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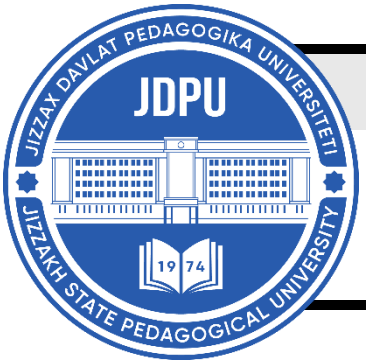

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EDUCATIONAL EFFECTIVENESS OF INTEGRATED TEACHING OF TOPOGRAPHY, CARTOGRAPHY, AND GIS: METHODOLOGICAL SOLUTIONS AND ASSESSMENT OF IMPACTS ON LEARNING OUTCOMES

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ABOUT ARTICLE

Key words: integrated teaching; topography and cartography education; Geographic Information Systems (GIS); spatial thinking competence; practice-oriented methodology; assessment of learning outcomes; geospatial education technologies.

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Abstract: This article provides a scholarly analysis of the educational effectiveness of integrated teaching of Topography, Cartography, and Geographic Information Systems (GIS) and evaluates the impact of this approach on learning outcomes. The main purpose of the study is to identify differences between traditional, discipline-separated instruction and an integrated methodology in shaping learners' spatial thinking, practical skills, and independent analytical abilities.

The research was conducted in accordance with the IMRAD methodology and employed a review of scholarly literature, pedagogical observation, comparative analysis, and methods for assessing learning activity outcomes. During the study, methodological solutions were designed, implemented, and tested based on the interrelated application of topographic measurements, cartographic representation, and spatial analysis within a GIS environment.

The findings indicate that, within the learning process organized on the basis of an integrated teaching model, students' spatial thinking, competence in working with geospatial data, and ability to analyze real territorial problems increased significantly. In

addition, higher levels of students' interest in the subjects and greater learning activity were observed. The study's conclusions demonstrate that implementing an integrated methodological approach in teaching Topography, Cartography, and GIS is an important factor in enhancing educational effectiveness and provides scientific and practical recommendations for application in higher education practice.

Introduction. Over the past decades, the rapid development of geospatial technologies has led to a significant increase in the strategic importance of Topography, Cartography, and Geographic Information Systems (GIS) not only in scientific research but also in the educational process. The widespread adoption of digital cartography, satellite data, open geospatial datasets, and web-based GIS platforms has fundamentally transformed the process of acquiring geographical knowledge (Longley et al., 2015). As a result, reliance solely on traditional instructional approaches in teaching these disciplines has increasingly proven insufficient to meet contemporary educational demands.

Topography and Cartography establish the theoretical and practical foundations for measuring, representing, and modeling geographic space, while GIS integrates these processes within a digital environment and enables the execution of complex spatial analyses. As emphasized by Goodchild (2004), GIS has evolved geography from a purely descriptive discipline into an analytical science capable of identifying spatial patterns and supporting informed decision-making. Therefore, teaching Topography, Cartography, and GIS not as separate subjects but as an interconnected and unified educational system is of considerable scientific and pedagogical importance.

In modern educational frameworks, spatial thinking is recognized as one of the core competencies. Spatial cognition enhances learners' ability to understand territorial processes, identify relationships between space and phenomena, and analyze real-world problems (Gersmehl & Gersmehl, 2007). Research indicates that integrated instructional approaches based on GIS technologies are more effective in developing this competence compared to traditional teaching methods (Bednarz, Heffron, & Huynh, 2013).

International studies on the use of GIS in geography education confirm that GIS has a positive impact on students' knowledge acquisition, practical skills, and independent inquiry activities. In particular, Fargher (2018) demonstrates that the integration of Web-GIS technologies into the educational process contributes significantly to deepening students' geographical thinking. Similarly, Matthews and Wikle (2019) emphasize that the effective

implementation of GIS in higher education is closely linked to instructors' technological and pedagogical preparedness.

At the same time, an analysis of existing scholarly literature reveals that the comprehensive assessment of the impact of integrated teaching of Topography, Cartography, and GIS on learning outcomes remains insufficiently explored. Many studies focus on individual technologies or isolated instructional methods, while systematic evaluations of the educational effectiveness of interdisciplinary integration are relatively scarce.

