Structural-Functional Model of Designing and Applying Interactive Cartographic Guides in the Professional Training of Geography Teachers

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Abstract: This study conceptualizes and evaluates a structural-functional model designed to integrate interactive cartographic guides into the higher professional education of geography teachers. Accelerated digitalization and advances in Geographic Information Systems (GIS) demand a transition from static visual aids to dynamic, multi-layered geoinformation systems. The proposed model unifies five interconnected structural blocks: Theoretical-Methodological, Technical-Technological, Procedural-Methodological, Practical-Empirical, and Monitoring-Diagnostic. Through methodological approaches including competency-based, constructivist, systems, and activity-based learning, the framework establishes a dynamic feedback loop that continuously enhances students' digital-geoinformation and professional-pedagogical competencies. Empirical validation demonstrates that structured utilization of web-based interactive maps (such as Leaflet.js and Web-GIS architectures) reduces routine map searching time by 40–50%, significantly boosting spatial-logical thinking and independent research skills. This framework provides a scalable pedagogical ecosystem for modernizing geography teacher education in accordance with international digital education standards. [Turdaliyev I.E., Abdurahmonov B.M. Structural-Functional Model of Designing and Applying Interactive Cartographic Guides in the Professional Training of Geography Teachers.
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Keywords: Interactive cartographic guides; Structural-functional model; Geography teacher training; Web-GIS; Geoinformation competence; Didactic cartography; Higher geography education.

Introduction

The global transformation of educational systems driven by digital technologies, spatial data infrastructure expansion, and Web-GIS platforms necessitates a fundamental redesign of teacher preparation programs in geography education. Traditional geography instruction has long relied on static paper maps and passive cartographic visual aids, which often limit learners to basic spatial recognition and low-level cognitive tasks [8, 9]. Modern geographical literacy requires higher-order cognitive competencies, including dynamic spatial analysis, multi-layered data synthesis, real-time spatial modeling, and geo-visualization.

In higher pedagogical education, cartographic training represents an invariant, system-forming core that directly shapes a prospective teacher’s spatial mindset, scientific world outlook, and methodological readiness. Developing cartographic competence requires bridging the gap between theoretical geographical knowledge and practical geoinformation skills [2, 4]. An interactive cartographic guide is defined as a multi-functional digital educational resource built on GIS and web-mapping technologies that facilitates dynamic spatial-temporal modeling, interactive data query, and multi-layered spatial analysis.

Despite growing interest in digital pedagogical tools, many higher education institutions lack a systematically structured, methodology-driven framework for embedding interactive maps into daily pedagogical practice. Unplanned or sporadic application of digital tools fails to yield long-term pedagogical effectiveness. Therefore, this study aims to formulate and justify a comprehensive **Structural-Functional Model** for designing and utilizing

interactive cartographic guides in training geography teachers.

LITERATURE REVIEW

The integration of digital technologies and Geographic Information Systems (GIS) into geographical education has been a focal point of contemporary pedagogical research. The transition from traditional, static cartographic visual aids to dynamic, web-based spatial frameworks represents a paradigm shift in how spatial literacy and geographical thinking are cultivated.

Theoretical foundations of cartographic pedagogy emphasize that maps are not merely illustrative visual aids, but primary didactic instruments that structure spatial-logical thinking and scientific inquiry. Early research in geodidactics highlighted the limitations of paper-based atlases, which restrict learners to passive spatial perception and declarative knowledge retrieval. Modern educational researchers, including Kerski [5] and Milson [7], assert that Web-GIS and interactive cloud-based mapping platforms transform learners from passive consumers of geographic information into active spatial analysts. Interactive cartography facilitates real-time data querying, multi-layered spatial overlay, dynamic scaling, and temporal modeling, which directly support higher-order cognitive processing according to Bloom's Taxonomy.

In higher pedagogical education, the development of prospective geography teachers' digital and cartographic competencies has received increasing attention. Studies by Barinova and Tamozhnyaya [4] stress that cartographic training forms the system-forming core of geography teacher preparation. However, traditional instructional methods often suffer from a disconnect between technical GIS training and methodological application in classroom settings. To bridge this gap, recent literature advocates for activity-based and constructivist frameworks where pre-service teachers design, manipulate, and evaluate interactive digital learning materials themselves.

Furthermore, research by Abdurahmonov and Suslov [3] highlights the imperative of structuring digital lesson plans around student-centered problem-solving tasks. Recent studies on digital transformation in Uzbek higher education demonstrate that embedding web-mapping tools (such as Leaflet.js [6], Mapbox, and interactive 3D platforms) into teacher training significantly enhances engagement, improves spatial visualization skills, and optimizes time management during pedagogical practice.

Despite these advancements, existing literature reveals a lack of comprehensive, structural-functional models that systematically link theoretical-methodological principles, Web-GIS technical infrastructure, procedural task hierarchies, empirical practice, and dynamic diagnostic feedback into a unified pedagogical framework. Most existing studies focus either solely on technical GIS implementation or general pedagogical strategies. This study addresses this theoretical and practical gap by designing and evaluating a holistic Structural-Functional Model for interactive cartographic guides in geography teacher education.

