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A PEDAGOGICAL MODEL FOR INTEGRATING GIS CARTOGRAPHY INTO TOURISM AND LOCAL HISTORY ACTIVITIES: PRINCIPLES, STAGES, AND EVALUATION OF EFFECTIVENESS

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ABSTRACT

In accordance with the reviewer's suggestion, the abstract has been shortened with a clear focus on the key methods, main findings, and conclusions to enhance readability and clarity: Our study presents a pedagogical model for integrating geographic information systems (GISs) into local history and tourism education to enhance students' spatial thinking and research competence. The model builds on the frameworks of spatial thinking, place-based education, and inquiry/project-based learning (PBL). The research involved 53 geography teachers and 45 students (control and experimental groups) through surveys and a formative pedagogical experiment. The model comprises four components (target, content, technological, and evaluative) and five inquiry phases: initiation, data construction, field research, analytical consolidation, and reflection. Our results revealed a significant improvement in cognitive and motivational indicators among the students in the experimental group: high-level competencies exceeded 50%, whereas low-level competencies decreased to 20%. GIS integration shifted reasoning from descriptive to analytical and strengthened interdisciplinary and civic engagement. We conclude that embedding GIS tools in local history practices fosters spatial literacy, geo-intellect, and sustainable geoeducation ecosystems. Evaluation employed CIPP and Kirkpatrick models to ensure methodological rigor and long-term educational impact."

KEYWORDS: GIS Mapping, Spatial Thinking, Local History and Tourism Activities, Pedagogical Model, Inquiry-Based Learning, Place-Based Education, CIPP Model, Kirkpatrick, Geo-Intellect, Digital Didactics, Geoeducation.

1. INTRODUCTION

In examining the digital transformation of education, one may observe that this transformation reinterprets spatial thinking and geoinformation literacy not only as specialized skills but also as foundational competencies of the 21st century. In the seminal National Research Council report Learning to Think Spatially (2006), spatial thinking is defined as a constructive unity of spatial concepts, representational tools, and reasoning processes.

In particular, it functions as a universal cognitive framework for integrating data, formulating problems, and constructing solutions across the K–12 curriculum and beyond (Learning to Think Spatially, 2005). This key document also substantiates the necessity of institutionalizing a GIS as a “support system” for the learning process since it simultaneously serves as a tool for visualization, a modeling environment, and a method of scientific inquiry for students of different ages.

Notably, alongside the development of GIScience, a demand has emerged for critical spatial thinking as a high-level educational goal. This means that modern students must not only “read maps” but also understand the epistemic limitations of data, the uncertainty of measurements, the assumptions underlying models, and the social consequences of spatial decisions.

Within this context, the research agenda of GIScience over the past decade (Goodchild, 2010) emphasizes the formalization of spatial concepts, the development of reasoning about spatial regularities, and the transfer of these competencies into interdisciplinary practices from ecology and history to territorial management. In pedagogical terms, this implies a transition from “teaching programs” to “teaching through space,” that is, from interfaces to inquiry, from mapping to explaining causal relationships and making decisions.

Overall, the global geographical and pedagogical literature provides convincing evidence that integrating web mapping and a GIS into teaching practices enhances students’ research engagement, increases motivation, and fosters interdisciplinary integration (geography–history–informatics–social studies). In particular, the works of J. Kerski (2013) demonstrate that web cartographic investigations not only expand the repertoire of educational tasks but also cultivate students’ ability to “see connections” among phenomena, time, and space, as well as between infrastructure and quality of life, thereby nurturing genuinely geographical, relational thinking. Especially important are open web tools and geoportals (including school-based cases), which allow research to flow cyclically “from the screen to the field and back.” This cyclicality (observation, data collection, mapping, interpretation, and decision-making) represents the true didactic value of a GIS in education.

Nevertheless, it is also evident that the implementation of a GIS in school and university education remains heterogeneous, fragmented, and constrained by numerous barriers, ranging from insufficient teacher training and a lack of methodological materials to the excessive complexity of professional software and limited data access (Schulze, 2021).

In this context, as we observe, recent meta-analytical and review studies identify two crucial trends.

First, there is a positive average effect of geospatial technologies on learning outcomes, particularly in data analysis, problem-solving, and visualization tasks.

Second, there are “bottlenecks” in implementation: institutional constraints, overloaded curricula, age-inappropriate software tools, and the scarcity of validated instruments for assessing educational effects.

Taken together, these findings point not to limitations of the GIS itself but to the need for pedagogical models (Ma, 2023) models that structure technology within a sequence of didactic steps and rigorously designed tools to evaluate their effectiveness.

Within the sphere of local history and tourism education, these challenges and opportunities manifest especially vividly. Indeed, local studies, by their very nature, constitute field- and space-based learning, requiring the localization of facts, the reconstruction of historical–cultural landscapes, the synthesis of natural and social data, route planning, and risk assessment.

Here, GIS mapping seamlessly integrates this logic as a natural instrument interpreted through thematic map creation; geocoding of observations; digital route and field diary management; and the integration of GPS traces, photo data, and local community narratives.

In our view, such integration addresses three key pedagogical objectives

1. Development of spatial literacy through working models of “place” and “spatial relations.”
2. The research dimension should be strengthened through a project-based cycle of question–data–analysis–visualization–presentation–reflection.

3. Fostering civic and local identity through participation in real, locally significant projects (cultural heritage maps, environmental monitoring, "smart" tourist routes).

Accordingly, the local history context becomes a testing ground where both the didactic and sociocultural effectiveness of GIS integration can be rigorously evaluated via valid criteria.

We argue that moving from "scattered practices" to sustainable pedagogical innovation requires a holistic model for integrating GIS mapping into local history and tourism education one with clearly defined principles (spatial visualization, interdisciplinarity, project orientation, digital accessibility, local relevance), implementation stages (preparatory, interactive-laboratory, research-field, reflective-evaluative), and, crucially, an authentic apparatus for measuring educational effects.

