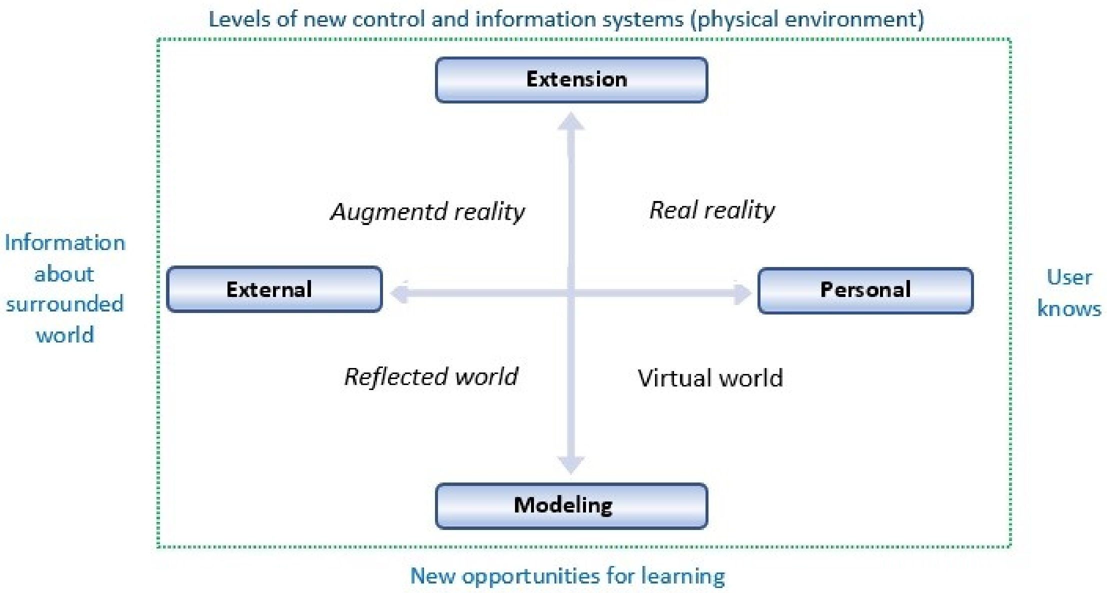

Figure 1: World representation in the synthetic environment (by [32]).

experience.

The possibilities of active learning methods and SLE have a certain parallelism, but with their own specifics.

2.2. Game-oriented learning technologies and modeling

As it is known, in most cases (under normal conditions of development), children begin to learn the world in a playful way. The game as a private and simplified model of the world makes it possible to model situations from the future life at a level accessible to the child. The expansion of opportunities for the use of ICT, their availability for various segments of the population and age groups, the overall growth of computer literacy, as well as the development of media and intellectual means of human access to the Internet, significantly expand the gaming potential of understanding the world, as well as the possibilities for human development in age and cognitive aspects. A game (especially in digital form) is becoming an important pedagogy for education in the twenty-first century. Using game-based learning models, future workers (primarily in the knowledge industry) are preparing for a quick response to changes in technology, career changes and career growth. The success of complex video games demonstrates that games can promote the development of strategic thinking, interpretive analysis, problem solving, plan formulation and execution, and adaptation to rapid change.

A promising form of organizing objective test methods for assessing the capabilities and readiness of a student can be a computer game built on the principle of reflection, i.e., with the provision of the possibility of control by the subject of the subject of activity on the basis of acquired experience and imagination without direct informational contacts with the subject itself. Reflexive control contributes to the balancing of sensory flows that affect a person and cause responses and contribute to the continuous harmonic self-development of a healthy person [14].

Systems that use various information test influences, the reaction of the subject to which gives information about the studied properties of his/her personality, belong to the class of biotechnical measuring and computing systems with test influences [27]. When building such a system, it is necessary to solve three problems:

1) selection of a test with the help of which a controlled informational impact on the subject is carried out;
2) the choice of a "guiding principle", in accordance with which the subject makes one or another decision to change the content of the test object;
3) implementation of the "test response" to the impact: the response of the subject to the presented test, allowing him/her to fulfill the chosen decision.

The choice of the modality of the test is usually carried out considering the studied personality trait and the age of the subject, his/her skills in tests' performing, working conditions and other factors. To implement a test action on the part of the subject in response to the impact, the simplest reactions of a motor nature are usually used, which are widely used in everyday life. Accurate selection of all three characteristics of the test method ensures the reproducibility, reliability, and validity of the test results.