Materials and Methods

Methodological Framework

The methodological foundation of this research integrates a structural-functional approach with competency-based, constructivist, systems, and activity-based learning paradigms:

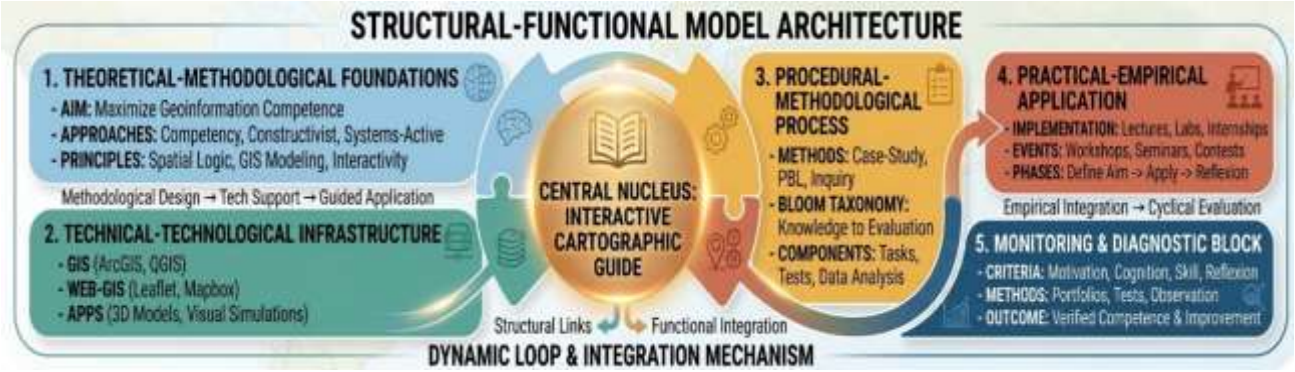


Figure -1. Structural-Functional Model Architecture

- **Competency-Based Approach:** Focuses on converting theoretical geographical knowledge into practical cartographic problem-solving skills.
- **Constructivist Learning Theory:** Reconceptualizes students from passive information receivers into active knowledge builders who construct spatial insights via direct interaction with dynamic maps.
- **Systems and Activity-Based Approaches:** Ensure structured, step-by-step engagement with cartographic tools across all stages of higher education coursework.

Design and Implementation Architecture

The experimental software architecture and software tools integrated into the model include[cite: 3, 4]:

1. **Desktop GIS Systems:** ArcGIS and QGIS for spatial data preprocessing, layer georeferencing, and database construction.
2. **Web-GIS and Web-Mapping Libraries:** JavaScript frameworks including Leaflet.js, deck.gl, Chart.js, and JSON-driven database structures deployed via custom portals (e.g., *geoexplorer.uz*)[cite: 3, 4].
3. **Interactive Applications:** Software packages including 3D population density models, interactive demographic platforms, and digital cartographic simulators.

Results

The Structural-Functional Model Architecture

The central nucleus of the developed pedagogical framework is the **Interactive Cartographic Guide**, which unifies five structurally linked operational modules:

Operational Mechanisms of the Model Blocks

1. **Theoretical-Methodological Block:** Defines strategic pedagogical aims and specialized cartographic-didactic principles, including spatial-logical consistency, geoinformation modeling, and interactive real-time feedback.
2. **Technical-Technological Block:** Supplies the technological infrastructure. It transitions students from passive consumers of maps into active digital cartographers and application developers.
3. **Procedural-Methodological Block:** Structures cartographic assignments according to Bloom's Cognitive Taxonomy:
   - *Knowledge & Understanding:* Reading dynamic legends and locating objects.
   - *Application & Analysis:* Spatial overlay operations to evaluate cause-and-effect relationships.
   - *Synthesis & Evaluation:* Designing new thematic layers and territorial development scenarios.
4. **Practical-Empirical Block:** Integrates interactive guides into lectures (problem-based visualization), practical seminars (case-study analysis), and independent study (geogaming and geokvests)[cite: 3, 4].
5. **Monitoring and Diagnostic Block:** Evaluates progress across four core criteria (Motivational-Valuable, Cognitive-Knowledge, Activity-Practical, and Reflective-Evaluative). The embedded feedback loop feeds evaluation data back into the methodological and technical blocks for continuous refinement.

Discussion

The empirical implementation of this structural-functional model in higher geography teacher education yields several distinct pedagogical advantages:

- **Time Efficiency and Active Engagement:** Replacing traditional static paper maps with Web-GIS interactive applications reduces time spent on manual map searching and paper data transcription by **40–50%**.
- **Development of Professional Competencies:** The multi-layered structure systematically advances three primary competence areas: Information-Methodological, GIS & Digital Cartographic, and Pedagogical-Communicative.
- **Shift from Passive to Research-Oriented Education:** Rather than memorizing static spatial boundaries, prospective teachers engage in interactive spatial inquiry, scenario planning, and independent web-mapping development[cite: 3, 4].

The continuous feedback mechanism ensures that the educational system remains dynamic, adaptive, and responsive to rapid technological advancements in geoinformation science.

Conclusion

The structural-functional model established in this study presents a holistic, science-based framework for integrating interactive cartographic guides into geography teacher preparation. By unifying theoretical-methodological foundations, modern Web-GIS infrastructure, Bloom-structured procedural methods, practical-empirical testing, and diagnostic feedback, the model transforms traditional cartographic instruction into a dynamic, research-driven pedagogical ecosystem[cite: 3, 4]. Future research will explore the further integration of AI-assisted spatial analytics and automated assessment modules into this interactive cartographic framework.

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