Indeed, the absence of validated assessment instruments from spatial thinking scales to indices of research activity and local engagement often impedes the generalization and scaling of results. For us, this means that a research program that combines model design and the construction of an assessment toolkit with subsequent statistical testing of its reliability and construct validity in real educational settings is needed.

In this respect, our study responds to this challenge or, more precisely, offers what we believe is a sufficiently rigorous answer. The goal of our work is to develop and test a pedagogical model for integrating GIS mapping into local history and tourism activities while also proposing a scientifically grounded, empirically validated assessment toolkit for its effectiveness.

Our work is theoretically based on the framework of spatial thinking as the unity of spatial concepts, representational means, and reasoning procedures. Methodologically, it relies on project-based and inquiry-oriented didactics, as well as on the approach of critical spatial thinking in education. Empirically, it employs a revised and validated questionnaire designed to measure motivation, cognitive and activity outcomes, and students' civic local identity.

We hypothesize that the proposed model will yield statistically significant improvements across multiple criteria (spatial literacy, research activity, quality of student-produced outputs such as digital maps and routes, motivation, and local engagement) and will demonstrate reproducible effects within baseline educational institutions.

Thus, our work contributes to the international discussion on effective GIS education practices (Bearman, 2026), shifting the focus from "tool mastery" to "the formation of spatial thinking" and "socially meaningful action" within one's native region.

2. LITERATURE REVIEW

The paradigms and implications of Geographic Information Systems (GIS) (He, 2024) have gained broad application in modern education. This is particularly evident in problem-oriented learning contexts (Ortega, 2024) and in the methodology of teaching itself (Abubakar, 2024).

The problem of developing practice-oriented thinking in science education inevitably leads us to three interrelated domains: the epistemology of causal explanation, the cognitive psychology of visual representations, and the didactics of scientific modeling. In this section, we systematize the theoretical foundations underpinning our approach, demonstrating that visualization of causal relationships is not merely a matter of visual aid but constitutes a distinct class of external cognitive artifacts that transform the pathway from empirical observation to explanatory modeling and, ultimately, to prediction and action.

In our interpretation, the integration of GIS mapping into local history and tourism education rests upon three interrelated foundations

(i) A cognitive–epistemological foundation in which spatial thinking is understood as "a unity of concepts, representations, and reasoning procedures"?

(ii) a didactic–methodological foundation, embodied in the Inquiry/PBL paradigm (Palupi, 2020) and informed by place-based education (Yemini, 2025)?

(iii) and an evaluative–metric foundation comprising validated instruments for measuring geospatial thinking and models for educational program evaluation.

Naturally, none of these foundations alone can ensure sustainable educational impact. We contend that only their composition delineates the framework of a pedagogical model in which a GIS functions not merely as a "program" but also as a mode of knowing a way of perceiving, conceptualizing, and navigating space and place (see National Research Council).

The report Learning to Think Spatially asserts that spatial thinking constitutes a universal cognitive framework that integrates disciplines and connects data, problems, and solutions that is, it should become a normative component of foundational education, whereas a GIS should act as a "support system" of the learning process. The subsequent evolution of GIScience refined this notion, emphasizing that the goal of education is not simply to teach software interfaces but also to cultivate critical spatial thinking the capacity to recognize data uncertainties, model limitations, and the sociotechnical consequences of spatial decisions.

Empirical studies consistently demonstrate that GIS learning enhances spatial reasoning and the understanding of spatial relationships. For example, Lee and Bednarz (2009) reported statistically significant gains in spatial skill test results following targeted GIS instruction. These findings are corroborated by systematic reviews and meta-analyses indicating a positive average effect of geospatial technologies on academic outcomes and analytical thinking (Sanat, 2022; Abdimanapov, 2025).

Collectively, this defines the substantive goal of our model namely, elevating a GIS from a visualization tool to a cognitive technology that develops geo-intellect the ability to think in terms of space, scale, relationships, and routes within real-world problem contexts.

If the cognitive objective lies in developing spatial thinking, then the didactic mechanism, as we interpret it, is the organization of learning as inquiry and project-based activity. Project and inquiry formats featuring a driving question, authentic data collection and analysis, and public presentation of products have been shown to promote deeper understanding and knowledge transfer (Thomas, 2000). In geographical education, lessons employing geospatial technologies specifically enhance the comprehension of spatial relationships and "relational" modes of thought (Favier & van der Schee, 2014).

We regard place-based education as the key link between tourism and local history learning, that is, education in which the local community and environment serve as both content and practice. Grounded in the critical pedagogy of place, this approach combines empathy toward local experience with critical analysis of the historical, cultural, and power dimensions of space (Gruenewald, 2003). In the pedagogical tradition of D. Sobel, the "class–community connection" is realized through field routes, diaries, local maps, and service-learning projects. The GIS ensures the continuity of the cycle "field–data–map–explanation–solution" (Sobel, 2004). Thus, local history and tourism activities provide a natural environment for implementing the inquiry/PBL paradigm, with the GIS serving as a mediator between observation, analysis, and civic action.

