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Integration of geoinformation mapping into tourism and local history activities as a tool for developing spatial thinking in schoolchildren

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Abstract

Our study focuses on the theoretical and methodological substantiation of integrating Geographic Information System (GIS) mapping into local history and tourism-oriented educational activities as an effective tool for developing spatial thinking among school students. The relevance of the research is driven by the need to enhance spatial competencies amid the digitalization of education and the strengthening of students' local identity. We propose an original model, GeoEduMap, which integrates pedagogical, cognitive, and technological components, including tiered diagnostics, task typologies, cartographic layers, and routes of interaction. The methodology is based on systemic-activity, cultural-historical, and cartographic approaches. Special attention is given to content localization through the use of authentic local history materials. The results of the study expand the methodological horizons of both local history and geographic education by integrating digital tools into meaning-oriented spatial learning practices.

Keywords: GeoEduMap, GIS education, Local history, Local identity, School mapping, Spatial thinking.

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1. Introduction

Modern education is undergoing a profound transformation, where the ability of students to comprehend, model, and interpret space within a digital environment is becoming essential. In this context, the philosophy of education acquires a spatial dimension. Knowledge is no longer purely textual or abstract; it becomes geolocated, contextual, and topological. Consequently, it becomes necessary to cultivate a cognitive map of the world in learners not merely as a metaphor but as a real set of spatial operations and references [1].

The ideology behind our research is grounded in the humanistic and activity-based foundations of education, where locality and spatial rootedness serve as means for developing the learner's subjectivity. We argue that local history and tourism-oriented educational activities, understood as meaningful engagement with one's native region, can be reinterpreted through the use of digital technologies, particularly Geographic Information Systems (GIS) [2, 3].

Thus, we consider GIS technologies not only as tools for visualization but also as interfaces between personal experience and spatial knowledge, thereby shaping spatial thinking as a key cognitive competence of the 21st century [4, 5].

It is evident that spatial thinking is recognized in modern pedagogy and cognitive psychology as a critically important ability for scientific literacy, engineering design, geographic understanding, and digital navigation [6]. We believe that its development requires more than a theoretical study of spatial concepts; it also necessitates active interaction with both physical and digital spaces.

Overall, geoinformation technologies provide a unique transdisciplinary platform, connecting geography, history, ecology, ICT, and project-based learning. Simultaneously, local history and tourism formats enable the transition from formal knowledge to contexts of personal experience and empirical learning, which makes the integration of GIS and local history both logically grounded and methodologically productive. This is particularly relevant for Kazakhstan, a country with vast territories rich in ancient monuments and culturally sacred areas.

The methodology of our research and implementation of the proposed model relies on the following foundational principles:

1. Constructivism [7, 8] which views knowledge as formed through active interaction with spatial and social environments.
2. Geoinformation approach [9] where data is georeferenced, allowing for the visualization of processes, events, and routes in space.
3. Project-based pedagogy [10-12] in which students create their own maps, digital routes, and presentations based on collected data.
4. STEAM integration [13] combining science, technology, arts, and humanities within the framework of local history investigations.

Thus, the integration of GIS into students' local history and tourism activities represents not merely a technological innovation but also an educational practice model that fosters the development of spatial thinking as a transversal competence.

It is worth noting that despite the growing interest in developing spatial thinking in education, current pedagogical approaches remain fragmented. Local history is often limited to patriotic education, while GIS is treated as a component of digital literacy or technical modeling. However, the integration of GIS and local history as a cognitive educational technology has scarcely been investigated systematically.

Our study is the first to conceptualize tourism-oriented local history education using GIS as a distinct type of educational environment, a cognitive-spatial simulator aimed at cultivating spatial thinking as a transversal meta-competence.

In contrast to traditional research focused on content-based GIS instruction, our study emphasizes the cognitive function of spatial technologies. That is, the students' capacity to form topological representations, correlate personal experience with the spatial structure of the world, model geo-events and routes, and critically interpret geospatial interrelations. We believe this perspective offers a new research paradigm, one that moves from the formal acquisition of spatial data to the development of thinking as a navigational function of consciousness.

Our work introduces a transdisciplinary methodology, combining:

- Cognitive psychology (Spatial thinking).
- Geographical education (Local history, topography, orientation).
- Digital didactics (GIS technologies, interactive mapping).
- Project-based pedagogy (School routes, digital local history).
- STEAM logic (Linking geography, engineering, history, and the arts).

In this context, we propose a new methodological framework in which GIS is not only a tool but also a form of thinking, and local history is not merely an object of knowledge but a means of self-orientation in the world.

Our study formulates the concept of digital local history, implemented through personalized GIS map-making, geoquests, digital visualization of local memory, and interactive spatial modeling of territorial changes. We argue that this practice creates new opportunities for shaping the school project as a spatial statement, where the map becomes an educational artifact and the student a cartographer-creator.

Fundamentally, this research draws attention to a new pedagogical paradigm, which shifts the focus of classical school education. This shift is illustrated in the following table (see Table 1):

Table 1.
Differentiation between traditional and new paradigms.

Traditional Paradigm	New Paradigm Proposed in this Study
Geography as knowledge about place	Geography as the construction of spatial meaning
Local history as the transmission of facts	Local history as an assemblage of personal and digital memory
Map as a tool	Map as a form of thinking and interpretation
GIS as a technological add-on	GIS as a cognitive environment for development

Based on this comparison, we can reorganize the process of cultivating students' spatial subjectivity within a new interpretive framework.

Accordingly, the scientific novelty of our study is expressed in:

- The formulation of the concept of integrative GIS-local history as a new type of educational practice.
- The introduction of the category “cartographic cognition” as an intermediate link between thinking and the digital environment.
- The substantiation of a methodology for developing spatial thinking through school GIS projects.
- The creation of a transdisciplinary model uniting cognitive, geographical, and digital components.

