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NEUROSCIENCE AND ARTIFICIAL INTELLIGENCE AS A COGNITIVE REVOLUTION IN EDUCATION

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Original research

A B S T R A C T

The relevance of the research is due to the fact that today's advances in cognitive sciences have led to a real cognitive revolution: we understand more and more how our brains work, including how our brains learn. And while this understanding alone does not yet guarantee the most effective learning solutions, it is proving useful for optimizing educational environments and processes. From a neuroscientist's point of view, education is not a mechanical accumulation of skills, but a work with cognitive resources, including an attempt to increase them. Education is increasingly using knowledge about the brain to build educational processes, but this knowledge alone does not guarantee the creation of the most effective learning solutions. Understanding neurodevelopmental activity can serve as a motivator for educators to teach effectively. The aim of the research is to present effective artificial intelligence tools at different stages of educational design.

1. INTRODUCTION

When implementing AI elements in the educational process, the central agents are teachers, pedagogical designers and methodologists - those who are most closely involved in curriculum development and interaction with learners (Yue et al., 2022). They are the ones who are actively involved in goal-setting, identifying audience and customer needs and demands (Huang & Shi, 2021).

An AI solution is thus designed partly at the request of a pedagogical designer and should be comfortable for them - automation of routine tasks, improvement of learning processes by means of AI allows them to free up time and pay attention to the creative component of work (Kulikov & Shirokova, 2020). However, here we face the key problem of AI: at the moment it is impossible to provide such technologies as a ready-made service, accessible and understandable to the end user (Holmes & Tuomi, 2022).

There are no ready-made solutions that allow a methodologist to simply take and apply any AI technology "out of the box" (Dolata & Crowston, 2023). At the moment, the application of AI is more like a constructor: it is necessary to search for suitable models, customize them, and adapt them to specific needs and tasks. AI is good for automating routine intellectual work, for example, for generating incorrect answer choices (Jarrahi, 2019). However, it should be remembered that such application of AI is cost-effective only on a large scale - when there are already accumulated data arrays (Do et al., 2022). With small volumes of data and tasks, manual labor remains more profitable, and AI implementation is impossible (Shaw et al., 2019).

It has long been known about the importance of environmental saturation for brain plasticity: the more stimulation the environment provides, the more active the changes are. But relatively recently, scientists have proven that the brain is flexible not only during the

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critical periods of our childhood, but throughout our lives. Advances in cognitive science have led to a true cognitive revolution: we increasingly understand how our brains work, including how our brains learn (Posner & DiGirolamo, 2000). And while this understanding alone does not yet guarantee the most effective learning solutions, it is proving useful for optimizing learning environments and processes.

This means that at any age we can successfully learn new things, build new skills and change behavior. And the most important thing here is experience. As soon as we have a new experience (begin to perform an unfamiliar action or encounter new information), synaptic connections are formed between brain neurons. Repeating the experience strengthens the connections formed, and conversely, if we stop practicing something, the connections responsible for these actions weaken. This is why both encountering the unfamiliar, the unexpected, and repetition is important for effective learning.

2. LITERATURE REVIEW

The empirical basis was the research of UNESCO IITE companies, studies of the authors: Luckin and Holmes, (2016), Intelligence Unleashed: An argument for AI in Education; Holmes (2020) Artificial Intelligence in Education. Perspectives and challenges for teaching and learning; Fan (2019), Will Artificial Intelligence Replace Us? Sociological and statistical research methods were used in the research process.

3. METHODOLOGY

When talking about artificial intelligence in learning, we should have in mind the elements of artificial intelligence - algorithms and "ensembles of algorithms" from pre-trained neural networks, which help to solve problems mainly in three directions:

1. Automation of recognition (of images, emotions, text, words, etc.).
2. Building a recommendation system (methods and algorithms that aid in the learning process by creating a ranked list of recommendation objects (e.g., e-courses) that are most appropriate for a learner with the right need and in the right context).
3. Building a sophisticated meta-system that can not only recommend courses or lessons in the right quantity and context, but also generate them, structure them, automatically create them.

Artificial intelligence today is developed within the first direction. Algorithms in the third direction are still very limited and primitive. Therefore, it is now worth putting efforts into the second direction - building recommendation systems.

Steps to build a recommender system.