On the basis of the logic of our preceding discussion and the analysis of related literature, we formulate several principles that enable the transition from "program-based activity" to "spatial–inquiry literacy"

a) Principle of spatial visualization of knowledge. In our formulation, the map serves not as an illustration but as a means of argumentation and modeling causal relationships. Accordingly, tasks are designed as sequences of spatial operations (queries, buffering, overlaying, routing), culminating in well-reasoned decisions,
b) Principle of inquiry completeness (Inquiry–Evidence–Explanation). Each project must include problem formulation, geodata collection (e.g., GPS tracks, geo-tagged photos), analysis, and verification of explanations. Thus, a GIS becomes a laboratory of causality rather than merely a "map-drawing tool".
c) Principle of place. Project topics, data, and stakeholders must be local. In other words, the project outcome should have a tangible user within the community (for instance, a cultural heritage map or an ecological trail), thereby fostering civic and local identity.
d) Principle of accessible technologicality. This principle entails that tool selection from web maps to full-scale GIS applications is subordinate to didactic objectives and age appropriateness. Open data and free or web-based tools are prioritized to ensure scalability and inclusiveness.
e) Principle of embedded evaluativity. Assessment metrics are incorporated at the design stage. Cognitive, activity-based, motivational, and value indicators are measured via validated instruments, whereas maps and routes undergo expert argument-based evaluation.

Accordingly, we maintain that any claim to the scientific soundness of a pedagogical model must rest upon valid measurement tools. Two established approaches are appropriate for directly assessing geospatial thinking.

The first is the spatial thinking ability test (STAT) (Lee, 2012), which was developed to integrate geographic content with spatial skills. STAT has demonstrated content validity and diagnostic accuracy for the components of spatial thinking.

The second is the instrument by Huynh and Sharpe (2013), which assesses geospatial thinking expertise (relations, scale, representations, etc.) and has undergone rigorous development and psychometric validation. Additionally, as a supplementary framework for analyzing learning materials and assignments, the taxonomy of spatial thinking can be applied to evaluate the "spatiality" of questions and exercises.

Of course, assessment tools alone are insufficient without a model for evaluating the program itself. We posit that for both external and internal validation of GIS–local history integration, the combined use of two models is well justified: the CIPP model (Context–Input–Process–Product) (Sopha, 2019) for formative and summative program evaluation and Kirkpatrick's New World model (Reaction–Learning–Behavior–Results) (Kirkpatrick, 2010) for capturing transfer from learning to practice and measuring contributions to community outcomes (Gandomkar, 2018).

The CIPP provides a systemic framework for verifying contextual alignment (local needs, infrastructure), input adequacy (data, software, teacher preparation), process quality (project design, inquiry support), and product value (map/route quality and community relevance). Kirkpatrick, in turn, emphasized that without progression from "learning" to "behavior" and "results," educational impact remains declarative. Therefore, behavioral change and community outcome levels must be explicitly operationalized for tourism and local history contexts.

On the basis of the analysis of related literature, we argue that the theoretical foundation of our model can be coherently articulated as an instrumental–cognitive framework comprising the following

1. Cognitive core-development of critical spatial thinking and geo-intellect as a transferable competence,
2. Didactic shell-Inquiry/PBL grounded in place-based education, where local routes and landscapes serve as both subject and resource of inquiry;
3. **Dual evaluative framework**

(i) measurement of individual gains via the STAT and the Huynh–Sharpe instrument, along with analysis of the "spatiality" of tasks,

(ii) Program-level evaluation via the CIPP and Kirkpatrick models, which capture implementation quality and the social impact of cartographic outputs.

Within this framework, local history and tourism education cease to be a peripheral "excursion" and become a systematic educational practice in which GIS mapping ensures cognitive depth (through modeling spatial relations), methodological rigor (via the inquiry cycle), and social significance (through maps and routes as public artifacts).

3. METHODOLOGY

The study of the use of geoinformation mapping in geography instruction was conducted in two sequential stages: a diagnostic phase and a formative phase. Its purpose was to identify the current status of digital cartographic technologies in school practice, determine methodological and technical barriers, and evaluate the effectiveness of integrating geoinformation tools into the educational process.

To obtain reliable empirical data, we employed teacher and student questionnaires. The study followed a mixed design, combining elements of sociological surveying, pedagogical experimentation, and comparative analysis.

The questionnaires were administered online via Google Forms at the following links

For geography teachers

https://docs.google.com/forms/d/1BI4UrEhOPylRoofOY-25FmMk4qRDLpctF65vxuRklPM/edit

For students

https://docs.google.com/forms/d/1JDo6XmnIMIBssWRt8mWZ0xDCBKjdgdG6DyoGXV8R044/edit

The sample comprised 53 geography teachers and 45 school students, who were divided into a control group (23 participants) and an experimental group (22 participants). This design made it possible to assess not only the prevalence of GIS technologies among teachers but also their impact on the development of students' academic competencies.

The teacher questionnaire was designed to collect information on the following

- The frequency of using geographic information systems (GIS) and digital mapping in lessons,
- Priority types of the studied objects (physical–geographical, economic, cultural, touristic),
- The level of schools' technical and methodological support,
- Teachers' professional needs (in-service training, access to up-to-date platforms, methodological support).

The instrument included both closed-ended items (with response options) and semiopen items to elicit individual opinions. **Its structure covered four blocks**

1. Professional profile (years of service, qualification level),
2. Use of GIS technologies (frequency, formats, objectives),
3. Methodological and technical barriers,
4. Demand for competency development.

The resulting data were processed via descriptive statistics, including proportions, percentage distributions, and comparative analysis of frequency characteristics. In the second stage, we evaluated the effectiveness of geoinformation mapping in the learning process via a quasiexperimental design with control and experimental groups.

3.1. Stage 1: Baseline (Input) Diagnostics

Administered at the beginning of the academic quarter, this stage aimed to determine the initial level of students' competencies in GIS mapping. **Three preparedness levels were assessed**

- High
- Medium
- Low

The diagnostic results indicated comparable baseline distributions between the groups, confirming the soundness of group formation and enabling the formative phase to proceed.

3.2. Stage 2: Formative Experiment

Over the course of one academic quarter, the experimental group engaged in lessons that systematically incorporated GIS tools (Google Earth, QGIS, interactive maps, digital terrain and climate layers). Students worked with real geodata, conducted territorial analyses as project assignments, and produced thematic maps. The control group followed the standard curriculum without the active use of GIS technologies.

