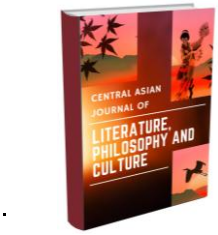

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Article

Modernizing Environmental Education Through Artificial Intelligence Tools

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Abstract: This article analyzes the theoretical foundations, practical approaches and possibilities of modernizing environmental education using artificial intelligence (AI) technologies in Uzbekistan. In the context of the global ecological crisis, the formation of environmental awareness among young people has become an urgent issue, and traditional educational methods are not sufficiently effective in this regard. The rapid development of artificial intelligence makes it possible to make environmental education interactive, individualized and practice-oriented. The study systematically analyzes the best practices of countries such as China, Iceland, the USA and Brazil. The analysis showed that AI tools allow for the visualization of complex environmental concepts, individualization of education, the formation of skills for working with real environmental data and the involvement of young people in environmental activities. The specific environmental problems of Uzbekistan - the Aral Sea crisis, limited water resources, desertification processes - require the development of AI solutions adapted to the local context. The article proposes the following solutions adapted for Uzbekistan: Aral Sea virtual laboratory, AI advisor for water resources management, interactive platform for waste sorting, etc. It also analyzes the problems of introducing AI tools into environmental education - technological infrastructure, teacher training, ethical and safety issues - and suggests ways to solve them.

Keywords: Artificial Intelligence, Environmental Education, Modernization, Youth Environmental Awareness, Interactive Platforms, Virtual Reality, Immersive Technologies, Aral Sea, Uzbekistan, Digital Transformation.

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1. Introduction

Digital transformation and new opportunities for environmental education

In the context of the global environmental crisis, the issue of forming environmental awareness among young people is gaining not only pedagogical, but also civilizational significance [1]. According to the United Nations, only 27% of schools worldwide have included "education for sustainable development" in their official assessment system, which means that 70% of students on our planet do not systematically learn "how to live with planet Earth." At the same time, traditional environmental education often remains at the theoretical level and does not provide sufficient tools for young people to understand real environmental problems and actively participate in solving them [2]. The rapid development of artificial intelligence (AI) technologies creates the opportunity to radically change environmental education. With the advent of ChatGPT at the end of 2022, generative SI technologies have penetrated all aspects of education and have become an impetus for a profound transformation of teaching methods. In particular, SI tools in

environmental education allow simplifying complex environmental concepts, individualizing education, and involving young people in solving real environmental problems. This article analyzes the theoretical foundations, practical approaches, and application possibilities of modernizing environmental education through artificial intelligence tools in the conditions of Uzbekistan [3].

2. Materials and Methods

Theoretical and methodological foundations of modernizing environmental education

Constructivist approach and integration of artificial intelligence

Enriching environmental education with SI tools is based on the theory of constructivist education. According to the constructivist approach, students actively acquire new knowledge by integrating it with existing experiences. The main principles of this theory - active learning, independent construction of knowledge, contextual learning, social interaction and taking into account the individual characteristics of students - are perfectly combined with the capabilities of SI technologies [4]. Another important theoretical basis for the use of artificial intelligence in education is Merrill's "First Principles of Instruction". This approach focuses on problem-based learning and puts forward five main principles: activating prior knowledge, demonstrating new content, applying new knowledge, testing it in a real context and integrating it into the experience of students. These principles are especially important in environmental education, since environmental problems are directly related to real life and solving them requires practical skills in addition to theoretical knowledge [5].

Cognitive Load Theory and SI Tools

In environmental education, mastering complex systematic concepts can be a cognitively demanding task for students. According to cognitive load theory, SI tools can increase students' learning efficiency by visualizing, simplifying, and organizing complex environmental information. For example, in a study conducted at the Jökulsárlón glacial lagoon in Iceland, 87.1 percent of students enjoyed the approach, and 82.5 percent said that the method increased their sense of connection to nature through virtual environments and anthropomorphic images created using artificial intelligence [6].

