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marslandresearcher@gmail.com

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Methods Of Using Interactive Cartographic Resources And Their Effectiveness In Increasing Students' Ecological Activity

Alimdjanov Farkhodjon Nimadjonovich[1], Turdaliev Ibrokhim Erali ogli[2]

[1]Lecturer, University of Business and Science, Namangan, 160107, Uzbekistan.
[2]Lecturer, Namangan State University, Namangan, 160107, Uzbekistan.
alimjanov.f@mail.ru ibrohimturdaliev@gmail.com

Abstract. The growing scale of environmental threats makes the formation of environmentally responsible and proactive student behavior one of the key tasks of higher education. Interactive cartographic resources-such as Web-GIS, online maps, story maps, and virtual excursions-represent a promising tool that allows visualizing the spatial distribution of ecological problems and connecting theoretical knowledge with the local context. The purpose of this article is to describe the methods of using interactive cartographic resources in higher education and assess their impact on students' environmental activism. The research was conducted in the form of a quasi-experiment involving 120 students in environmental and geographical fields, divided into control and experimental groups. The experimental group worked within a model that included the analysis of existing Web-GIS projects, the development of students' own interactive maps of local ecological problems, and virtual ecological excursions. The results demonstrated statistically significant improvements in environmental knowledge, value orientations, and eco-oriented behavior among students in the experimental group compared with the control group. The strongest effect was observed in project-based work involving the creation of interactive maps of local environmental issues. The study concludes that deliberate integration of interactive cartographic resources into courses on ecology and sustainable development is highly beneficial and offers practical recommendations for educators.
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1. Introduction.

Accelerating climate change, ecosystem degradation, and increasing technogenic risks have transformed the environmental agenda into one of the key strategic directions of modern societal development. In this context, higher education institutions are expected not only to deliver knowledge about the environment but also to cultivate sustainable values and practices of environmentally responsible behavior among future professionals. In this article, *students' environmental activism* is defined as a combination of environmental knowledge, value orientations, and real participation in conservation and resource-saving activities (campaigns, volunteering, ecological initiatives on campus and within local communities).

Parallel to the intensification of environmental challenges, universities are experiencing rapid digitalization of the educational process. One of the most meaningful aspects of this trend is the integration of geoinformation technologies and interactive cartographic resources: Web-GIS platforms, online maps, geoportals, story maps, and virtual field trips. These tools make it possible to work with real spatial data concerning air quality, vegetation density, land-use structure, pollution sources, and other indicators. As a result, students perceive environmental problems not as abstractions but as spatially localized issues, enhancing their sense of personal involvement.

Studies show that the use of Web-GIS in geographic and environmental education contributes to the development of spatial thinking, skills in interpreting multilayer maps, and understanding the relationships between natural and socio-economic factors [1]. However, most research focuses on

cognitive outcomes (academic performance, spatial skills), while the behavioral component—actual changes in environmental behavior and participation in conservation initiatives—remains underexplored.

In university practice, interactive cartographic resources are often used only illustratively: instructors show an online map or a satellite image, but students remain passive observers. Under such conditions, the potential of Web-GIS for cultivating environmental activism is only partially realized. This situation reveals several contradictions:

- between the rich possibilities of interactive maps and their fragmented, episodic use;
- between the goal of developing an active civic and environmental stance and the predominance of reproductive forms of map-based learning;
- between students' technical readiness to use digital tools and educators' insufficient methodological readiness.

The purpose of this study is to describe and justify methods of using interactive cartographic resources specifically aimed at enhancing students' environmental activism and to empirically evaluate their effectiveness.

The research objectives include:

1. Analyzing modern approaches to the use of Web-GIS and interactive maps in environmental education.
2. Developing a methodological model incorporating active, project-based, and reflective student engagement with interactive maps.
3. Assessing the impact of the proposed model on students' knowledge, values, and behavioral indicators of environmental activism.

2. Literature Review.

Existing national and international studies reveal several research dimensions.

First, many works explore the integration of Web-GIS into geographic and environmental education. The findings indicate that Web-GIS projects enhance motivation, develop spatial reasoning skills, and support competencies in sustainable development [1]. Li et al. demonstrate that using Web-GIS to study natural hazards enables learners to visualize the spatial structure of risks and better understand their formation mechanisms [1]. Sofias and colleagues report increased student engagement and improved multilayer map interpretation skills when working with Web-GIS projects [2].

Second, significant research has been conducted in ecological mapping, focusing on principles of creating maps of pollution, ecosystem stability, and environmental capacity. Educational resources emphasize the importance of involving students in mapping based on field and statistical data as a means of fostering ecological culture.

Third, interactive methods in environmental education—such as role-playing games, web quests, and group projects—are actively discussed. Studies reveal that interactive methods strengthen the value component of ecological consciousness and improve communication skills; however, the specific role of cartographic resources within these formats remains insufficiently investigated.

Finally, several authors consider digital platforms and mobile applications aimed at fostering environmental activism: online courses on sustainable development, pollution-monitoring apps, and crowdsourced maps of environmental hotspots. It has been shown that involving learners in digital mapping of local ecological problems increases participation in volunteer projects and environmental campaigns.