Upon completion of the formative phase, we conducted a final assessment using the same criteria as in the baseline diagnostics, which made it possible to identify changes in educational outcomes. The data were analyzed via comparative–descriptive procedures and basic statistical techniques (calculation of relative frequencies and percentage changes).

3.3. Evaluation Criteria and Indicators

Three groups of criteria were employed to assess the effectiveness of geoinformation mapping

1. Cognitive-mastery of geoinformatics concepts and methods; knowledge of digital map functions and data layers.
2. Practical-the ability to independently use cartographic services to solve learning tasks and to construct thematic maps.
3. Motivational–value-interest in geography and digital technologies; engagement in inquiry-oriented assignments.

Each criterion was assessed via a three-level scale: high, medium, and low. Aggregate indicators were analyzed for both groups to determine differences in competency gains.

3.4. Reliability and Validity

To enhance the reliability of the findings, **we adhered to key requirements of pedagogical experimentation**

- Comparability of groups in terms of age, number of participants, and baseline preparedness.
- Standardization of questionnaires and diagnostic instruments.
- Internal consistency checks (cross-validation of teacher and student responses),
- Visual and statistical verification of change dynamics.

In summary, the methodology integrates survey-based diagnostics with an experimental approach, enabling us not only to identify current practices and barriers to the use of geoinformation mapping but also to demonstrate its tangible effectiveness in improving students' academic outcomes.

4. PEDAGOGICAL MODEL OF INTEGRATION

The pedagogical model we propose for integrating GIS mapping into local history and tourism education is conceived as a holistic didactic–research framework in which technology is not merely attached to the lesson but also shapes a distinctive mode of knowing the place. Specifically, it guides the learner from the formulation of a spatial question and data collection to analysis, visualization, reasoning, and public communication of results.

Our theoretical model is grounded in the framework of spatial thinking, project-based and inquiry-based didactics, and place-based pedagogy, as well as in contemporary approaches to technological pedagogical content knowledge (TPACK) (Mishra & Koehler, 2006) and the SAMR hierarchy of digital task transformation (Bicalho, 2023).

To ensure the verifiability of the educational effects, the model includes a dual evaluative contour

1) The measurement of individual educational outcomes (geospatial thinking skills, motivation, research activity) via validated instruments, and
2) Program-level evaluation via the CIPP and Kirkpatrick frameworks.

Finally, from a methodological standpoint, the implementation of the model follows the logic of design-based research (DBR), which presupposes iterative cycles of design, testing, analysis, and refinement within real educational contexts (Erickson, 1986).

4.1. Model Architecture: From Cognitive Goals to Technology and Context

Architecturally, the model is structured around four interrelated components: goal-oriented, content, technological-procedural, and contextual-evaluative.

The goal-oriented component defines the educational outcome as the development of the geo-intellect the integrative ability to think spatially, in terms of scale and relationships, through cartographic representations and analytical reasoning. Drawing from our teaching practice, we note that in the context of local history and tourism, this manifests as the ability to design and evaluate routes, identify spatial patterns in the cultural–historical landscape, and correlate natural and social data.

The content component determines the "learning material" of projects: local geodata, thematic layers (natural objects, monuments, infrastructure), historical and cultural narratives, field observations, and trajectories. Content integration is aimed at weaving together heterogeneous sources such as open data repositories, GPS tracks, photo fields, and interviews with bearers of local memory (Haklay, 2013).

The technological-procedural component operationalizes the TPACK nexus, ensuring that the choice of tools and procedures (web maps, desktop GIS, mobile apps, sensors) follows pedagogical logic rather than a technological fashion.

The SAMR hierarchy serves as a transformation benchmark from substitution to augmentation, then to modification, and finally to redefinition of learning tasks that would be impossible without geotechnologies.

The contextual-evaluative component captures the alignment of pedagogical intent with institutional and community conditions while ensuring the measurability of educational effects.

4.2. Didactic Cycle: Phases and Their Logic

The model is realized through five phases organized into a unified inquiry cycle. Each phase has its own goals, products, quality criteria, and assessment checkpoints.

Phase I. Initiation and Formulation of the Spatial Question The starting point of this phase is a socially significant local problem (for example, "Which route through Turkestan's intangible heritage sites minimizes transportation risk while maximizing cultural richness?").

The teacher and students jointly formulate the research question, specify spatial units of analysis (cell, block, route, district), and discuss data limitations and possible sources of error. At this stage, the evaluation design is also established defining indicators, evidence collection approaches, and subsequent analysis procedures (Stufflebeam, 2003).

Phase II. Data Construction and Cartographic Modelling The optimal configuration of this phase involves students developing the project's data structure (attribute dictionaries, codebooks), collecting in situ data (GPS tracks, photo tags), aggregating official and volunteered geographic information (VGI) sources, and performing primary cleaning and normalization.

The process then transitions to spatial operations buffering, overlay, grid analysis, isochrone generation, and multicriteria routing. The objective is to transform the map into a means of explanation rather than mere illustration (MacEachren, 1995; Roth, 2013). Within SAMR logic, this corresponds to the modification and redefinition stage, where tasks are designed such that, without GIS, they would be methodologically incomplete.

Phase III. Field Research and Hypothesis Calibration Preliminary routes and maps are tested in the field to verify, refine, and calibrate parameters (time, accessibility, risks, and infrastructure quality). Feedback from stakeholders (tour guides, museum staff, and local communities) helps adjust route quality criteria and cultural relevance. This phase is critical for developing causal explanations and for transitioning from an objectivist "map-as-picture" to a reflective "map-in-action."

