



United Nations Educational, Scientific and Cultural Organization  
Junior Academy of Sciences of Ukraine  
under the auspices of UNESCO

# **THEORY AND PRACTICE OF SCIENCE EDUCATION**

**Volume 1**

**Issue 1**

**Kyiv, 2019**

# **THEORY AND PRACTICE OF SCIENCE EDUCATION**

## **Volume 1**

### **Issue 1**

#### **Scientific Journal**

The State Registration Certificate of the print media KB 23739-13579P (17.12. 2018).

*The Junior Academy of Sciences of Ukraine initiated the creation of “Theory and Practice of Science Education” journal with a view to share internationally its real-life experience in the implementation of science education in teaching practice, and introduce international experience in the development of these scientific issues to Ukrainian educators. The journal aims at the development of science education, creation on its pages a space for high-quality communication between the theorist and practitioners regarding the issues of science education, raising the level of competence of educators working with gifted students. The semiannual journal to be served as a platform for discussion of current problems in the implementation of science education principles, a discussion area and a tool for dissemination of information about modern methods of science education.*

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ISBN 978-617-7734-13-9

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## **Artificial Intelligence Systems in Adaptive Learning**

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*The article states that the mass introduction of advanced technologies related to presentation of educational materials and expanding the variety of educational activities, etc. into the educational system necessitates the development of new didactic approaches. The main feature of such learning is its personalized focus - the adaptability of learning to the individual students' needs.*

*As indicated in the article, one of the promising ways to organize such learning is the creation of a high-tech educational platform, the functioning of which is provided by computer technologies involving artificial intelligence. The article describes the technologies of artificial intelligence systems and their functions in the development of educational platforms. The article defines the technologies of adaptive educational platforms, where personalized learning trajectories can be formed using the functions of artificial intelligence, which significantly optimizes the time required for knowledge acquisition by each student. It is noted that the use of artificial intelligence technologies allows effective monitoring and analysis of not only the results of the completed educational tasks, but also their performance course.*

*This provides an opportunity for a deeper analysis of knowledge acquisition by students. The approach is based on the technologies of automatic sorting, multimedia reproduction of learning process, and the ability to monitor students' thinking, and adaptive analytics, which allows improving the individualization of learning. Artificial intelligence helps to develop a personalized educational approach for each student in order to make learning more effective.*

*The article justifies the need for application of artificial intelligence technologies with the view to determine the individual characteristics of each student and analyze his/her learning achievements for further adjustment. At the same time, the introduction of artificial intelligence should be aimed at preserving and enhancing all strong aspects of teacher's activities. New technologies need to be implemented carefully and pedagogically appropriately in order to avoid making students "childish". It should be remembered that the leadership position in any educational process belongs to the teacher.*

*Key words: artificial intelligence, artificial neural networks, machine learning, programmed learning, adaptive learning, adaptive education, adaptive educational platform, individual-typological features of the student*

## **Introduction**

Education is a key factor for an innovative economy. Today's society needs educated people with a high level of digital literacy, who are able to use and improve human achievements in the high-tech sphere. The World Economic Forum lists priority skills that will be required in the workforce in the coming years: critical thinking, creativity, people management, coordinating with others, emotional intelligence, judgment and decision making, service orientation, negotiation, cognitive flexibility. These developments will transform the way we live, and the way we work. Some jobs will disappear, others will grow and jobs that even exist today will become commonplace. What is certain is that the future workforce will need to align its skillset to keep pace. [Gray, 2016]. The successful person of the future needs to have creative thinking, ability to generate new ideas and implement them, desire to learn lifelong – these are the key principles of the present [Kastrup, 2018]. Therefore, to realize these key principles it's necessary to provide modern high quality education, where teacher plays a leading role.

Today, teachers spend a lot of time on the routine work identifying the individual characteristics of students and developing appropriate, individualized educational content, which also has to comply with the curriculum. There is little time left for direct contact with children, although primary school students require an individual approach as a basis for unlocking their talents and potential. It is rather difficult to fulfill this task in a proper way without having powerful computer tools. And taking into account the fact that students' individual characteristics are not permanent and can continuously change depending on internal (health, stress, etc.) and external (climate, social, etc.) factors - it becomes even impossible. In our opinion, considering the complexity and versatility of this task, there is a need to develop such computer-based tools on the basis of artificial intelligence for identifying the individual characteristics of the students.

## **Artificial Intelligence Issues**

Artificial intelligence (AI) – a system of functional computer technologies, which closely reproduce human thinking and skills such as analyzing complex systems, making informed judgments, maintaining a meaningful dialogue, etc.

Generally, there are three main divisions of AI - neural networks, machine learning and deep learning. Neural networks (often called artificial neural networks, or ANN) essentially mimic biological neural networks by modeling and processing nonlinear relationships between inputs and outputs in parallel. Machine learning generally uses statistics and data to help improve machine, while deep learning computes multi-layer neural networks for more advanced learning [Anne Sraders, 2019].