We believe that these contributions advance both educational theory and practice, offering a pathway for the formation of a new type of spatially aware and digitally literate subject.

The object of our research is the process of developing spatial thinking in students through the implementation of tourism-oriented local history activities in the educational environment.

The subject of the study is the modeling of pedagogical conditions and didactic tools for integrating GIS mapping into local history and tourism activities as a means to foster students’ spatial thinking.

Accordingly, the aim of our study is to develop and theoretically justify a model for the integration of GIS mapping into tourism and local history education, aimed at cultivating spatial thinking in Kazakhstani school students.

In line with this aim, the following research tasks were addressed:

1. Theoretical analysis of psychological and pedagogical approaches to spatial thinking and the conditions for its development during school age.
2. Investigation of the potential of GIS technologies as educational resources within the context of local history activities.
3. Substantiation of the pedagogical potential of tourism-based local history education as an environment for cognitive and spatial competence development.
4. Design of a model for integrating GIS technologies into the structure of school-based local history projects.

These tasks aim to verify or refute our main (null) hypothesis:

If Geographic Information System (GIS) mapping is integrated into school-based tourism and local history activities as an interactive and cognitive tool, this will lead to a significant enhancement of students’ spatial thinking by creating conditions for cognitive navigation, visualization of local experience, and meaningful construction of spatial models of reality.

It is evident that the development of spatial thinking in school students is one of the key priorities of modern education, especially in the context of digitalization, urbanization, and the growing need for skills in navigation, visualization, and interpretation of spatial data. In this regard, spatial thinking should be understood as a fundamental cognitive skill underlying geographical, mathematical, engineering, and humanities literacy [14, 15].

The use of Geographic Information Systems (GIS) in educational practice has become widespread over the past two decades. Research indicates that the integration of GIS technologies enhances students’ skills in spatial analysis, critical thinking, and complex problem-solving [16, 17]. As such, cartographic visualization and work with digital layers increase students’ cognitive engagement and expand the boundaries of traditional subject-based instruction. In particular, GIS enables the interpretation of territory in a multi-layered context: natural, social, cultural, and historical.

Local history and school-based tourism possess high pedagogical potential for shaping students’ geographic identity and subjectivity [18]. Local history practice allows the connection of abstract knowledge with specific topoi (familiar streets, monuments, routes), creating the conditions for building mental maps and spatial rootedness [19].

Thus, tourism and local history activities supported by GIS tools offer a path beyond “paper-based geography” by activating students' research, project-based, and creative capacities.

Classical and contemporary psychological approaches to the development of spatial thinking are found in the works of Gruber [20] who identified the topological stage of cognitive development, and Vygotsky and Cole [21] who highlighted the role of the Zone of Proximal Development, including in spatial and navigational dimensions.

Egenhofer and Mark [22] proposed a typology of spatial thinking that includes localization, orientation, navigation, and the construction of spatial relationships. This framework underpins modern diagnostic models used in international assessments such as PISA [23], TIMSS [24] and national monitoring systems.

Morton [25] emphasized the importance of spatial justice - the equitable distribution of access to knowledge and territory. In this context, the map becomes not only a tool for knowledge but also a form of social subjectivity.

Contemporary digital platforms enable students to engage in active project-based learning without requiring advanced technical expertise. As Bednarz [26] points out that what matters most is not technological proficiency but the methodological competence of the teacher and their ability to guide the development of spatial thinking through dialogue, reflection, and visualization.

Moreover, the GIS-based approach aligns with the STEM/STEAM education paradigm and project-based learning, serving as a connecting bridge between geography, computer science, history, and the arts.

2. Materials and Methods

The methodological framework of our study is based on an interdisciplinary approach that integrates principles from pedagogy, cognitive psychology, geoinformatics, and local history practice. The aim of the research is to provide a theoretical and methodological justification for a model integrating Geographic Information System (GIS) mapping into tourism and local history activities in order to foster spatial thinking among school students.

The research draws upon the following conceptual foundations:

- Cultural-historical theory of cognitive development (L.S. Vygotsky): The map is viewed as a tool for development within the Zone of Proximal Development through collaborative and meaning-centered activity.
- Cognitive development stages by Jean Piaget: Particular focus is placed on the transition from topological to project-symbolic levels of spatial thinking.
- Mental map theory by Meenar et al. [27]: Local space is understood through subjective cartography and spatial identity.
- Spatial typology by QGIS Development Team [28]: This serves as a foundation for designing the levels of spatial thinking diagnostics.
- Principles of GIS-based education [29]: GIS is considered a tool for developing both digital and spatial literacy.

As part of our theoretical modeling, we developed the original GeoEduMap model, which includes the following components:

- A methodological framework for the GIS module.
- Levels of spatial thinking development.
- A typology of tasks and cartographic layers.
- Routes of pedagogical interaction in the classroom.
- A system of criteria and indicators for diagnostics.

Our model is constructed as a systemic-activity-based structure, incorporating input (environmental), procedural (pedagogical), and output (cognitive and personal) parameters.

Given the theoretical nature of the study, we applied the following research methods (see Table 2):

Table 2.
Research methods.

Method	Description
Theoretical modeling	Construction of the GeoEduMap pedagogical model based on literature analysis and educational practice.
Analysis and synthesis of scientific sources	Systematization of knowledge from pedagogy, cognitive psychology, and geoinformatics
Frame analysis	Structuring of the conceptual field: “spatial thinking,” “cartographic subjectivity,” “local identity.”
Structural decomposition method	Identification of diagnostic levels, map elements, task types, and mechanisms of interaction
Design of visual and diagnostic tools	Creation of block diagrams, graphs, and assessment models based on theoretical reconstruction

Empirical validation of the model was not the objective at this stage; however, the logic of its construction allows for subsequent experimental implementation in school settings.