Phase IV. Analytical Consolidation and Public Communication At this stage, the results are presented in the form of interactive maps, route sheets, story maps, and dashboards. The key operation here is the justification of solutions: Why does this route or zoning plan? What compromises were made among the criteria? What data limitations influence the conclusions? Analytical rubrics for map and narrative quality are applied, and "Kirkpatrick levels" are documented namely, reactions and learning, the transition to behavior through actual excursions and practice changes, and results such as contributions to cultural events, tourism services, and educational outcomes.

Phase V. Reflection, Evaluation, and Redesign Individual outcomes are assessed pre- and postintervention via the STAT and Huynh–Sharpe geospatial thinking instruments. Motivational and behavioral indicators are measured through questionnaires and activity journals. At the program level, the CIPP model is applied: context relevance, input adequacy, process quality, and product value. The results are fed back into Phase I, in line with DBR principles, initiating the next improvement cycle.

4.3. Task Design Principles and Quality Criteria

We identify the transferability of the model in a set of standardizable design principles for task development

1. Spatiality of the question. Every task must require reasoning about location, scale, and relationships.
2. Data authenticity. The use of real local data, open geoportals, and VGI enhances the identity and relevance of outcomes.
3. Explanatory mapping. The map functions as an argumentation tool, where visual decisions are linked to hypotheses and multicriteria reasoning.
4. TPACK alignment. The choice of tools and functions (buffering, grid analysis, routing) should follow disciplinary logic and student age; technology should reinforce content and methods.
5. SAMR escalation. Tasks should gradually shift from substitution/augmentation to modification and redefinition toward goals unachievable without geotechnology.
6. Accessibility and equity. Principles of Universal Design for Learning (UDL)-multimodal representation, action variability, and engagement diversity-ensures the inclusion of all learners.

For operationalization, we introduce quality rubrics covering (a) data and procedural accuracy, (b) transparency of analytical logic, (c) validity of visual decisions, (d) justification of route/zone choice, and (e) social significance of the artifact. These rubrics function both as learning and assessment instruments.

4.4. Measuring Effectiveness: Indicators, Indices, and Evaluation Design

The evaluation system integrates both individual- and program-level metrics.

Individual Metrics

1. Geospatial thinking: STAT and Huynh–Sharpe instruments.
2. Research activity: participation checklist across cycle phases (initiation, data collection, analysis, fieldwork, communication).
3. Motivation/identity: Likert-type scales of interest in local history, sense of place, and civic engagement (with reliability and construct validity testing).
4. Product quality: cartographic and routing rubrics.

Program Metrics

CIPP Dimensions

- Context (data/software access, partnerships),
- Input (teacher preparation, methodological support),
- Process (quality of project implementation, adherence to inquiry cycle),
- Product (practice sustainability, community relevance of maps).

Evaluation Design

A quasiexperimental pre-post design with a control group (where available) or repeated measures within a single group was used. Analyses include paired comparisons, mixed-effects models for repeated measures, tests of measurement invariance across subgroups, and subgroup moderation analyses (age, prior ICT experience). Multilevel models account for data nesting (classes and schools).

4.5. Ethics, Data, and Sustainability: Frameworks for Responsible Geo-education

Integrating a GIS into real local history and tourism practices naturally raises issues of data ethics and geoprivacy. The collection and publication of geotags must comply with consent and anonymization standards. Students should also be taught to critically interpret spatial data, recognizing bias and uncertainty (Kitchin, 2014).

Model sustainability is ensured through partnerships with school museums, municipal cultural centers, and tourism organizations, as well as through cumulative geoportals where students' artifacts form a "living repository" of local knowledge. In the DBR framework, sustainability implies not a one-time implementation but rather the evolution of a local geoeducation ecosystem including teacher training programs, task libraries, and open repositories of data and maps.

Thus, our pedagogical model for integrating GIS mapping into local history and tourism education is not conceived as a toolkit but rather as a cognitively and methodologically coherent system in which spatial technologies serve as a medium of scientific inquiry and civic engagement.

We believe that the strength of our model lies in its alignment of goals, content, technology, and evaluation and its sustainability in the cyclical nature of its design, openness to data, partnerships, and reflection.

5. PROFESSIONAL PROFILE AND PEDAGOGICAL BACKGROUND OF RESPONDENTS

In our survey study, a defining feature of the teacher sample was the high proportion of educators with extensive professional experience. Specifically, 86.8% of the respondents reported more than ten years of teaching experience in geography. Those with up to five years of experience accounted for 7.5%, whereas 5.7% fell within the 5–10-year range (N = 53). The distribution structure is presented in Table 1. These proportions indicate a professionally mature community of practitioners possessing stable methodological orientations and substantial "accumulated knowledge" of geography teaching practices. Moreover, the small share of early-career teachers reflects a staffing risk to the long-term sustainability of innovation, ranging from the renewal of methodological practices to the intergenerational transfer of digital competencies.

Table 1: Distribution of Geography Teachers by Teaching Experience (N = 53).

Experience Category	Percentage, %	Approx. Number of Respondents
Less than 5 years	7.5	≈ 4
5–10 years	5.7	≈ 3
More than 10 years	86.8	≈ 46
Total	100	53

According to Table 1, the empirical pattern of using digital maps and GISs in the classroom reveals broad yet episodic acceptance, with a limited share of consistent, "day-to-day" applications. More than half of the sample (28 out of 53) reported using a GIS "depending on the content and goal of the lesson," representing an adaptive strategy; that is, GIS tools are employed only when they are pedagogically relevant to the topic and learning objectives.

Moreover, 15.1% of the respondents (≈ 8 teachers) reported constant use of a GIS, an indicator of digital pedagogical maturity at the classroom level. Another 13.2% (≈ 7 teachers) and 15.1% (≈ 8 teachers) indicated rare and occasional use (once a month or less; several times per year), whereas 3.8% (2 teachers) reported no GIS use at all. The data are summarized in Table 2.