3. Results and Discussion

Main areas of application of artificial intelligence tools in environmental education

1. Interactive and individualized learning platforms

Artificial intelligence-based learning platforms allow for the organization of environmental education tailored to the knowledge level, interests, and learning speed of each student. The "智汇环生" (Smart Environment) platform, implemented at a higher education institution in Henan Province, China, is a clear example of this. This platform divides courses such as "Solid Waste Recycling" into 234 subtopics, analyzes student behavior and learning indicators in real time, and forms an individualized learning trajectory for each student [7].

The ExposomeX platform, implemented at Peking University, is serving as an important tool in teaching the connection between the environment and health. The platform integrates more than 20 databases, containing information on approximately 1.2 billion environmental factors and more than 17,000 diseases. Through this platform, students have the opportunity to work with real-world environmental data, analyze them, and build AI models.

2. Immersive technologies: virtual and augmented reality

The combination of virtual (VR) and augmented reality (AR) technologies with artificial intelligence is creating completely new opportunities in environmental education [8]. These technologies make abstract environmental concepts “visible and tangible.” In AR courses at Peking University, students have the opportunity to “disassemble” virtual models and observe complex biological processes using AR devices.

3. Chatbots and virtual assistants

Artificial intelligence-based chatbots act as individual teachers working 24/7 in environmental education. In a study conducted in China, the Flipped AI-Chatbot Learning (FACL) module was developed, which combines generative SI and the flipped classroom method. In this module, students interact with AI chatbots before class and independently master a new topic, and in the classroom they deepen their knowledge through active teaching methods.

4. Visualization and modeling of ecological data

Artificial intelligence allows us to bring complex ecological data into a visual and understandable form. AIGC video reports created by the Chinese Xinhua News Agency use AI to process satellite data and ground monitoring results, transforming complex ecological processes such as "the sky has cleared, the water has become clearer" into visual images [9].

The NeuroClimaLens and NeuroClimaBot tools, which are being developed within the framework of the NEUROCLIMA project, allow us to monitor the processes of adaptation to climate change and analyze changes in the behavior of citizens.

International experience and practical examples

AI-based environmental education in universities

The example of Peking University's "ExposomeX" platform shows that artificial intelligence-based educational tools not only improve the quality of teaching, but also help students participate in scientific research. A number of scientific articles written by students on the platform have been published in prestigious international journals [10].

Special modules dedicated to climate change have been created within the framework of the "Day of AI" program developed by the Massachusetts Institute of Technology (MIT). Through modules such as "Making Sense of our Surroundings", "Ecobit Explorers", "Telling Climate Stories with Data", students have the opportunity to work with real climate data, analyze them and form their own conclusions.

AI technologies in nature reserves and national parks

The use of artificial intelligence technologies in nature reserves is taking environmental education to a new level. Based on the "世优波塔 AI 数字人智能体" (Shiyou Bota AI digital human agent) technology introduced in China's Hanma National Reserve, a 3D digital image of a moose (an animal belonging to the deer family) was created. This digital image can answer visitors' questions about the cold climate ecosystem, the lifestyle of moose, and the rules of the reserve with more than 98 percent accuracy.

The "智观动物" (Smart Animal Observation) system introduced in Tangjiahe Reserve allows real-time identification of wild animals through video surveillance and information about them to visitors.

International cooperation projects

The memorandum of cooperation signed between Suzano (Brazil), Tencent (China) and the Ecofuturo Institute within the framework of COP30 is an important international initiative in the field of environmental education based on artificial intelligence [11]. The project will use Tencent-developed species identification tools to monitor native species in Neblinas Park and other reserves, as well as create immersive nature education programs. The UNESCO-supported AI-CLIMATE EDU initiative aims to train people for a

sustainable future by integrating artificial intelligence and climate education. The initiative is developing interactive platforms that simplify complex climate data, real-time simulations, and gamified learning experiences tailored to different educational levels.

Opportunities for introducing AI tools in Uzbekistan

Analysis of existing infrastructure and resources

In recent years, Uzbekistan has been making great efforts to develop digital infrastructure. Within the framework of the "Digital Uzbekistan - 2030" strategy, special attention is paid to digitizing the education system, expanding Internet connectivity, and training personnel in the field of information technologies [12]. This creates the basis for introducing artificial intelligence tools into environmental education.