Artificial neural networks (ANNs) are computational models, which directly or partially reproduce biological neural networks. The calculations are performed in parallel at different levels of the base modules, neurons, and nonlinear relations between input and output data of all levels are processed. Artificial neural networks are characterized by the fact that they contain adaptive connections between artificial neurons of different computational levels, which are configured by a specific algorithm to optimize the model. The models can become more complex, packed with generated artificial neurons and in this way the number of data levels, neurons at any level and the number of connections between neurons (deep learning) increase.

Machine learning (ML) is a subset of artificial intelligence, which closely reproduce a learning process in which software “learns” systematically and consistently (training). During such “learning”, the program analyzes significant layers of data and tracks patterns for classifying data or generating forecasts [Kaplan & Haenlein, 2019].

Artificial intelligence and machine learning are no longer a fantasy but an integral part of the innovation economy of today. Voice assistants like Amazon Echo or Siri have introduced these technologies into our lives. There are already available online assistants and adaptive programmes for training that make it possible to individualize the educational process and automate specific technical tasks using artificial intelligence.

Certainly, artificial intelligence cannot replace a person completely; but it can process much bigger volumes of data than any person. Therefore, tasks may be performed much faster and more accurately.

### **Artificial Intelligence in Education**

Some developers of educational software have started to use these advantages in order to create programs able to adapt to individual characteristics of each student. This makes the learning adaptive. The basis of scientific substantiation of adaptive learning have been laid by the classics of pedagogy: Johann Amos Comenius, Johann Heinrich Pestalozzi and etc. The outstanding educator, philosopher and writer, J. Comenius, described the most important principle of didactics - the principle of individual approach, where individual characteristics of the student must be taken into account for successful learning. Humanist Johann Pestalozzi pointed in his works to the need of considering the individual characteristics to bring to perfection mental, physical and moral qualities that are inherent in children’s nature.

Burrhus Frederic Skinner, Harvard University professor and psychologist, founder of behaviorism, implemented the idea of adaptive and personalized learning through a linear system of programmed learning. According to this system, students consistently go through all stages of the curriculum that includes a specific set of tasks. Accordingly, if the student answered the question correctly, he/she proceeds to the next task, otherwise the student must perform the same task again.

Norman Allison Crowder, an American educator, has offered an extensive system of programmed learning. It differs from the linear one by providing several answers to each question, where only one answer is correct. The students must choose the right answer from the list to move on to the next task. In case of a false answer, they are offered to study respective materials and then fulfill the assignment again.

There is also mixed programmed learning that includes elements of linear and extended learning. Programmed learning can also differ by the method of entering the answer, degree of adaptation to the individual characteristics of students, etc.

The central task of programmed learning is the development of software for educational purposes able to create the conditions for achieving the goals of developmental teaching. The teacher’s role is not reduced with computer use. In the context of such learning, the teacher has an additional opportunity to quickly manage the activities of each student, identify difficulties in performing tasks and change the learning process [Bilyk & Sheremet, 2019]. Under such circumstances, learning becomes less managed and a student turns into a full-fledged player. The

student may control and adjust now each stage of own activities. The issue of machine learning mechanisms use in education has long been discussed in the scientific community, but high cost, large size, low performance of computers and lack of perfect computer networks have made this idea meaningless in the past. That idea seemed to become real only in the late 2000s, and adaptive and personalized learning gained a new impetus.

Universities are already using AI algorithms to personalize learning and deliver content that is suited to students' needs and pace of learning – and this is only likely to continue. This idea is built on research that shows different people have different aptitudes, skills and orientations to learn when exposed to the same content and learning environments [Nafis & Kendall, 2018]

Enlearn, the organisation based in Seattle, has also developed an adaptive educational platform that can be used to create personalized curricula through machine learning in order to optimize learning time of each student. The Enlearn team notes that their tool shapes the learning process using a large number of small and imperceptible components in order to analyze what exactly impedes the student's learning effectiveness. Then, similar to tutor, the tool helps the students to fill their knowledge gaps before starting to learn new material [Enlearn, 2019].

The software uses technology developed by the Center for Game Science at the University of Washington. With this technology, the effectiveness of learning has improved significantly. According to the director of the Center for Game Science and Enlearn founder, Zoran Popovic, artificial intelligence can promote personalized approach to learning; it enables providing the curriculum that the student needs at the particular moment [Pierce & Hathaway, 2018].