Table 2: Frequency of GIS Use in Geography Teaching (N = 53).

Frequency/Usage Mode	Approx. Number	Percentage, %
Constantly (in most or every lesson)	≈ 8	15.1
Depending on content and lesson objectives	28	
Rarely (once a month or less)	≈ 7	13.2
Occasionally (a few times per year)	≈ 8	15.1
Not used	2	3.8
Total	53	100

As shown in Table 2, the strategy of didactic relevance (context-dependent inclusion) is currently predominant. However, only approximately one in seven teachers reached the stage of regular GIS integration as an "everyday grammar" of the lesson. Behind this trend lies a constellation of barriers: infrastructural constraints, a shortage of methodological resources, and limited time for preparing instructional cases.

The content profile of GIS use demonstrates a traditional natural–geographical bias: 31 out of 53 teachers (over half the sample) focus primarily on physical components such as relief, climate, and hydrography. Moreover, 15.1% (≈ 8) focus mainly on economic–geographical objects, 15.1% (≈ 8) focus on cultural–historical and regional (local heritage) objects, and 11.3% (≈ 6) focus on tourism-related sites (Table 3). This distribution suggests a gradual broadening of the cartographic focus toward sociocultural themes, although the natural core of the geography curriculum remains dominant.

Table 3: Objects of Primary Attention in GIS Mapping (N = 53).

Priority Object Group	Approx. Number	Percentage, %
Physical-geographical (relief, climate, water, etc.)	31	>50
Economic-geographical	8	15.1
Cultural-historical and regional (local studies)	8	15.1
Touristic	6	11.3
Total	53	100

As Table 3 illustrates, the paradigm of a "natural science core" continues to dominate digital visualization in geography, whereas interdisciplinary sociocultural and economic themes are only beginning to form a "second wave" of digital didactics.

This highlights the potential for diversification toward case studies in urban geography, demography, cultural geography, and geoeconomics.

Teacher requests emphasize a pronounced need for methodological and pedagogical support over purely technical resources.

The most frequently cited needs include the development of teaching materials and lesson frameworks (54.7%, ≈ 29 teachers), professional development courses (52.8%, ≈ 28), and access to modern GIS platforms and digital mapping ecosystems (50.9%, ≈ 27).

Hardware provision (47.2%, ≈ 25) and technical support (22.6%, ≈ 12) were secondary concerns. Project-based work with students (24.5%, ≈ 13) was requested less frequently, likely reflecting a lack of ready-made scenarios and teachers' limited preparation time (Table 4).

Table 4: Requested Resources and Support for GIS Integration.

Area of Need	Approx. Number	Percentage, %
Instructional materials and lesson plans	29	54.7
Professional development courses	28	52.8
Access to modern GIS platforms	27	50.9
School equipment and hardware	25	47.2
Project-based learning with students	13	24.5
Technical support	12	22.6
Other	2	3.8

As shown in Table 4, the methodological ecosystem emerges as the foremost priority: teachers do not require as much "hardware and software" as do didactically structured scenarios, task templates, examples of thematic layers, evaluation rubrics, and training modules that is, resources that reduce the transaction costs of integrating a GIS into actual classroom practice.

The baseline level of student competencies was comparable across groups. In the control group (N = 23), the percentages were as follows: high, 26.08% (≈ 6 students); medium, 39.13% (≈ 9); and low, 35.78% (≈ 8). In the experimental group (N = 22), the proportions were as follows: high, 22.72% (≈ 5); medium, 45.45% (≈ 10); and low, 31.81% (≈ 7).

Thus, the experimental group began with a slightly more balanced profile (higher medium, lower low) but without significant disparities, allowing subsequent changes to be attributed credibly to the pedagogical intervention (Table 5).

Table 5: Baseline Diagnostics of Learning Competencies (Group Shares).

Level	Control, %	Control, No.	Experimental, %	Experimental, No.
High	26.08	≈ 6	22.72	≈ 5
Medium	39.13	≈ 9	45.45	≈ 10
Low	35.78	≈ 8	31.81	≈ 7
Total	100	23	100	22

As Table 5 demonstrates, the groups were statistically comparable in their initial profiles. The experimental group was slightly less polarized (fewer "low," more "medium"), enabling valid interpretation of subsequent positive dynamics as an effect of GIS-based pedagogical intervention.

The results of the formative stage show an asymmetrical gain in favor of the experimental group

High level: In the experimental group, the share of students with high-level competencies exceeded half (>50%), whereas in the control group, it remained at approximately one quarter. This finding indicates that the probability of moving into the "high" competence zone is substantially greater when GIS tools are intentionally integrated into instructions.

Medium level: The proportion of students at the "medium" level in both groups stabilized between 35–40%, representing a zone of stability: students neither regressed to "low" nor yet advanced to "high".

Low level: In the control group, approximately half of the students remained at a low level, compared with approximately 20% in the experimental group. In other words, the "risk of regression" after the formative stage was approximately 2.5 times lower in the experimental group than in the control group.

Although the final diagnostic results were expressed primarily in descriptive terms (ranges and qualitative comparisons), the ratios of ">50% vs. ~25%" for the high level and "~20% vs. ~50%" for the low level provide solid evidence of a strong instructional effect of geoinformation intervention. Specifically, the distribution shifted from "low" to "high," with the "medium" level acting as a stabilizing zone.

This aligns with related research demonstrating the impact of spatial data visualization on the cognitive structure of geographical understanding from the formation of mental maps and topological relations to the transfer of knowledge in tasks of spatial pattern analysis and explanation.

In summary, GIS-based mapping, when embedded into learning tasks, transforms "maps-as-illustrations" into "maps-as-reasoning tools." This approach becomes a means of formulating questions, constructing evidence, and generating explanations. Along this cognitive trajectory, students advance from recognizing local facts to operating with spatial relations and layers of attributes, accounting for the observed improvements in competence levels.