Development of adapted SI solutions

The specific environmental problems of Uzbekistan - the Aral Sea crisis, limited water resources, desertification processes, atmospheric air pollution - require the development of SI solutions adapted to the local context. In particular:

Aral Sea Virtual Laboratory - creation of a virtual platform that allows modeling ecological changes in the Aral Sea basin in historical dynamics and forecasting future scenarios using artificial intelligence.

AI Water Management Advisor – a mobile application that provides real-time recommendations on the efficient use of water resources in agriculture.

Interactive Waste Sorting Learning Platform – a gamified platform that teaches students how to properly sort waste using AI-based image recognition technology [13].

Stages of integration into educational programs

In Uzbekistan, the introduction of artificial intelligence tools into environmental education can be carried out in the following stages:

1. Preparatory stage (1-2 years) – retraining of teaching staff, analysis of existing AI tools, development of pilot projects.
2. Implementation of pilot projects (2-3 years) – testing of AI tools in selected higher educational institutions and schools, evaluation of effectiveness.
3. Scaling and integration (3-5 years) – expansion of successful experiences on a republican scale, creation of a national environmental education platform.

Cooperation opportunities

Uzbekistan has the opportunity to use the above-mentioned experiences within the framework of international cooperation. In particular:

- Joining the UNESCO "AI-CLIMATE EDU" initiative;
- Studying and adapting the best practices of China, South Korea and the European Union;
- Involving local IT companies and startups in the development of AI solutions for environmental education [14].

Problems and solutions

Technological and infrastructural problems

One of the main obstacles to the introduction of artificial intelligence tools into environmental education in Uzbekistan is the insufficient development of technological infrastructure, especially in rural areas, low internet speed and coverage. To solve this problem, it is necessary to develop AI tools that can work offline and expand the use of mobile applications.

Training of pedagogical personnel

To effectively use artificial intelligence tools, teachers themselves must be familiar with these technologies. Currently, most teachers do not have sufficient knowledge and skills in working with AI tools. To solve this problem:

- **Organizing retraining courses for teachers;**
- **Introducing a special course "Artificial Intelligence in Environmental Education" in pedagogical universities;**

Creating mechanisms for disseminating the experience of advanced teachers.

Ethical and safety issues

The experience of the Ecomindfulness project shows that a number of ethical issues arise when using artificial intelligence: the risk of students becoming overly attached to AI, the suppression of creative thinking, and copyright issues [15]. To address these issues:

- Develop clear rules and regulations for the use of AI tools;
- Develop students' critical thinking and information source evaluation skills;
- Develop the understanding that AI tools are only auxiliary tools, and that the main solutions should be made by the person themselves.

4. Conclusion and Recommendations

Modernization of environmental education through artificial intelligence tools can play an important role in raising the environmental awareness of Uzbek youth. International experience shows that AI technologies:

- Simplify and visualize complex environmental concepts;
- Individualize education and adapt it to the needs of each student;
- Involve young people in solving real environmental problems;
- Deliver environmental knowledge in a gamified and interesting way;
- Enable high-quality education even in remote and resource-limited environments.

The following proposals can be put forward for the introduction of artificial intelligence tools into environmental education in Uzbekistan:

1. Creation of a national environmental education platform - development of a single AI-based platform adapted for all stages of education, taking into account the ecological characteristics of Uzbekistan.
2. Selection of pilot regions - testing AI tools in the Aral Sea region, large cities and mountainous regions.
3. Establish a system for training pedagogical personnel - opening the direction of "Digital technologies and artificial intelligence in environmental education" in higher educational institutions, organizing advanced training courses for existing teachers.
4. Expanding international cooperation - implementing joint projects in cooperation with such prestigious organizations and educational institutions as UNESCO, MIT, Peking University.
5. Supporting the creation of local content - enriching environmental content in the Uzbek language through artificial intelligence tools, attracting local specialists and programmers.

Artificial intelligence technologies have the potential to radically change environmental education. The important thing is to introduce these technologies in a way that serves to develop independent critical thinking of young people, in harmony with humanistic and ecological values.

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