These efforts will benefit both in the moment and in the long run.

1. Develop a description of the educational program. This step includes constructing, creating, and populating a rubric of terms that relate to the learning outcomes. It can be a detailed list of all terms related to the educational outcomes of the program, a detailed description of the program based on taxonomy (know, be able, possess) or a hierarchical list of terms.
2. Analyzing and marking up the actual results of the activities of the participants of the educational process. This includes analyzing the digital footprint, feedback, and reflections.
3. Comparing the results of the analysis with the previously developed educational program. This step involves refining the program, building a logic in the format "if..., then...", which will help form links between the program content and the educational focus.

The result can be a recommendatory system of courses that will select relevant content for the learner's educational needs.

The main areas of influence of cognitive sciences on education (Chen et al., 2020):

- The idea of brain plasticity;
- Knowledge of age-related changes in the brain and their relationship to the formation of cognitive skills;
- Optimizing teaching methods and trying to test their effectiveness at the level of changes that occur in the brain;
- Understanding the impact of the digital environment on cognitive skills;
- Motivating learning using insights from neuroscience;
- Combating misconceptions (Jia et al., 2024).

Although neuroplasticity persists throughout life, it is important to realize that changes occur with age to the brain that affect cognitive abilities. Some areas, such as the visual cortex, do not change much over the years. However, areas related to memory do not change much after the age of 40. The frontal areas of the brain, which are involved in complex cognitive processes, begin to change even earlier.

This is followed by changes in our abilities: for example, our reaction speed falls continuously from the age of 20; our ability to perform mathematical operations begins to deteriorate on average from the age of 40. In a typical situation, our reserves grow in youth, peak, and decline in old age. At some point, the lack of cognitive resources starts to become a discomfort. That is why the modern approach of neuroscience is that we should act not at the age of 45 or 50, when the peak is passed, but much earlier. It is necessary to raise cognitive resources while still young so that their reduction in old age does not cause discomfort.

There are three proven ways to stimulate brain plasticity:

1. Load your brain with a variety of cognitive tasks.
2. Physical activity.
3. A proper diet, such as a Mediterranean-type diet. It is important to avoid chronic stress! It leads to the death of

brain cells (e.g. those that provide our memory), significantly hinders the ability to make creative decisions, affects our DNA and through an epigenetic mechanism can affect the genes of the next generations, causing increased sensitivity to stress in the offspring.

Three myths about brain function.

Exposing myths about brain function (also called "neuromyths") is not a new topic. But as trainers around the world continue to develop the creative right hemisphere and offer ways to engage the brain more than 10%, it's useful to remember these myths. For example, so that we don't accidentally spread them ourselves.

Myth #1. Childhood is a critical period of development.

The brain has a critical period of development, from birth to age three, when its most important systems are formed. All future human abilities depend on it. In fact, there is no limited developmental period for all brain systems. There are stages when the brain is more sensitive to experience and more actively changes its structure and functional organization under its influence. But, firstly, the brain can create new connections between neurons not only in childhood, but throughout life. This property is called neuroplasticity (Emelianova, 2021)

Second, different brain systems show a different capacity for plasticity depending on age. For example, the systems responsible for semantics change equally throughout life in response to experience, with no critical periods (Zawacki-Richter et al., 2019). And the parts of the brain responsible for language acquisition in terms of grammar and pronunciation are most plastic in early childhood.

How can this be used in teaching?

1. Take into account the age-specific plasticity of different brain systems when developing training programs.
2. Organize training for all ages by understanding the principles of neuroplasticity:
   - new neural connections are formed when faced with unfamiliar tasks;
   - frequently used connections become stronger, rarely used connections become depleted.

For example, error learning can be applied when there is a gap between what the learner's brain expects and what happens. This encourages testing existing knowledge and finding new solutions in an unexpected situation.

Myth #2. Our brain only works at 10%.

To increase productivity, it remains to figure out how to "turn on" the other 90%! In fact, a person uses the whole brain in one way or another, but depending on the task at hand, some areas of the brain are more active than others. It can be compared to a car, in which every mechanism works when needed and no one presses the gas pedal at the same time as the brake. Another thing is that a person does not always use his resources to their full capacity. For example, you can develop the ability to memorize the sequence of cards in a deck in 15-20 seconds. This will happen not by "plugging in" to an unused brain, but by forming and strengthening connections between neurons.