Our research is aimed at application in the context of school education in the Republic of Kazakhstan, including rural and small-scale schools. When designing tasks, examples, and diagnostic cases, we employed real local contexts, including geographical features, cultural heritage sites, folklore narratives, and ecological characteristics of the region. This made it possible to incorporate cultural-environmental and motivational factors that are essential for the development of spatial subjectivity in students.

3. Results

We propose the concept of an online complex of tools for teaching chemistry based on a systems approach.

The creation of a set of online tools for teaching chemistry via a systemic approach opens new opportunities for effectively mastering the material. Online resources allow for the personalization of the learning process, taking into account the learning characteristics of each student and improving practical skills. The integration of such tools requires careful preparation and development, but this makes teaching chemistry more engaging, accessible, and effective.

3.1. GeoEduMap

Let us examine the structure of the model for integrating Geographic Information System (GIS) mapping into local history and tourism activities as a tool for developing students' spatial thinking.

Figure 1 presents a block diagram of GIS-based local history as a cognitive-spatial simulator, which we refer to as GeoEduMap.

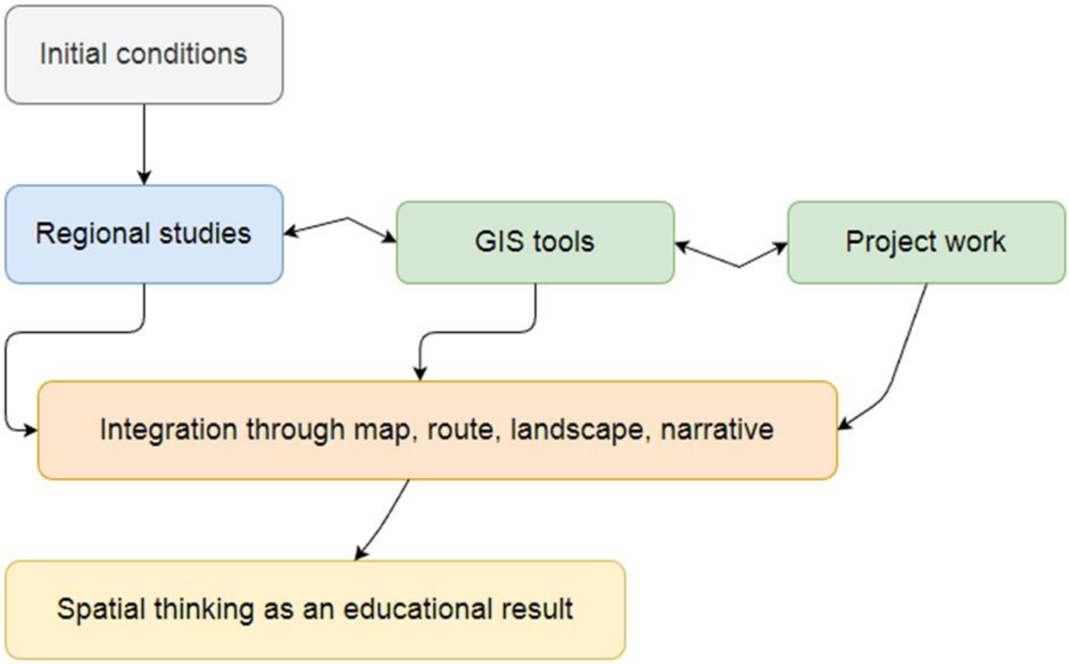

Figure 1.
Block Diagram of GeoEduMap.

In the diagram, the initial conditions represent the input level, which is interpreted through the following components:

1. Educational environment:
- A school with access to ICT.
- Support for project-based activities.
- Curricula in geography, history, and social studies.

2. Target groups:
- Students in grades 5–9.
- Teachers of geography, computer science, history, and social studies.

3. Students' initial competencies:
- Basic ICT skills.
- Introductory knowledge of maps and geography.
- Local socio-cultural experience (Village, district, city).

This is followed by the methodological framework (see Figure 2), interpreted through educational components. The framework illustrates the key elements that make up the structure of the GeoEduMap model: local history, GIS, project-based, and interdisciplinary components.

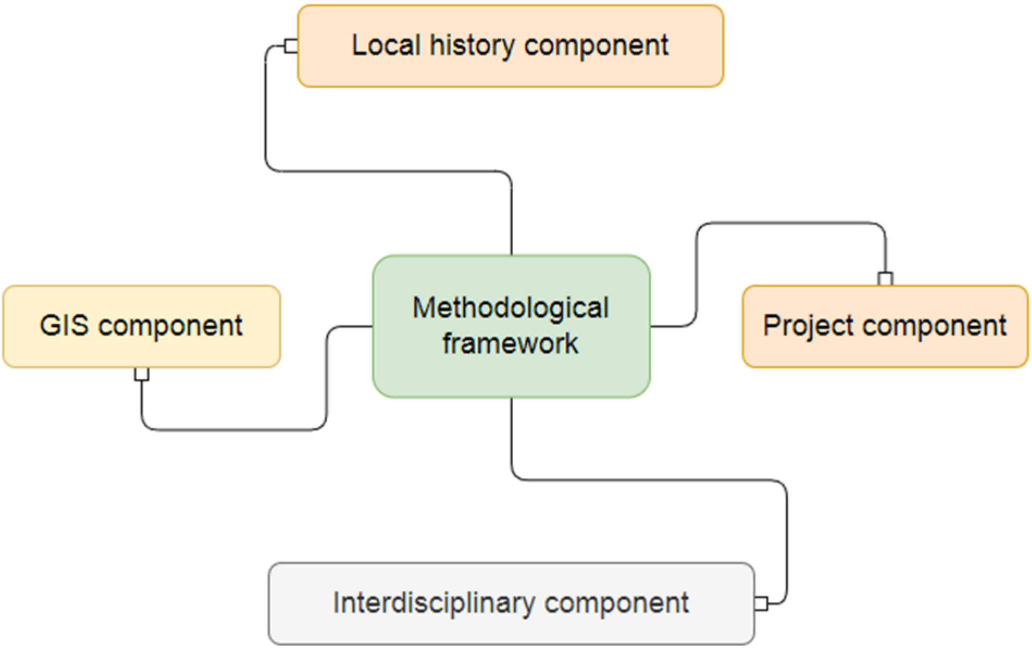

Figure 2.
Methodological framework of GeoEduMap.