Unique software solutions using artificial intelligence make it easier for teachers to perform routine tasks at different stages of the learning process. For example, Thinkster Math educational project combines the curricula of experienced teachers and innovative artificial intelligence, what allows to effectively monitor and analyze not only the results of the completed educational tasks, but also their course. This provides an opportunity for a deeper analysis of knowledge acquisition by students. The innovations of this educational project are based on technologies of automatic sorting, multimedia playback of lessons, monitoring the student's thinking and adaptive analytics, which helps to deepen the individualization of learning. Artificial intelligence helps to personalize learning approach for each student to make it as effective as possible. Artificial intelligence technologies determine the individual characteristics of each student and analyze the learning results for further correction.

It is possible to satisfy the individual students' needs in adaptive learning, provided that their individual characteristics are thoroughly studied. One of these important characteristics is the individual-typological features of the student.

There is a need to use existing technologies and create new means to determine the individual-typological characteristics of the student. Our daily lives are rich in a variety of computerized services, the vast majority of which are adaptive, e.g. they are tailored to the individual preferences of each user. It is known to register in computerized services, such as social networks, e-mail, online shops, online banks, booking services, hotels, vehicles, e-government services and etc., the user is required to provide personal information; there may be requests to identify user location, different types of surveys and user tracking in such services. In

this way the user preferences are determined, according to which specific offers are suggested. Emotional state monitoring systems allow to accurately and qualitatively simulate the recognition of human emotions with the help of an input graphic image.

Such technologies, provided they comply with ethical norms, would also be appropriate for use in computerized educational resources with a view to establish a set of indicators that would help in identification of individual-typological characteristics of a student. All students have individual characteristics; this is natural, as everybody has own path of development and acquires various typological features of higher nervous activity, which determine the peculiarities of every person, and in our case – learner. Individual characteristics include the specificity of feelings, perception, thinking, memory, imagination, interests, abilities, talents, temperament, character, etc. Identifying these traits and qualities determined by the individual-typological characteristics of a student is quite a difficult task, which fulfillment in the course of adaptive learning is important and essential.

Due to the improvement of artificial intelligence technologies, individual characteristics are already considered in the intelligent tutoring systems and will be applied at all learning stages in the near future. Similar technologies are used in Brazilian intelligent tutoring systems Geekie. It contains many video tutorials, assignments and tests prepared by educators from the leading Brazilian schools. The system covers all school curriculum disciplines and helps students to prepare for final exams. If a student does not understand something, he or she can revise the material and take the test again. Prior to learning start, a student plans his/her own learning path independently, according to which the system adapts learning content to student's individual program. The system instantly analyzes the results of completed tasks, explains what and why is correct or incorrect, indicates and recommends the areas the student shall pay attention to. Teachers moderate the process only.

The transmission of content is one of the platform's main benefits, says André Urani's headteacher, Marcela de Oliveira: "You simply don't need a teacher to carry out this part" [Rigby, 2016]. Instead of being lectured en masse on subjects in which they may fail to understand a given element, students, she says, do better when they can set their own pace, return to difficult components in their own time and get things wrong without fear of being shown up in front of their classmates. The idea at André Urani, says Oliveira, is that teachers become mentors rather than lecturers, while the children take a more active role in the study process: "They stop being pupils, and become students" [Rigby, 2016].

The American Knewton platform (Fig/ 1) operates according to similar principles and aims to introduce intelligent educational systems into university education. Knewton developers create courses that students and teachers can adapt to their goals. Knewton was among the first companies to use data analytics technologies in education, which allowed it to build an adaptive educational platform able to provide a modern learning management system. The Knewton system supports learning process through three major services: student guidance, analytics for teachers and students, and statistics data for development of hardware and software and provision of appropriate subject content. The Knewton methodology is based on the technology of learning trajectory planning and a complex model of assessing student's activity throughout the whole study period, which is completely different from the majority of educational software.

According to Knewton, adaptive education must provide real-time response to the individual performance of a student and his/her actions in the system. This approach increases



the chances that a student receives the required learning materials at the right time and will be able to achieve the set goals. For example, if a student has difficulties solving some of the tasks, the system will be able to identify which topics have been misunderstood and offer materials to fill knowledge gaps exactly in that topics.

Knewton collaborates with many organisations worldwide, including (Fig. 2), Arizona State University (ASU), Cambridge University Press, Cengage, Elsevier, Gutenberg Technology, Gyldendal (Norway), Houghton Mifflin Harcourt, Microsoft, Macmillan Education, Malmberg, Lelivrescolaire, Pearson, Sanoma, Santillana and etc.

The image shows a screenshot of the Knewton website. At the top, there is a navigation bar with the Knewton logo on the left and links for INSTRUCTORS, STUDENTS, PARTNERS, BLOG, BUY, and SIGN IN on the right. Below the navigation bar, there is a section titled "Alta: New for higher education". The text describes Alta as Knewton's newest product for higher education, a complete courseware solution that combines adaptive learning technology with high quality content. It mentions that Alta is available in multiple courses in math, statistics, economics, and chemistry. To the right of the text is an image of a laptop displaying a graph titled "3.1 Demand in Markets for Goods and Services".