How can this be used in learning?

Remember that we don't have 90% of our brains "off" and allocate our resources wisely for tasks. For example, eliminate distractions like cell phones or checking email when you should be focusing on learning. To increase the efficiency of learning, taking into account the mechanisms of memorization of information by the brain: learn new things in small portions; switch between focused and unfocused modes of concentration; allocate enough time for sleep, as during this process the consolidation of memory occurs - its transition from short-term to long-term (Barakina et al. 2020).

Myth #3. Rational left and creative right.

The left hemisphere of our brain is responsible for analytical abilities and the right hemisphere is responsible for creative abilities. People are divided into left-hemispheric and right-hemispheric. In fact, the hemispheres of the brain are closely related and interact to solve both analytical and creative tasks. There are tasks in which one of the hemispheres predominates, but the other hemisphere also performs indispensable functions. For example, the language center is located in the left hemisphere, but the right hemisphere is responsible for intonation and accent. Therefore, if there is progress in analytics or creativity, the person has improved the functions of both hemispheres.

How can this be used in teaching?

Do not waste time pumping one of the hemispheres, while harmoniously developing the brain as a whole. This is facilitated by forms of learning that require solving complex tasks. For example, working in a group not only helps to internalize knowledge by explaining and discussing information with others, but also, like any public practice, teaches you to think quickly and react adequately to stress.

Tools for testing the effectiveness of educational technology.

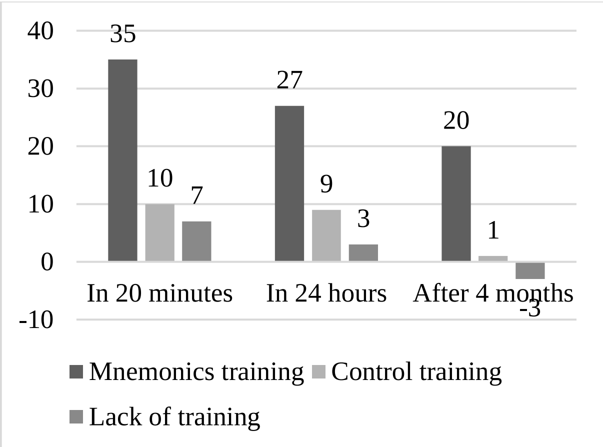

Figure 1. Results of training using mnemonics in comparison with other methods.

On the one hand, we increasingly understand how our brains learn. Key areas of the brain associated with memory, motivation, and attention are known. On the other hand, it is becoming apparent how many different brain processes are involved in learning. For example, there is memory associated with emotional skills, procedural skills, memorization of facts, meanings - all of these are different types of memory and brain systems. Therefore, a wide variety of brain systems need to be engaged for effective learning, and this seriously hampers the development of universal approaches in education.

Neuroscience provides tools that allow us to see the effectiveness of the effects of training technologies on the brain. For example, Dutch scientists have recently shown how mnemotechnique training can achieve sustained results in memorizing information (see Figure 1).

The results of the study showed that 6 months of training in the new technology changes the functional connections in the brain between key areas involved in analyzing information and memory. As a result, memorization is much better than without training, and the result persists even after 4 months.

Research shows that the digital environment has both positive and negative effects on our cognitive abilities. For example, in one study, subjects performed simple information retrieval tasks. The first stage used the Internet or their memory. In the second stage, a new simple task was given, and those who had used the global network in the first stage used it again. Those who had used their memory in the first stage used the Internet less, turning to their own resources.

Thus, easy access to information leads to the fact that even to solve simple tasks a person may stop using his resources. This can lead to a loss of cognitive skills, as unused connections in the brain gradually weaken.

In another study, subjects searched for information, familiarized themselves with it, and put it into specific file structures. As a result, 15% of people remembered both the information they found and where they saved it. Only 10% remembered what they found. 30% remembered where they saved the information, but did not remember its content. Probably the very ability to save information on a disk causes us to forget it.

Therefore, digital technologies introduced in education can have positive effects but also negative ones: with easy access to information, we cannot always systematize it and we lose the skills to use our own resources.

