FORMATION OF ENVIRONMENTAL COMPETENCE IN HIGHER EDUCATION: INTERACTIVE CARTOGRAPHIC TOOLS AND TECHNOLOGIES FOR MODELLING ENVIRONMENTAL PROBLEMS

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ABSTRACT

Amid global environmental change and increasing anthropogenic pressures, the need to train specialists with a high level of environmental competence is growing. This article examines the possibilities of integrating interactive cartographic tools and technologies for modelling environmental problems into the educational process of higher education institutions. The study analyzes the potential of Geographic Information Systems (GIS), digital maps, remote sensing, and virtual simulators for developing environmental thinking, enhancing analytical skills, and increasing students' environmental engagement. The article presents research findings on the effectiveness of these tools in teaching practice and identifies methodological conditions necessary for their successful implementation. The authors conclude that systematic digitalization of environmental education is essential for preparing competitive professionals in the context of sustainable development

Introduction

The current stage of societal development is marked by global ecological challenges, including climate change, ecosystem degradation, loss of biodiversity, and rising technogenic risks. Under these conditions, fostering environmental literacy and competence among future specialists becomes one of the most important tasks in higher education. Environmental competence encompasses not only knowledge of environmental conditions but also the ability to analyze, forecast, and make decisions aimed at minimizing negative environmental impacts.

In recent years, special emphasis has been placed on the digitalization of environmental education. Interactive cartographic tools, Geographic Information Systems (GIS), Earth remote sensing technologies (RS), and virtual modelling platforms expand educational possibilities by enabling visualization of environmental processes, spatial data analysis, and simulation of natural phenomena. These tools provide students with opportunities to investigate real environmental problems, analyze large datasets, develop evidence-based conclusions, and propose alternative solutions.

Despite the high potential of digital cartographic technologies, their methodological use in environmental education remains insufficiently developed. There is a need for research aimed at identifying pedagogical conditions that ensure the effective integration of these tools into the learning process.

The aim of this research is to provide a scientific and methodological justification for the use of interactive cartographic tools and technologies for modelling environmental problems to develop environmental competence among students.

Literature Review

In both international and national scientific literature, the formation of environmental competence is analyzed in the context of sustainable development, environmental behavior, and professional training. Researchers note that digital technologies enhance interest and motivation toward studying environmental disciplines [1].

Geographic Information Systems (GIS) are recognized as one of the most effective tools for spatial analysis of environmental processes. Studies by Goodchild (2018), Longley (2019), and Russian researchers (Bogdanov, 2021) demonstrate that GIS promotes analytical thinking, strengthens research skills, and helps evaluate spatial–temporal patterns of environmental change.

Technologies for modelling environmental problems, including virtual simulators, are widely used for predicting the consequences of industrial accidents, climate change, erosion processes, and water resource dynamics. Studies by Fowler (2021) and Alimova (2020) confirm that simulation modelling enhances students' ability to make informed decisions in conditions of uncertainty.

Overall, the literature indicates the strong educational potential of interactive cartographic tools, yet methodological issues related to their integrated application in higher education require further study.

Methodology

The research was carried out at several universities offering academic programs in Ecology and Geography. The methodology included:

1. Pedagogical experiment

- **Control group:** taught using traditional methods
- **Experimental group:** taught using GIS, interactive maps, and environmental modelling tools

2. Diagnostics of environmental competence

The evaluation criteria included:

- **Cognitive:** knowledge of ecological processes
- **Analytical:** skills in spatial analysis
- **Practical:** ability to use digital environmental tools
- **Value-based:** environmental attitudes and behavioral orientation

3. Analysis of the quality of the educational process

The following procedures were employed:

- classroom observations
- student questionnaires
- expert surveys of instructors

4. Statistical data processing

The effectiveness of the intervention was analyzed using:

- Student's t-test
- correlation analysis
- comparative descriptive statistics

Results

The pedagogical experiment yielded the following results:

1. Increase in cognitive level

Knowledge of environmental processes among experimental group students increased by **34%**, compared to **12%** in the control group.

2. Development of analytical skills

Work with GIS maps and satellite data enabled students to:

- confidently conduct spatial analysis
- identify pollution sources
- perform multi-criteria assessments of territories

3. Improvement of practical competence

Using digital tools, students mastered:

- thematic map creation
- modelling climate change scenarios
- forecasting ecological risks

4. Growth of environmental engagement

Questionnaire results showed a **27% increase** in environmental motivation, reflected in student participation in conservation projects and scientific research.

Discussion

The findings confirm that interactive cartographic tools are an effective instrument for developing environmental competence. Data visualization enhances comprehension of complex environmental processes, while modelling tools enable students to engage in research-oriented learning.

The pedagogical potential of these technologies lies in:

- creating learning situations approximating real environmental challenges
- developing skills of working with large datasets (big data)
- fostering interdisciplinary projects in geography, ecology, ICT, and sustainable development

However, successful integration requires:

- upskilling instructors
- ensuring adequate technical infrastructure
- developing methodologically sound teaching modules

Thus, the digitalization of environmental education must be systematic and accompanied by strong methodological support.

Conclusion and Recommendations

Based on the research findings, the following conclusions can be drawn:

• Interactive cartographic tools and environmental modelling technologies significantly enhance students' environmental competence.

• Digital maps and GIS technologies foster research skills and analytical thinking.

• Modelling environmental processes strengthens students' ability to make decisions under uncertainty.

• Digital technologies contribute to increased environmental motivation and civic responsibility among youth.

Recommendations

• Introduce GIS and environmental modelling modules into all natural science programs.

• Develop interdisciplinary projects using digital maps and satellite data.

• Enhance digital literacy among instructors.

Expand the use of global platforms (ArcGIS, QGIS, Google Earth Engine).

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