*Fig. 1. Knewton educational platform*

The image shows a screenshot of the Adaptive Curriculum website. The browser address bar shows the URL "https://www.adaptivecurriculum.com/us/". The website features a navigation bar with links for Products, Solutions, Catalog, Research, About Us, Contact Us, and Free Trial. The main content area has a heading "Welcome to a new way of learning" and a sub-heading "Math and Science for Digital-Age Learners". There are three call-to-action buttons: "REQUEST INFORMATION", "GET A FREE TRIAL", and "CHECK OUT THE NEW AC APPS!". Below this, there is a quote: "Teaching and learning is a little different now. We need to meet our students in the digital realm and be sure they are ready for the real world." and a short paragraph about the platform's benefits. At the bottom, there are three more call-to-action buttons: "Connect Students to Their World", "Implement Common Core—Now!", and "Focus on STEM".

*Fig. 2. Adaptive Curriculum educational platform*

Arizona State University (ASU) together with Knewton and its partner, Pearson, initiated an experiment on implementing adaptive learning in 2011. Introduction of adaptive learning for

first-year students in mathematics was intended both, to assist teachers and help students to work on the material independently. The Knewton system used data to determine a students' level of knowledge and which way of learning was the most effective for them. Based on analysis of this data, the system provided recommendations on the sequence of study topics. On the other hand, the Knewton system provided teachers with real-time reports that helped them to identify weaknesses in student preparation, develop a tailored curriculum for each student and pay special attention to the topics that students learned the worst. The experiment demonstrated that the results of academic performance improved by 18%, and the rate of student dismissals decreased by 47%.

Dreambox has developed an intelligent system that teaches mathematics in schools. Driven by Intelligent Adaptive Learning Technology, DreamBox adapts to students' actions to meet them at the right level – with personalized instruction that promotes student decision making and strategy development. DreamBox empowers educators with real-time data and academic insights to inform learning and customizable professional development aligned to instructional goals and focused on educators' individual needs [DreamBox, 2019].

Australian scientist Dror Ben-Naim developed an open platform, which enables teachers to create the interactive courses and use intellectual capacity of system to adopt the curricula to each student, to create innovative digital learning experiences. Smart Sparrow provides interactive and authentic simulations and uses rules-based logic, set by the instructor, to adapt learning to an individual student's needs. More than a dozen of courses have been developed on the platform, mostly for universities. Smart Sparrow began as a research group at the University of New South Wales (UNSW) and is now a global leader in online education with a focus on adaptive and personalized learning technology. More than 500 institutions worldwide currently use the platform: "Our software makes it easier and more cost effective to create digital learning experiences. Instead of just posting content online, the digital learning experience becomes more personalized, more intelligent, more adaptive" [Matthew Hall, 2018]. These platforms are constantly developing and improving.

Going by the 50-year timeline, and the current rate of technological development, the new wave of technological growth that began after the 2000s can be expected to come to maturity in the next five decades. That is, we can expect the next drastic change around the next three decades or less. This means we can safely predict that even the most clearly traditional educational roles like curriculum development, instructional design, lesson planning, summative assessments requiring some open-ended approaches, school management and similar duties will not remain human preserves for too long. The implication of this is that much less school duties will gradually require human teachers, with the result that the roles of human teachers in some fields of education will become totally unnecessary as time progresses. This calls for a projection into the future regarding the positive and negative implications of these developments and how to prepare for them [Bosede & Cheok, 2018: 11-12].

### **Conclusions**

The mass introduction of advanced technologies related to presentation of educational materials and expanding the variety of educational activities, etc. into the educational system necessitates the development of new didactic approaches. It is caused by the fact that computing

power has developed to the extent, that we could already speak of automated learning courses (ALC) or learning management systems (LMS) as a quasi-subject of the educational process. The main feature of such learning is its personalized focus – the adaptability of the learning process to the individual student’s needs. In our opinion, regarding the complexity and versatility of the task such computer-based tools for identifying the individual characteristics of students should be developed on the basis of artificial intelligence. AI-technologies are developing rapidly and already widely implemented in the industrial and domestic spheres of live. Unfortunately, the pace of introduction of these technologies in the education remains slow. In addition to the need to incorporate AI technologies into the learning process, they should also be included in the curriculum as an object of study, since today's students need to work in the future where AI becomes necessary.

Artificial intelligence tools may help to make audiences of the best educational institutions accessible to everyone, regardless of the language of communication or special needs and to reduce incoherence between different schools. At the same time, the introduction of artificial intelligence should be aimed at preserving and enhancing all strong aspects of teacher’s activity. New technologies need to be implemented carefully and pedagogically appropriately in order to avoid making students “childish”. It should be remembered that the leadership position in any educational process belongs to the teacher.

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