Despite extensive research, key issues remain insufficiently explored: (1) how different methods of working with interactive maps (viewing, analytical tasks, creating maps) affect components of environmental activism; (2) which didactic conditions ensure sustained impact; (3) how to assess not only cognitive but also behavioral outcomes. The present study addresses these gaps.

3. Methodology.

The research was conducted at two universities offering courses in Ecology and Geography. The sample consisted of 120 second- and third-year students: 60 in the control group (CG) and 60 in the experimental group (EG). The groups were comparable in gender, age, and initial environmental knowledge (pre-test differences were statistically insignificant, $p > 0.05$).

Research design. A quasi-experimental pre-test/post-test design with a control group was employed. The CG was taught using traditional methods: lectures, seminar discussions, work with printed maps. The EG was taught using a specially designed set of methods integrating interactive cartographic resources.

Key methodological elements in the EG

1. **Analytical assignments using existing Web-GIS projects.** Students analyzed open-access interactive ecological maps (air quality, heat islands, green infrastructure, etc.), identified hotspots, and compared cartographic data with statistics and local observations.

2. **Project-based ecological mapping of local areas.** Small groups (3–5 students) developed their own interactive maps using Web-GIS tools (ArcGIS, Google My Maps):
    - selecting a local environmental problem (yard conditions, small rivers, accessibility of green spaces);
    - collecting data (surveys, field observations, open datasets);
    - constructing map layers and visualization;
    - formulating recommendations for local authorities and communities.
3. **Virtual ecological excursions.** Using Google Earth and story maps, virtual field trips were conducted to areas experiencing land-use changes, vegetation degradation, or increased technogenic pressure.
4. **Reflective and communicative activities.** Students presented projects, participated in discussions, and wrote reflective essays on their personal attitudes toward identified problems and possible forms of involvement.

Diagnostics

Environmental activism was assessed using:

- a 30-item environmental knowledge test;
- a Likert-scale questionnaire on environmental values and attitudes;
- an index of environmental behavior (frequency of eco-oriented practices in the past three months);
- content analysis of reflective essays.

4. Results.

Cognitive outcomes

In the CG, the average test score increased from 18.2 to 20.0 (9.9% growth).

In the EG, the score increased from 18.4 to 23.1 (25.5% growth).

The between-group difference was statistically significant ($p < 0.01$, $d \approx 0.7$), indicating higher effectiveness of the interactive model.

Value–motivational outcomes

The integral indicator of environmental attitudes increased by 0.3 points in the CG and by 0.8 points in the EG ($p < 0.05$). The most significant changes occurred among students actively engaged in project-based mapping.

Behavioral outcomes: The environmental behavior index increased from 2.1 to 2.3 in the CG, and from 2.0 to 2.7 in the EG ($p < 0.05$, $d \approx 0.5$). A moderate positive correlation was found between hours spent on project-based mapping and behavior index growth ($r \approx 0.4$).

Qualitative data

Students in the EG reported that working with "live" maps showing polluted or problematic sites "near home" or on campus made environmental issues *real* and motivated them to take action. Many expressed intentions to continue participating in ecological volunteering or initiate local environmental projects.

5. Discussion.

The results align with previous studies highlighting the high didactic value of Web-GIS and interactive maps in environmental education [1]. However, this study demonstrates that the *nature* of map-based activity is the decisive factor. The greatest impact occurs when students act as *active co-creators* of cartographic products rather than passive viewers.

Project-based ecological mapping of local areas strengthens the "localization effect": students perceive environmental issues as directly relevant and personally significant. This aligns with research suggesting that combining digital mapping with virtual/real excursions reinforces ecological values and a sense of responsibility.

Importantly, interactive maps serve dual functions: as tools for data analysis and as instruments of communication and advocacy. Student-created interactive maps and story maps can be used in dialogue with university administration, local authorities, and communities, increasing the perceived importance of academic work.

Limitations include quasi-experimental design, reliance on self-reported behaviors, and the focus on environmental and geography majors. Nevertheless, the findings provide a foundation for extending this model to other fields.

6. Conclusion and Recommendations.

The study allows drawing the following conclusions:

1. Interactive cartographic resources, when used purposefully and methodologically, significantly enhance not only environmental knowledge but also attitudes and environmentally responsible behavior among students.
2. The most effective methods are those requiring active student engagement: project-based ecological mapping, creation of interactive maps and story maps, integration of field data with Web-GIS tools.
3. Virtual ecological excursions and analytical assignments using existing Web-GIS projects reinforce understanding of the spatial nature of ecological problems and motivate participation in environmental initiatives.

Practical recommendations

- Integrate modules on interactive maps and Web-GIS into courses on ecology and sustainable development.
- Organize at least one semester-long group project on ecological mapping of the campus or local area.
- Use student project outcomes in dialogue with university and municipal authorities.
- Support professional development of educators in digital cartographic technologies.
- Combine quantitative and qualitative methods for assessing changes in students' environmental activism.

Implementing these recommendations will transform interactive cartographic resources into a powerful tool for shaping environmentally active and responsible young people.

Corresponding author:
Alimdjanov F at. el.
University of Business and Science, Namangan, Uzbekistan
Contact alimjanov.f@mail.ru

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