Synthesizing data from both teachers and students yields a coherent picture

1. The teaching community is experienced and methodologically stable; however, for most, GIS integration remains adaptive and episodic, while only a minority practice regular use. Consolidating these practices requires a methodological ecosystem ready-made scenarios, tasks, assessment rubrics, and professional development opportunities as confirmed by the structure of teacher requests (Table 4).
2. On the student side, targeted use of geoinformation tools produces a redistribution of competency levels: a rise in "high," a marked reduction in "low," and stabilization of "medium." The effect is not decorative but cognitively structural: the language of learning shifts from descriptive to analytical reasoning.

Overall, our results demonstrate that the transition from "illustrative" to "operational" use of maps data-as-argument, layers-as-variables, map-as-model is the principal mechanism of educational improvement. This finding is consistent with international evidence on the role of a GIS in enhancing spatial thinking and students' inquiry competence.

6. RESULTS AND DISCUSSION

6.1. The Cognitive–Didactic Nature of the Observed Effect

Our empirical findings are fully consistent with the initial hypothesis that integrating GIS mapping into the inquiry-learning cycle is not a "decorative" add-on to an explanatory figure but rather a means of constructing explanations, testing hypotheses, and making well-reasoned decisions in a local context. In the experimental group, where GIS was systematically embedded across all project stages, from the formulation of a spatial question and the construction of the dataset to field verification, analytical consolidation, and public communication, the distribution of preparedness levels shifted from "low" to "high," whereas the proportion of "medium" remained relatively stable.

In other words, students at the "medium" level were statistically more likely to move into the "high-achievement zone," and the "low" level showed a marked reduction compared with the control group taught without targeted geoinformation intervention. These shifts corroborate the contemporary pedagogical claim that visual-spatial representation functions as a language of scientific reasoning in school.

Substantively, the observed gains operate through three interrelated mechanisms; First, the cartographic artifact is increased from an illustration to a model with explicit variable layers, buffering/overlay/routing operations, and verifiable route-optimization criteria.

Second, by transferring the learning activity into a "field loop" (route-observation-geocoding-model refinement), the hypotheses are critically calibrated, and the quality parameters are adjusted.

Third, by anchoring the product socially, interactive maps and route sheets have real "users" in the school community, museums, and tourist centers. Along this trajectory, the map becomes an instrument of argumentation ("Why does this solution?"), not merely a vehicle for "showing things beautifully."

6.2. Teacher Profile as a Condition for Scalability

The sample was dominated by teachers with extensive experience (approximately 87% with more than ten years of experience). On the one hand, this ensures methodological stability and habituation to evidence-based argumentation in geography lessons.

On the other hand, it signals a staffing risk stemming from a "thin layer" of early-career teachers those crucial for rapid diffusion of digital practices and the associated norms of data, replication, and evaluation.

It is unsurprising that the highest demand was for methodological lesson constructors, sample tasks, evaluation rubrics, and professional development. In short, teachers primarily "order" didactics rather than hardware or specialized professional software. This structural pattern aligns well with the TPACK framework: technology scales sustainably only when it is finely tuned to disciplinary meaning and the pedagogical scenario rather than the reverse.

6.3. Actual Frequency and Object Focus of GIS Practices

Empirically, the use of a GIS "depending on the lesson's goals and content" outweighs constant integration; only a minority report regular ("nearly every lesson") applications. This reveals a "bottleneck" in everyday routines: teachers are willing to deploy geoinformation tools when they are didactically meaningful, but they lack a robust suite of standardized inquiry tasks carefully adapted to students' age and the curriculum.

The object focus is predominantly natural–geographical (relief, climate, hydrography), whereas the "second wave" (economic–geographical and cultural–historical topics) is growing but not yet dominant. For local history and tourism, this suggests an underused potential for cross-disciplinary integration (history, social studies, informatics), with a GIS serving as a mediator between layers of nature, economy, and culture.

6.4. Experimental Dynamics: From "Illustrative" to "Explanatory" Map Use

Overall, comparing baseline and final diagnostics revealed an asymmetrical effect favoring the experimental group: the share of "high level" competencies exceeded half of the group, whereas the "low level" fell to approximately one-fifth. In the control group, by contrast, "high" remained at approximately one quarter, and "low" hovered near one half.

Even under a conservative interpretation (relying on the proportional relationships reported), the effect can be considered educationally strong not merely statistically significant but pedagogically meaningful. The shift in level distributions indicates a "recoding" of students' reasoning in favor of spatial argumentation and the analytical grammar of maps. We emphasize that this dynamic cannot be reduced to a "novelty effect." The model's architecture incorporates design-based research (DBR) principles: explicit spatial questioning, dataset construction, field-based redesign, public defense of solutions, and reflective evaluation via CIPP/Kirkpatrick. It is precisely this coupling of cognitive aims ("geo-intellect" as the ability to think in terms of scale and relations), processes (inquiry/PBL, place-based education), and evaluations (individual and program metrics) that drive sustainable growth.

6.5. Internal Validity and Limitations

Our study design accounted for group comparability at baseline and employed standardized diagnostic procedures. Nevertheless, several limitations warrant careful interpretation.

First, the quasiexperimental nature and potential class/school effects (data nesting) suggest that future iterations should employ multilevel mixed-effects models and tests of measurement invariance.

Second, while the proportional endline estimates provide a compelling substantive picture, publication-grade rigor requires a complete matrix of individual outcomes.

Finally, the object bias toward physical geography may understate the contributions of a GIS to social and cultural tasks; deliberate expansion of cases in urban studies, heritage, and service-learning is therefore advisable.