The simplest test studies are based on human sensorimotor responses. As test stimuli, stimuli of three sensory modalities, which have proven themselves in practice, are usually used: visual, auditory, and tactile, i.e., those modalities that are used in presenting an operational image of a real situation. However, in SLE, the possibilities of sensory influence are expanded by using electrophysiological signals to input a response (for example, using AR). At the same time, the fixed indicators complement the assessment of the situation, characterizing it from different angles. Additional opportunities for such testing appear if physiologically substantiated influences are used to stimulate these responses, especially at the stages of education and training for a profession. But the introduction of such means of feedback requires considering the psychophysiological characteristics of students of different age groups, taking into account the characteristics of their sensitively sensitive age.

2.3. Features of the biotechtonics of a synthetic learning environment

It follows from the above that modern means of cognition – training, development, games, education – are increasingly moving from the interaction "human-human" to interaction in the "human-technology-environment" system, which the meaning of the concept of a biotechnical system (BTS) needs in extension. Proposed by V. M. Akhutin, the term "BTS" characterized this class of systems as "a set of biological and technical elements combined into a functional unified system of purposeful behavior" [28]. Its main biological element is considered to be a person, whose main function was to control a technical system that was supposed to perform certain tasks with objects of human cognitive interest external to BTS.

Considering the results of the analysis of trends towards the expansion of the concept of BTS, an interpretation was proposed for a new direction in the field of scientific research and education – "biotechtonics", which combines all research in the form of a single scientific concept of a fundamental nature: "unification of the living with the inanimate (artificial) object" [27]. At the same time, it should be borne in mind that today a human lives in the information (it is often called digital) era, when the world around is represented not so much by technical (having spatial localization) means, but by technological ones (in the digital space, technology and the environment of activity are increasingly the same). Therefore, the concept of "biotechnical system" can be expanded to include the so-called "biotechnical technologies", which becomes especially relevant in the digital world. The difference between this type of technology lies in the fact that among the technological operations included in it, great importance should be given to operations that are associated with ensuring work safety and creating optimal conditions for human life and work. At the same time, a person interacts mainly with information technologies, with information and knowledge that affect him, and not with material objects, both in the process of management and in the process of studying the outside world to use it effectively.

The process of cognition itself can be represented as a dialogue system, in which the technical unit (TU) is included, which creates a synthetic learning environment (figure 2), in which a human researcher (HR), if he/she wants to get an idea about the properties of the object of his/her interest (OI), must have certain connections with this object. Moreover, double multidirectional arrows emphasize that direct connections from HR and OI to TU differ from the reverse links – from TU to HR and OI.

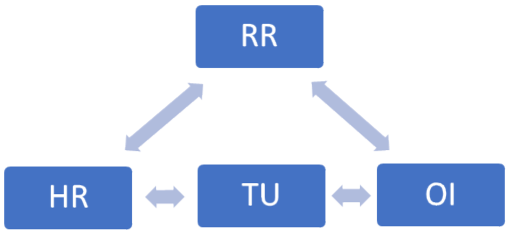

Figure 2: Synthetic learning environment.

All elements in the system exchange a kind of "requests" and "answers", which can be implemented in various ways using various techniques, methods, and technical means. Such interaction can be material, energy and most often informational, therefore, connections must be adapted to the transfer of matter, energy or information. The transmission itself is carried out through the environment surrounding all of these elements, and it is understood that the material-objective environment is represented by a part that is in the immediate environment of HR and OI. The real environment (real reality, RR) includes the environment directly at the point of interaction and the digital environment, which is limitless (more precisely, limited by the physical network used for interaction). This environment is active and affects both biological objects that are in a state of dialogue (both at the moment of direct interaction and delayed), but these biological objects themselves also affect the characteristics of the RR.

The object of interest in a real environment manifests its activity in various physical forms, the parameters of which contain information about its characteristics and properties. At the same time, it should be noted that the researcher himself directly reacts only to such signals that are perceived by his sensory analyzers. The most commonly used for such interaction are analyzers: visual (VA), auditory (AA) and tactile (TA). HR responses are most often manifested in