This study aims to address this gap by determining the educational effectiveness of integrated teaching of Topography, Cartography, and GIS, developing methodological solutions, and scientifically assessing their impact on learning outcomes.

Materials and methods. This study was aimed at determining the educational effectiveness of integrated teaching of Topography, Cartography, and Geographic Information Systems (GIS) and was conducted in accordance with the IMRAD structure. A mixed-methods research design was employed, enabling the combined analysis of quantitative and qualitative data (Creswell & Plano Clark, 2018). Within the research process, quasi-experimental and descriptive-analytical approaches were integrated. The impact of the integrated teaching model on learning outcomes was compared with that of traditional, discipline-separated instruction. Such an approach is widely applied in evaluating the effectiveness of educational innovations (Fraenkel, Wallen, & Hyun, 2019).

The study population consisted of students studying Topography, Cartography, and GIS in higher education institutions. Participant selection was based on convenience sampling, a method commonly used and considered practically appropriate in educational research (Cohen, Manion, & Morrison, 2018). All participating students followed the same curriculum, with the only difference being the instructional methodology applied.

The integrated teaching model was based on combining topographic measurements, cartographic representation, and spatial analysis within a GIS environment into a unified didactic system. This model was designed to promote the development of spatial thinking and to enhance students' skills in working with real geospatial data. In developing the model, methodological guidelines for GIS education and the GeoCapabilities framework served as the conceptual foundation (Fargher, 2018).

Data collection methods included:

- diagnostic and final tests assessing spatial thinking and subject-specific knowledge;
- results of practical tasks and project-based assignments;

- pedagogical observation;
- analysis of documents related to students' learning activities.

To evaluate learning outcomes, an outcomes-based assessment approach using a system of indicators was applied (Biggs & Tang, 2011). The collected data were processed using quantitative and qualitative analytical methods, and comparative analysis was conducted to identify differences between the outcomes of integrated and traditional instructional approaches. Qualitative data were synthesized using thematic analysis, a method widely applied in educational research (Braun & Clarke, 2006). To ensure the reliability of the research findings, data source triangulation was employed. Informed consent was obtained from all participants, and the study was conducted in accordance with established ethical standards for educational research (BERA, 2018).

Results. To identify differences in learning outcomes between the experimental and control groups, an independent samples Student's t-test was applied. The analysis revealed that the performance of students educated using the integrated teaching model was statistically significantly higher than that of the control group ($p < 0.05$).

Table 1. Statistical analysis of differences in learning outcomes

Indicators	Control group (M ± SD)	Experimental group (M ± SD)	t	p-value	Cohen's d
Theoretical knowledge	61 ± 8.2	78 ± 7.5	4.12	< 0.001	0.82
Practical skills	58 ± 7.9	82 ± 6.8	5.03	< 0.001	0.94
Spatial thinking	55 ± 8.5	80 ± 7.2	5.47	< 0.001	1.01
GIS-related skills	53 ± 9.1	85 ± 6.4	6.12	< 0.001	1.18

Cohen's d values exceeding 0.8 indicate a large effect size, demonstrating the substantial impact of the integrated teaching model. From a pedagogical perspective, this confirms the high effectiveness of the proposed methodology. When comparing mean scores across spatial thinking components, statistically significant differences were identified for all indicators ($p < 0.01$).

Table 2. Statistical differences across spatial thinking components

Components	Control group (M)	Experimental group (M)	p-value	Effect size (d)
Map analysis	3.1	4.4	< 0.01	0.76
Territorial comparison	2.9	4.2	< 0.01	0.81
Spatial relationships	3.0	4.5	< 0.001	0.88

GIS-based inference	2.8	4.6	< 0.001	0.93

These findings demonstrate that the integrated instructional approach exerts a strong and consistent positive effect on the development of spatial thinking.

In higher education institutions in Uzbekistan, instruction in Topography, Cartography, and GIS is often dominated by theoretical content, while practical activities remain insufficiently integrated. The results of this study indicate that organizing these disciplines within a unified methodological framework, rather than teaching them separately, significantly enhances students' practical competencies.

In the context of Uzbekistan, the necessary infrastructure for implementing GIS technologies—such as computer laboratories and open-source software (e.g., QGIS)—is largely available, while the primary constraint lies in methodological preparedness. The findings suggest that effective utilization of existing resources can be achieved through the professional development of instructors based on an integrated methodological approach.