The educational components are detailed in the following table (see Table 3).

Table 3.
Research methods.

Component	Content
Local History Block	Research of local areas, monuments, routes, and community history
GIS Technologies	QGIS QGIS Development Team [28], ArcGIS Online Bednarz and Lee [29], Google My Maps Al Fauzi et al. [30], uMap McInnes et al. [31]
Project-Based Activity	Digital expeditions, geoquests, and creation of custom GIS maps
Interdisciplinarity	Geography + history + ICT + ecology + culture
Reflective Block	Discussion of object significance, map interpretation, and narrative creation

As shown in Figure 2, the methodological framework of the GeoEduMap model is a four-component system integrating local history, GIS, project-based learning, and interdisciplinarity. Each component performs a distinct didactic function while maintaining functional interconnection with the others. Their interaction forms a complex pedagogical environment capable not only of transmitting knowledge but also of initiating students into acts of spatial modeling, cognitive reflection, and subjective cartographic creation.

Local history in this model is not merely a source of local data but a spatial-cultural context in which learning unfolds. We argue that it activates students' embodied, emotional, and value-based perceptions of place rather than abstract cognition. The model shifts from reproductive learning of facts to a personally meaningful rediscovery of local space through exploration, movement, and memory-making.

Thus, local history in GeoEduMap serves as an ontological foundation. It establishes the student's primary connection to territory not as a map, but as lived space.

The GIS component introduces the language of digital space into the educational process, coordinates, layers, symbols, and routes. This transforms student thinking into explicitly spatial cognition: the student does not simply memorize objects but perceives their relationships, topological connections, densities, and structures. Through practical mapping, route creation, and digital visualization, the map becomes an internal cognitive structure, not just an external reference.

Moreover, the GIS component enhances students' digital literacy, engaging them with real-world geo-analytical tools (uMap, Google My Maps, ArcGIS), making the model contemporary and applicable.

The project-based component shifts the student from being a passive recipient of information to an active researcher and spatial designer. In the project logic, the student defines a research question, selects mapping objects, processes and interprets data, visualizes outcomes, and presents the final product publicly.

Hence, the project becomes a personal cognitive map, integrating observation, experience, digital tools, and meaning. This component is especially important for forming students' agency and intrinsic motivation for engaging with space.

Within the model, spatial thinking is understood not merely as a geographic skill but as a universal cognitive capacity relevant to history, ecology, cultural studies, mathematics (e.g., scale), literature (e.g., hero's journey), and even art (e.g., visual form). The model thus encourages interdisciplinary enrichment of the map, turning it into a cognitive model of the world constructed through the convergence of multiple subjects.

We argue that this component is critical for implementing the STEAM approach in education and enables the inclusion of GIS-local history in interdisciplinary projects, festivals, academic weeks, and creative labs.

In general, the methodological framework of the GeoEduMap model, as we see it, overcomes the disciplinary fragmentation typical of school education by organizing it around space as a central category. It promotes a shift from perceiving territory as external reality to understanding it as a thinking environment, supporting multidimensional thinking (sensorial, symbolic, logical-spatial), developing practice-oriented literacy (use of digital tools, data, and cartographic reasoning), and strengthening students' emotional connection to their community village, neighborhood, or region.

Furthermore, the model can be effectively integrated into both curricular subjects (geography, history, ICT) and extracurricular or project-based activities, demonstrating its adaptability and resilience.

Thus, the methodological framework of GeoEduMap is a core element of the pedagogical design. It provides ontological depth through the local history component, technological relevance via the GIS component, personal engagement through project-based learning, and cognitive breadth through interdisciplinary integration.

We believe this framework enables the authentic educational movement from local experience to digital mapping and onward to spatial reflection, which, in essence, defines the formation of spatial thinking in the 21st century and in modern Kazakhstan.

The integration mechanisms of the model are illustrated in Figure 3, which demonstrates how cognitive, pedagogical, and technological levels are aligned to achieve a synthesis of subject, space, and digital tools.

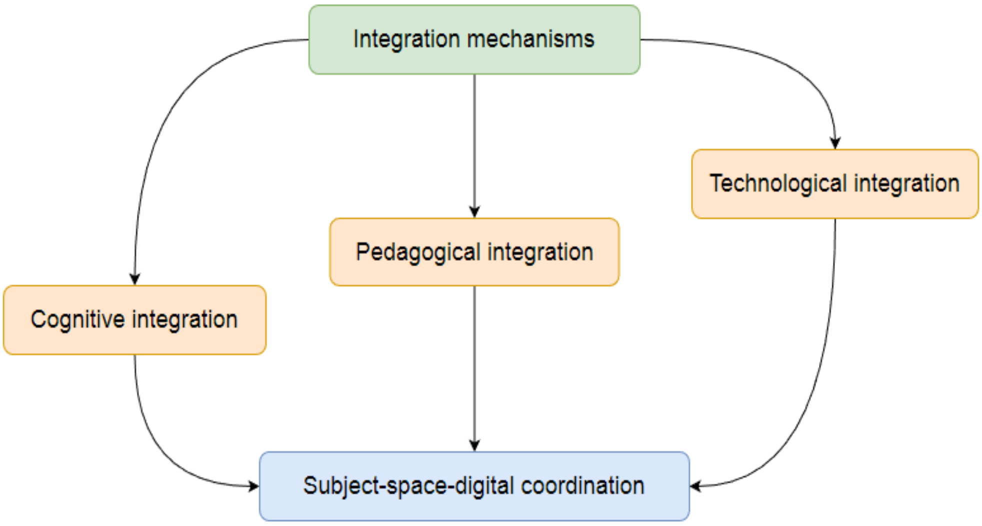

Figure 3.
Integration mechanisms of GeoEduMap.