6.6. Practical Implications for Schools and Municipal Communities

The educational effect in our study manifests not only in test gains but also in the quality of public artifacts interactive maps, route sheets, and story maps. Their life cycle (from a class dashboard to a school geoportal) operates as a "social laboratory" of data.

Regional partnerships with museums, libraries, and tourism offices broaden the audience for these artifacts, increase their validity, and reduce transaction costs for data maintenance. On the school side, this implies institutionalizing TPACK/SAMR-oriented professional development, building a task library and an open repository of layers, and adopting validated instruments of geospatial thinking as standard diagnostics.

This "triangle of sustainability"

a) Methodological constructors,
b) Data and access infrastructure, and
c) Evaluation and feedback-is a necessary condition for scaling the observed effect.

6.7. Theoretical Contribution and Positioning in the International Agenda

Our results complement the international research stream, showing that geospatial technologies in secondary education enhance spatial reasoning, support relational thinking, and strengthen transfer to authentic tasks. The distinctive contribution of our study lies in its emphasis on the local history and tourism context, including field calibration and dual program evaluation. This reframes the debate from "interface mastery" to the formation of the geo-intellect as a transferable competence.

In doing so, we propose a pedagogically testable pathway from "program-based instruction" to "learning through space," which is methodologically consonant with the Learning to Think Spatially framework (National Research Council) and approaches to critical spatial thinking.

7. CONCLUSION

In this study, we demonstrated that our model of integrating GIS cartography into tourism-oriented and local-history educational activities is indeed productive. However, this productivity is not a mere mechanical adjustment of the lesson format. We regard it as something more profound a cognitive technology that transforms the very language of classroom reasoning from descriptive to explanatory-analytical.

In our focus, we interpreted the development of geo-intelligence as a generalizable capacity to think in terms of space, scale, and connections to operate with data, models, and visual arguments. Our empirical results appear to confirm the shift we observed. Specifically, in the experimental group, the proportion of learners demonstrating a high level of preparedness exceeded half of the cohort, whereas the share of the "low" level was reduced to roughly one-fifth. In contrast, the control group retained the typical "quarter–half" (high–low) structure. The differences we observed align well with the theoretical expectations of the learning-to-think spatial framework and the principles of contemporary GIScience. Accordingly, we argue that the map, which functions as a medium for modeling and hypothesis testing, becomes a means of constructing causal explanations, not merely an illustration.

The theoretical contribution of our research lies in articulating the interconnection of three foundational dimensions

(i) Cognitive critical spatial thinking as the unity of concepts, representational tools, and reasoning procedures,
(ii) Didactic the inquiry/PBL approach grounded in place-based education and the "critical pedagogy of place"
(iii) (iii) Evaluative the dual-loop CIPP and Kirkpatrick frameworks, which capture not only learning gains but also behavioral transfer and socially meaningful outcomes.

Taken together, this triadic composition clarifies an important shift in the international agenda from teaching software to learning through space. In this sense, a GIS functions as a mediator between observation, data, and civic action.

Methodologically, our model emphasizes a move from fragmented implementations to design-based research (DBR) logic, interpreted here through iterative cycles of design, testing, field calibration, and reflection embedded within the intervention's very architecture.

We believe that the TPACK–SAMR linkage effectively aligns content, technology, and pedagogical scenarios. Within this alignment, the tasks evolved progressively from "substitution" to "redefinition", i.e., they were formulated in such a way that without geotechnologies, they would be methodologically incomplete.

It is precisely this trajectory supported by validated instruments for measuring geospatial thinking that, we believe, explains the observed asymmetry of effects in favor of the experimental group.

Overall, our practical results extend beyond classroom metrics. Interactive maps, route sheets, and "story maps" have become public artifacts valued within both school and municipal communities. This life cycle of an educational product creates local geoeducation ecosystems for example, partnerships with school museums and tourist centers, cumulative geoportals, libraries of standard tasks and rubrics, and modular professional development courses.

We have also postulated a systemic triad of sustainability

a) a methodological ecosystem,
b) a data and access infrastructure, and
c) Assessment and feedback mechanisms which together minimize the transactional costs of embedding a GIS into everyday pedagogy and create conditions for scaling.

Naturally, our model has certain limitations. The constraints of a quasiexperimental design and the predominance of natural-geographic cases in the current repertoire impose boundaries on generalization.

However, these limitations define a transparent and authentic roadmap for further research

1. Expanding case studies toward urban studies, cultural heritage, and service-learning,

2. Employing multilevel mixed-effects models and testing measurement invariance to account for data nesting,
3. Constructing full matrices of individual outcomes and repositories of open data/code to ensure reproducibility;
4. More explicitly operationalizing Kirkpatrick's levels at behavioral and results tiers (e.g., influence on school practices or contribution to local services).

Finally, our results highlight the ethical dimension of working with spatial data. In this context, teaching critical data literacy recognizing uncertainty, bias, and the sociotechnical consequences of spatial decisions has become an essential element of responsible geoeducation.

In this sense, GIS integration, as we interpret it, opens not only instrumental but also civic horizons. It can foster local and civic identities, strengthen students' direct participation in real regional community challenges, and, no less importantly, cultivate a culture of well-reasoned spatial decision-making.

In summary, our research makes conceptual, methodological, and applied contributions. Conceptually, it explicitly articulates geo-intelligence as a high-level educational goal and demonstrates how a GIS makes that goal attainable in the school context. Methodologically, it presents a reproducible intervention design supported by validated measures. Practically, it offers artifacts that live beyond the classroom and convert learning activity into public value.

Thus, our study proposes an original model of sustainable pedagogical innovation one synchronized with international benchmarks yet acutely sensitive to local contexts and regional specificities.

The next stage of our research will focus on scaling through open task libraries, regional professional-development networks, and the institutionalization of spatial-thinking metrics in regular systems of educational quality assessment.

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