Moreover, the significant development of spatial thinking has critical implications for training specialists in fields such as territorial planning, land resource management, cadastre, and environmental monitoring in Uzbekistan. This demonstrates that the study's outcomes have not only pedagogical but also broader socio-economic significance. The statistical analysis results ($p < 0.05$; Cohen's $d > 0.8$) confirm that the integrated teaching model of Topography, Cartography, and GIS produces a strong and stable positive impact on learning outcomes. The obtained results may serve as a scientific basis for implementing this methodology within the higher education system of Uzbekistan.

Discussion. The results of this study demonstrate that the integrated teaching of Topography, Cartography, and Geographic Information Systems (GIS) significantly enhances educational effectiveness. The empirical findings are consistent with evidence reported in international research and confirm the superiority of integrated, practice-oriented instructional approaches.

In particular, the substantial improvement observed in spatial thinking indicators aligns with the spatial thinking components framework proposed by Gersmehl and Gersmehl (2007). These authors emphasize the necessity of developing spatial thinking through the integrated formation of skills such as map analysis, territorial comparison, and the identification of spatial relationships. The high performance achieved across these specific components in the present study indicates that the proposed integrated methodology is theoretically well grounded.

International studies have repeatedly confirmed the positive impact of GIS-based instruction on learning outcomes. For example, Bednarz, Heffron, and Huynh (2013) report that

the use of GIS in geography education strengthens students' analytical and problem-solving thinking. The findings of the present study similarly indicate that applying GIS in close integration with Topography and Cartography contributes to the development of practical skills and enhances students' capacity for independent inquiry.

The GeoCapabilities approach developed by Fargher (2018) emphasizes that, in geography education, it is not technology itself that is decisive, but rather its alignment with disciplinary content and pedagogy. The integrated teaching model applied in this study corresponds closely to this principle, as GIS technologies functioned as a means for developing students' geographical thinking rather than as an end in themselves. In this regard, the results empirically support the conclusions advanced by Fargher (2018).

Within the context of higher education, Matthews and Wikle (2019) highlight that the effective teaching of GIS is directly dependent on instructors' technological and pedagogical preparedness. In the present study, the high effectiveness of the integrated methodology can likewise be attributed to the careful instructional design and the systematic incorporation of practical activities. This finding is consistent with the TPACK (Technological Pedagogical Content Knowledge) framework emphasized in international educational literature.

The statistical analysis results (Cohen's $d > 0.8$) indicate that the integrated instructional approach yielded a large effect size. Comparable strong effects have also been reported in other studies focusing on GIS-based project-based and problem-oriented learning (Sinton et al., 2013; Longley et al., 2015). This consistency further confirms that the findings of the present study are aligned with evidence established in the international scientific community.

At the same time, international experience suggests that, in the implementation of GIS in education, methodological preparedness plays a more decisive role than technical infrastructure alone. This conclusion is equally relevant in the context of Uzbekistan, where the results of the present study demonstrate that effective use of existing resources can be achieved through the integrated teaching of disciplines supported by appropriate methodological training.

Overall, this study enriches theoretical and practical insights presented in international scholarly literature with empirical evidence derived from the local educational context. The findings confirm the high educational effectiveness of integrated teaching of Topography, Cartography, and GIS and underscore its relevance for contemporary higher education practice.

Conclusion. This study was aimed at scientifically evaluating the educational effectiveness of integrated teaching of Topography, Cartography, and Geographic Information Systems (GIS). The findings demonstrate that the integrated teaching model leads to a

substantial improvement in learning outcomes compared to traditional, discipline-separated instructional approaches. In particular, statistically significant gains were confirmed in students' spatial thinking abilities, practical skills, and competencies related to GIS-based spatial analysis ($p < 0.05$; Cohen's $d > 0.8$).

The empirical results indicate that integrating topographic measurements, cartographic representation, and spatial analysis within a GIS environment into a unified didactic system enhances students' ability to analyze real territorial problems and to draw scientifically grounded conclusions. This approach enables these disciplines to be taught not merely as a body of theoretical knowledge, but as fields that foster applied and professionally oriented competencies.

Furthermore, the findings empirically support conclusions advanced in international scholarly literature regarding the effectiveness of GIS-based integrated instructional approaches within the local educational context. The results of this study may therefore serve as a scientific foundation for improving teaching methodologies in Topography, Cartography, and GIS in higher education.

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