The integration mechanisms of the GeoEduMap model represent a system of processes that coordinate and align multi-level elements of the educational environment: students' cognitive processes, teachers' pedagogical strategies, and the technological tools of geographic information mapping.

Within the model structure, we identify three key mechanisms of integration:

1. Cognitive integration - the fusion of spatial thinking with personal experience and worldview formation.
2. Pedagogical integration - the organization of a didactic environment that activates students' spatial and action-based resources.
3. Technological integration - the implementation of GIS tools as mediators between real and conceptual space.

In our interpretation, the culmination of these mechanisms is the alignment of subject, space, and digital representation, where the student becomes not only a user of the map but also its author, interpreter, and internalizing navigator.

It is important to emphasize that cognitive integration does not merely imply adding spatial data to academic content, but rather a restructuring of the very logic of cognition within a spatial-modeling framework. The student no longer simply learns about facts and objects but begins to relate them spatially, detect connections and trajectories, construct causal-topological chains, and form mental maps of their environment.

In this way, spatial thinking ceases to be abstract and becomes an embodied cognitive practice, combining sensory perception, digital representation, and conceptual understanding.

Pedagogical integration ensures that the educational process creates meaningful and action-oriented engagement with space. The teacher does not simply transmit ready-made maps but designs learning scenarios in which the student independently chooses a research route, formulates a question, observes, measures, collects data, and participates in the co-creation of the map.

Here, the teacher functions as a facilitator of spatial subjectivity, establishing the motivational and methodological conditions in which the map becomes a living space of meaning.

GIS technologies serve a mediating function in the model: they connect empirical observation with analytical thinking, offering tools for visualization, interpretation, and collaborative map editing. The digital map functions as a cognitive interface; working with layers, coordinates, and routes stimulates logical-spatial mental structures. Tools such as uMap, Google My Maps, and ArcGIS Online allow the project to be adapted to different age groups, levels of proficiency, and learning contexts.

As a result, technological integration transforms student thinking into spatial-hybrid cognition, combining real places, digital representations, and personal narratives.

Overall, these mechanisms give rise to a triangular alignment system:

- The subject (student), gaining cognitive and local agency, designs the territory.
- The space ceases to be a "neutral map" and becomes a personalized cognitive landscape.
- The digital layer (GIS tools) does not suppress meaning but rather serves as a medium for semantic articulation and communication.

This type of alignment forms a spatial-digital subjectivity, in which the map becomes not just an educational product but a form of thinking, self-definition, and expression.

In our view, the integration mechanisms of GeoEduMap bridge the gap between knowledge, perception, and action that is often characteristic of traditional school instruction. The model unifies cognitive and activity-based aspects of learning, creates conditions for reflective navigation in local and cultural space, and fosters the development of meta-disciplinary and transdisciplinary competencies, including critical thinking, spatial visualization, digital literacy, and place-based identity.

Moreover, this alignment of subject–space–digital tool makes the model applicable in inclusive and multicultural settings, allowing every student to create "their own map" regardless of skill level or background.

In summary, the integration mechanisms of the GeoEduMap model ensure its functional coherence and pedagogical viability. They are grounded in a triple synthesis of:

- Cognitive development (Spatial thinking).
- Pedagogical engagement (Activity- and subject-based learning).
- Technological facilitation (Digital visualization and interactivity).

This synthesis enables the formation of a new educational subjectivity, in which students navigate space independently, conceptualize territory as a cultural field, and express their local identity through a digital map.

Ultimately, the integration mechanisms transform the map from an instructional material into a pedagogical event, a moment of encounter between student and space as a meaningful reality (see Table 4):

Table 4.
Step-by-step implementation of the GeoEduMap model.

Stage	Stage name	Contents and actions	Tools and Resources	Expected result
I	Diagnostic and preparatory	- Assessing the initial level of spatial thinking of students - Training teachers in basic GIS skills - Forming groups	Questionnaires, tests, manuals, video courses	Groups have been formed, teachers have been trained, and initial diagnostics have been carried out.
II	Motivational and introductory	- Discussion of the concepts of "space", "locality", "native territory" - Introduction to GIS programs - Mini-projects	QGIS, Google My Maps, StoryMap Bender [32], Google Earth maps Patterson [33]	Students are motivated and have mastered the interface of basic GIS tools.
III	Research and local history	- Choice of topic: historical, ecological, cultural route - Collection of information on the ground and in archives	Smartphones, GPS, interviews, archives, cameras	Local history material was collected, and an expeditionary survey was conducted.
IV	Cartographic -digital	- Building a GIS map of the route - Linking photographs, videos, text to coordinates - Creating a digital product	uMap, ArcGIS Online, Canva, presentations	A GIS map was created, and students became authors of spatial content.
V	Reflexive-analytical	- Presentation of maps - Discussion of changes in the perception of the territory - Self-assessment and feedback	Google Forms, Iqbal et al. [34], essays, group discussions	Developing reflection, spatial self-awareness, and personal connection with the territory.
VI	Evaluative and generalizing	- Re-diagnosis of spatial thinking - Assessment of individual and group progress - Collection of feedback	Comparative tests, expert assessment, portfolio	Confirmation of the model's effectiveness, recording of educational results.