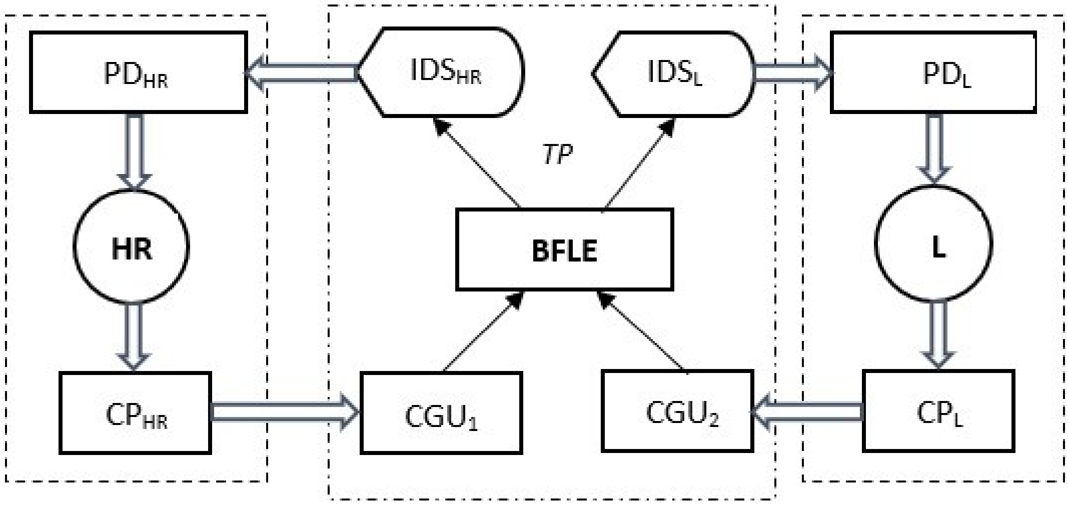

Figure 3: Generalized biotechnical system with one student.

the form of locomotive (motor) movements. These features of a human must also be considered when creating a SLE so that his/her activities correspond to ordinary work activities, which allows him/her to form working skills (figure 3).

In the figure 3, the model of the process of interaction between a researcher HR and a learner (L) reflects the place and role of technical devices included in the technical part (TP) of the teaching system. With direct contact of HR with L, HR can connect all his sensory and effector formations to get an idea of L, but his/her possibilities are limited.

To expand his/her ideas, HR is forced to create special technical means, both when obtaining information about the properties of the L, and when influensing on it. These units include the information display system (IDS_{HR}) with the playback device (PD_{HR}), the control panel (CP_{HR}), and the BPK_1 command generation unit (CGU_1). The learning environment is formed by the block of its formation (BFLE); it is presented as an image on the PD_L, which, in accordance with the teaching program, can change the content of this image using its control panel CP_L. Through the block BPK_2, L can changes the content of the presented image in accordance with the task being solved. In order to observe L's actions while studying his/her scenario, a second playback device PD_L can be included in the TP, on which the entire process of his/her activity is reproduced. The BFLE may contain storage devices that allow to evaluate the work of the L after the completion of the research.

The main block, which determines the type of image of the synthetic environment, the method of analyzing and changing its visual content, as well as processing the parameters of the psychophysiological state of the L, is the block for forming the BFLE synthetic environment.

Compared to the material-objective world in a digital learning environment, the interaction of HR and L can be carried out without direct human effectors, by controlling using electrical signals of the human brain (EEG, EMG) and the corresponding transducers. At the same time, the informational and emotional components of human activity, the role and capabilities of its cognitive part increase.

The means of dialogue between man and technology today have expanded significantly, but the principles of the synthesis of teaching BTS have remained the same. Virtual and augmented reality expand the possibilities of interaction between a human and technical and technological teaching aids, but HR still forms in his/her mind only a model of the object of knowledge (cognitive model of activity), and the subject of knowledge itself interacts not with the object of knowledge, but with its model – the image on the IDS_L, which he himself builds based on his own ideas based on the current level of awareness. Expanding the possibilities of means of cognition, creating new tools, methods, and technologies for studying L contributes to a deeper study of it, and such processes only improve the quality of the model, leaving the still unknown beyond its limits.

Such ideas could be useful in development of BTS, where visual communication has a great importance (f.e., in [30]) and in systems for prediction of a human performance [8], as well as when designing BTS of measuring of psychophysiological indices that could be built-in more complex educational and work tools [24]. A special significance design of the synthetic learning environment has in STEM and STEAM education of future educators [33].

3. Conclusions and future research

- In the XXI century, educational space acquires new features with the strengthening of the role of synthetic artificial learning environment.
- A synthetic learning environment becomes an independent subject of learning due to the expansion of its content and didactic potential, active participation (suggestions, provision of choices and polylogue, "immersion", the ability to adapt the learning process to the needs and abilities of the student, etc.) in the formation of competencies student, as well as the possibility of his/her socialization.
- The basis for the creation of complex synthetic learning environments are biotechnical systems, which provide a variety of means to control the content of images for models of these environments, both on the part of the researcher and the student.
- It is advisable to focus further research on the considered problem on solving the issues of developing the scientific and applied direction of biotechtonics in several directions: the synthesis of environmental models, methods for controlling the content of plots and considering the peculiarities of the student's activity in such a learning environment of different content.

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