As children, we memorize facts easily and spontaneously, even if we never need them. As we get older, learning becomes more difficult. As an adult, in order to learn or memorize something, it is important to understand why you are doing it. This includes the practical benefits of new skills (e.g., why learn a foreign language) and understanding the meaning of learning activities (e.g., why repeat new words regularly).

Knowledge about how learning happens at the brain level reveals the meaning of certain actions and helps us to effectively organize our individual learning process. For example, in one of the most popular courses on Coursera - Learning how to learn1 - Professor Barbara Oakley, together with neuroscientist and professional trainer Terence Sejnowski, explains to people how to learn based on the mechanisms of the brain. The Higher School of Economics team adapted this course for teenagers, and now it is available to high school students in Russian. Thus, the very understanding of how our brains work can serve as a motivator for effective learning.

4. RESULTS AND DISCUSSIONS

The main stages of pedagogical design of adaptive learning to build an intelligent tutoring system are presented in Figure 2.

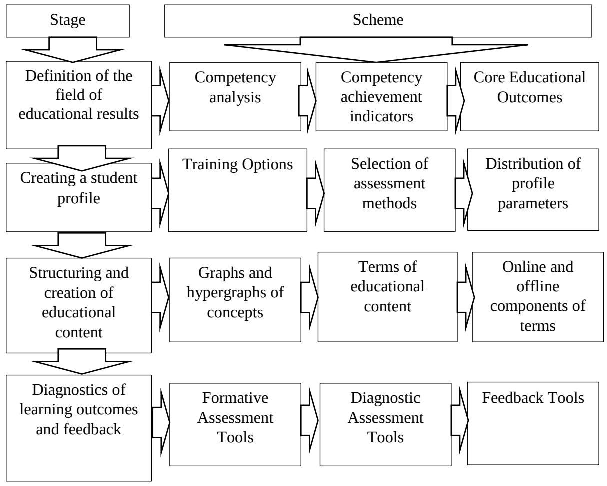

Figure 2. Staging the implementation of artificial intelligence in the design of adaptive learning.

Obviously, artificial intelligence will need information about effective teaching approaches such as providing feedback, assessment, and recommending follow-up content in order to work with this model.

The following are the main courses of action that can be taken by any methodologist and instructional designer who wishes to call upon the power of AI to help.

1. Engage with a large team of experts.

The path to using AI is not closed to methodologists and educators who do not understand AI learning models and are not data scientists. The current state of the field suggests that education stakeholders need to improve their technology literacy, understand how technology works, its limitations and applications to more easily manage a technical team.

The development of artificial intelligence in education cannot be handled by some invited team of AI developers. The result is achieved through coordinated actions of several specialists. The methodologist's task is to supervise the team's actions and guide them ideologically.

Types of specialists involved in the development of AI solutions:

- Lead methodologist (project manager).
- Data analysts.
- Data linguists and NLP specialists.
- Educational data engineers and ED designers.
- Data engineers and database specialists.
- Knowledge engineers and partitioners.
- Data-scientists and machine learning specialists.

2. Understand the capabilities of AI-based systems.
Speaking about artificial intelligence in learning, we should keep in mind the elements of artificial intelligence - algorithms and "ensembles of algorithms" from pre-trained neural networks, which help to solve problems mainly in three directions:
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Artificial intelligence is today developed within the first direction. Algorithms in the third direction are still very limited and primitive. Therefore, we should now make efforts in the second direction - building recommendation systems.

5. CONCLUSIONS

From a neuroscientist's point of view, education is not a mechanical accumulation of skills, but a work with cognitive resources, including an attempt to increase them. We are increasingly using knowledge about the brain to build educational processes, but this knowledge alone does not guarantee the most effective learning solutions. Different factors influence how a particular person learns: genes, brain, society and the environment as a whole. Not everything is determined by the brain, but it is useful to understand how the brain is affected by learning processes in order to adjust the environment, test learning outcomes, and utilize its resources as effectively and as long as possible.
Misconceptions about how the brain works arise from outdated scientific data or illiterate simplification of complex concepts. Knowing what is a myth and what is a proven fact will help you choose appropriate training methods and avoid wasting time on ineffective ones.
The presented intelligent tutoring system confirms the hypothesis that complex algorithms and AI models are not always required to use it in the learning process

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