Each phase can last from 1 to 2 weeks, with flexibility depending on student age and school schedule. The model can also be adapted for extracurricular activities, summer schools, or urban educational intensives. If necessary, the phases can be integrated into subject curricula, such as geography, history, or ICT.

3.2. Spatial Thinking Diagnostics

Let us now consider a model for diagnosing students' spatial thinking within the framework of the GeoEduMap project, specifically, the integration of Geographic Information System (GIS) mapping into local history and tourism-oriented educational activities. We refer to this diagnostic subsystem as GeoCognosis.

Our approach is designed to include levels, indicators, methods, and forms of assessment both before and after the implementation of the project. The purpose of this model is to identify and evaluate the level of spatial thinking development in school students as a result of GIS-based local history integration.

The diagnostic framework focuses on six core components of spatial thinking, presented in the following table (see Table 5):

Table 5.
Diagnosable components of spatial thinking.

Component	**Description**
1. Topological Perception	Understanding the relative position of objects ("near," "between," "to the right of")
2. Spatial Orientation	Ability to interpret a map and relate it to real-world environments
3. Scale-Based Thinking	Understanding distances, scaling up/down, and working with map scales
4. Mental Mapping	Ability to create internal representations of routes, areas, and spatial relationships
5. Geographic Interpretation	Understanding the interrelations between space, events, and phenomena
6. Navigational Strategies	Ability to plan routes, find shortest paths, and reason logically in spatial terms

These components are presented in a block format in Figure 4, which illustrates the internal structure of the spatial thinking competence targeted by the GeoEduMap model.

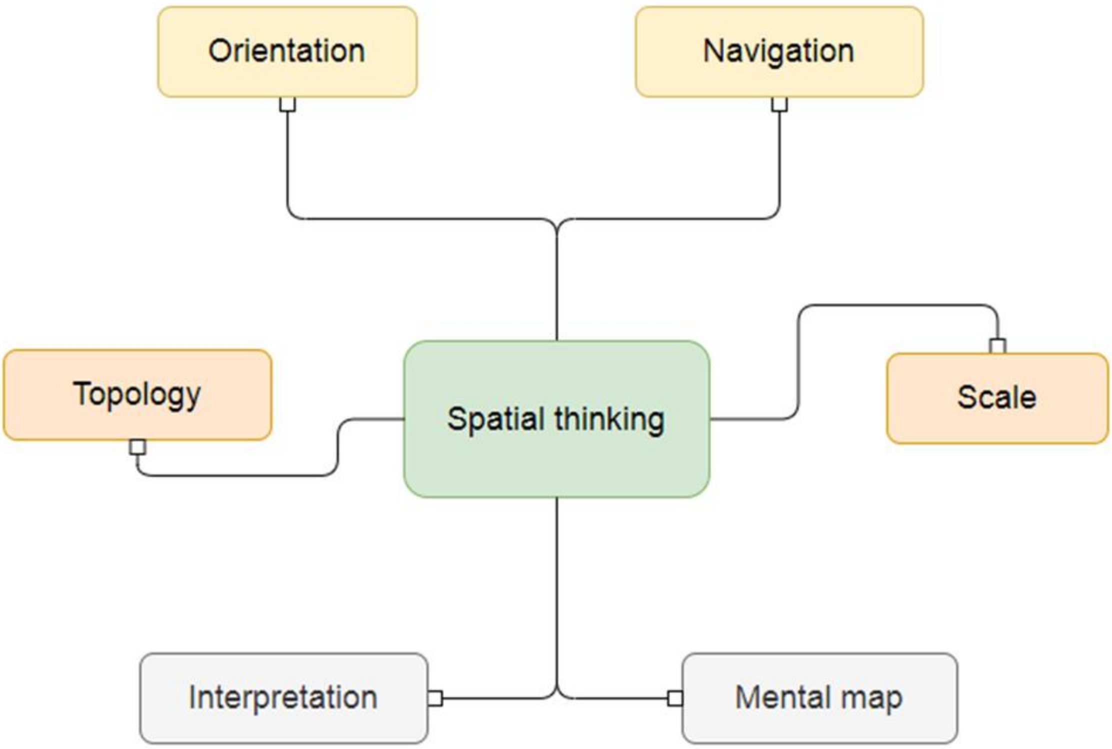

Figure 4.
Block diagram of diagnosable components of spatial thinking.

Within this structure, we define four levels of spatial thinking development, as shown in the following table (see Table 6).

Table 6.
Levels of spatial thinking development.

Level	Characteristics
Basic	Operates with simple spatial concepts; reproduces ready-made maps
Intermediate	Can build basic mental maps; uses scale and coordinates
Advanced	Interprets spatial connections in the real world; creates routes; explains spatial patterns
Creative	Constructs new spatial models; connects space and time; uses GIS as a language of thought

Based on this classification, we can state that developing spatial thinking in students requires not only pedagogical efforts but also valid diagnostic tools capable of identifying baseline levels, tracking growth, and supporting differentiated instruction.

Our four-level assessment scale spans from minimal spatial proficiency to complex cartographic modeling. Each level corresponds to:

- Distinct forms of thinking.
- Typical errors.
- Patterns of spatial behavior.
- And pedagogical goals.

Such a gradation enables not only assessment but also goal-setting, individualization, and reflection in the learning process.

Basic Level: Perceptual–Descriptive Approach

At this level, students are only able to orient themselves in directly perceivable space: "to the left," "to the right," "below," "next to" but they struggle with abstract spatial relations or internal mental maps. Their understanding of space is fragmented, tied to familiar objects, and they memorize routes as chains of events rather than structured systems.

Diagnostic indicators at this level include:

- Inability to interpret even simple maps without legends.
- Frequent errors in determining direction and distance.
- Linear, unstructured perception of the environment.

The pedagogical goal for this level is to develop students’ primary spatial logic through:

- Physical activity.
- Orientation exercises.
- Simple maps.
- And basic route construction.

Intermediate Level: Operational Relational Stage

At this level, the student begins to understand spatial relationships as logical connections between objects. In particular, they are now able to read maps with a legend, use scale, orient themselves using multiple reference points, and mentally reconstruct a basic map of a familiar area.

This stage marks the onset of spatial ordering, where systematic orientation skills begin to form.

Diagnostic indicators of this level include:

- Ability to construct routes while accounting for obstacles.
- Transition from “point-based” to “network-based” thinking.
- Ability to explain the spatial arrangement of objects.

The pedagogical goal at this level is to help students build an operational foundation of spatial skills, including map reading and topological transformations (rotation, scale, orientation).

Advanced Level: Analytical–Synthetic Stage

At this level, the student’s spatial thinking functions as a tool for analysis and synthesis. The learner is now capable of interpreting complex diagrams and maps, identifying relationships between spatial phenomena, explaining topographic patterns (e.g., why a village emerged near a river), and constructing mental models of territories they have never directly experienced.

We interpret this as the level at which space becomes a material for cognition, not merely a setting or background.

Diagnostic indicators include:

- Ability to transform spatial diagrams and models.
- Use of maps to support hypotheses.
- Critical reflection on cartographic sources.

The teacher's task here is to integrate spatial thinking into inquiry-based learning, involving students in GIS work and encouraging them to create their own maps.

Creative Level: Modeling and Conceptual Stage

This highest level is characterized by the student's ability to use space as a language of thought and as a form of meaningful expression. The student is capable of creating multi-layered maps, constructing digital narratives with visual structure, and integrating data, emotions, meanings, and routes into a single cartographic image. At this level, students can interpret not only physical space but also social, cultural, and ecological geographies.

Diagnostic indicators of this level include:

- Development of a personal connection to the map.

- Emergence of spatial reflection (e.g., “What does this place mean?”).
- Ability to combine space, time, and symbol into cohesive representations.

The pedagogical objective here is to support spatial-cartographic subjectivity and to integrate spatial thinking into the student’s worldview.

Thus, our four-level diagnostic model makes it possible to personalize each learner’s development trajectory, enable formative assessment (not only final results but also growth over time), and use spatial thinking as an indicator of cognitive development, while also identifying bottlenecks and designing developmental interventions.

Unlike traditional approaches, which are often limited to testing knowledge of geography, our model encompasses cognitive, behavioral, and reflective components, allowing the teacher to diagnose the learning process itself, not only the outcome. The model is applicable across observation formats, map-based assignments, self-assessment, and project presentations.

The four-level spatial thinking diagnostic model we have developed and proposed provides a holistic framework for assessing cognitive development in students. It enables both teachers and students to recognize not only the current level but also the growth vector, and serves as a basis for constructing an individual learning path in spatial cognition. Moreover, our model can be fully integrated into project-based, research-driven, and GIS-oriented educational activities.

We argue that the integration of this model into pedagogical practice enables the development and monitoring of one of the key competencies of the 21st century the ability to think spatially, meaningfully, and navigationally in a world where physical and digital spaces are increasingly intertwined.

4. Discussion

The theoretical and methodological results we have obtained confirm that the integration of Geographic Information System (GIS) mapping into local history and tourism-oriented educational activities holds significant potential as a tool for developing students’ spatial thinking. At the core of our proposed model, GeoEduMap, lies the idea of multi-level pedagogical interaction that activates the cognitive, emotional-value, and inquiry-based components of the learning process.

1. From Reproductive Knowledge to Subjective Spatial Action

In traditional educational practice, the map often functions as an object of reproductive perception. However, within the GeoEduMap model, it is transformed into a tool for cognitive action, enabling the student to become a subject of space, not merely its observer. This transition aligns with Vygotsky’s concept of the Zone of Proximal Development, as well as with contemporary views on the activity-based nature of thinking.

Creating personalized map layers, marking meaningful places, designing routes, and crafting navigational legends engage students in meaning-generating activities that foster spatial reflection. This approach fosters not only geographic literacy but also the development of meta-disciplinary competencies.

2. Spatial Thinking as a Transversal Competence

The results of our theoretical analysis demonstrate that spatial thinking is not a narrowly specialized skill but a transversal cognitive capacity linked to visualization, orientation, scaling, anticipation, and reflection.

The levels we identified, from topological to creative design, correspond to the typology of Egenhofer & Mark (2001) and outline a progressive trajectory from local orientation to meaningful spatial mastery. This confirms the feasibility of stepwise diagnostics of student growth, as proposed in our model.

3. Integrative Effects of GIS in Local History and Tourism Activities

The integration mechanisms outlined in our model demonstrate that GIS becomes a platform for the convergence of multiple forms of activity: observation, discussion, narration, routing, and analysis. This dissolves traditional boundaries between theory and practice, between disciplines and types of thinking. As a mediator, GIS aligns several vectors:

- Technical (Skills in working with interfaces, layers, and coordinates).
- Cognitive (Analysis of spatial relationships, transformation of data into knowledge).
- Cultural (Place-based memory, local identity, family routes).
- Communicative (collaborative work, presentation, and discussion of decisions).

Thus, we argue that GIS functions as a unifying interface between the digital environment and students' real lives, facilitating the emergence of fully developed spatial subjectivity.

4. Local Context as a Factor of Motivation and Identity

A defining feature of our GeoEduMap model is its anchoring in local contexts: students’ native villages, districts, mausoleums, monuments, and routes. This not only lowers the entry barrier for participation but also enhances motivational engagement. Local anchoring activates the sensory-emotional dimension of learning, making the map “their own” and the project personally meaningful.

Focusing on local space does not limit the scope of thinking. On the contrary, it serves as a launching platform for developing global cartographic consciousness. Thus, both value-oriented and civic components of education are developed, in accordance with the principles of spatial justice, as described by Iqbal et al. [34].

5. Pedagogical Implication: The Map as Dialogue

A key theoretical and methodological insight of this study is the understanding that a map is not merely a product but a dialogic medium. It records not only objects and coordinates but also meanings, relationships, and routes of thought. This requires a new teacher role: not that of a transmitter but of a navigator and mediator of development.

The teacher's role is not to correct a "wrong layer," but to ask questions that trigger reflection: "Why did you choose this place?", "What does this point mean to you?"

Such an approach is especially relevant within the framework of competency-based education and project-based pedagogy.

Based on our research, we draw the following general conclusions:

- GIS-based mapping becomes an integral part of the educational environment, promoting the development of spatial thinking through active, meaningful, and interdisciplinary activity.
- The GeoEduMap model offers a comprehensive, stepwise framework that accounts for thinking levels, task types, interaction formats, and diagnostic tools.
- The results indicate high methodological efficacy of GIS integration in school-based local history, especially under conditions of localization, digitalization, and a subject-centered approach.

5. Conclusion

Our theoretical and methodological research has made it possible to propose and substantiate an original model for integrating Geographic Information System (GIS) mapping into local history and tourism-oriented activities as an effective tool for developing spatial thinking among school students. Within the framework of the GeoEduMap model, we have systematized the structure of spatial thinking, proposed diagnostic levels, identified key types of tasks and pedagogical interaction routes, and outlined the mediators and integration channels through which GIS enters the educational process.

The results of our study confirm that GIS-based mapping, when properly embedded into local history activities through sound methodology, contributes to:

- *The development of visual-spatial and analytical competencies.*
- *The enhancement of student agency in exploring and understanding local space*.
- *The formation of mental maps is a meaningful anchoring of knowledge about one's environment*.
- *The integration of interdisciplinary approaches, including geography, informatics, history, ecology, and civic education.*

A key innovation of our work is the creation of a step-by-step didactic system, encompassing:

1. *Levels of spatial thinking development (From topological perception to navigation and spatial design).*
2. *Types of digital tasks and cartographic layers.*
3. *Channels of interaction, both inside and outside the classroom.*
4. *A structured diagnostic framework for measuring outcomes.*

This transition from fragmented technology adoption to a coherent pedagogical module supported by a robust methodological framework offers a replicable and scalable solution.

We believe that a particularly valuable contribution to educational practice is the emphasis on local context: students come to understand their native environment not merely as a backdrop, but as a meaningful territory. This increases motivation, engagement, and fosters local historical identity and spatial subjectivity. In this way, GIS becomes not only a tool but a growth environment for students, one that supports navigation through both geographic and cultural spaces.

The schemes and modular solutions we have developed can be implemented in a variety of educational settings: as part of school curricula, elective courses, extracurricular clubs, or project-based learning modules. The GeoEduMap model is designed to be scalable and adaptable to diverse regions and age groups, including localization for specific villages, cities, or regions.

In conclusion, the model we propose opens new horizons for modernizing the spatial dimension of school education, contributing to the formation of a generation capable of navigating not only physical but also cognitive and cultural spaces in today's complex world.

References

[1] E. Maclin, "Designing better maps: A guide for GIS users," *Photogrammetric Engineering & Remote Sensing*, vol. 83, no. 9, pp. 603–604, 2017. https://doi.org/10.14358/pers.83.9.603

[2] M. W. Wilson, "On being technopositional in digital geographies," *Cultural Geographies*, vol. 25, no. 1, pp. 7-21, 2018. https://doi.org/10.1177/1474474017743030

[3] K. Sanat, U. Nurbol, A. Bakhadurkhan, S. Anargul, D. Zukhra, and K. Gulfat, "Teachers' opinions about technological pedagogical content knowledge used in geography lessons," *World Journal on Educational Technology Current Issues,* vol. 14, no. 4, pp. 1217–1224, 2022. https://doi.org/10.18844/wjet.v14i4.7731

[4] R. S. Bednarz and J. Lee, "The components of spatial thinking: Empirical evidence," *Procedia-Social and Behavioral Sciences,* vol. 21, pp. 103-107, 2011. https://doi.org/10.1016/j.sbspro.2011.07.048

[5] B. Abdimanapov, S. Kumarbekuly, and I. Gaisin, "Technology for achieving learning objectives through a system-activity approach and the development of critical thinking in geography studies," *Journal of Ecohumanism*, vol. 3, no. 8, pp. 11989–12003, 2024. https://doi.org/10.62754/joe.v3i8.5797

[6] National Research Council, *Learning to think spatially: GIS as a support system in the K–12 curriculum*. Washington, DC: National Academies Press, 2005.

[7] J. Piaget, *The grasp of consciousness: Action and concept in the young child (S. Wedgwood, Trans.)*. Cambridge, MA: Harvard University Press, 1976.

[8] L. S. Vygotsky, *The development of scientific concepts in childhood (A. Kozulin, Ed. & Trans.). In L. S. Vygotsky, Thought and language*. Cambridge, MA: MIT Press, 1986.

[9] I. Gryl and T. Jekel, "Re-centring geoinformation in secondary education: Toward a spatial citizenship approach," *Cartographica: The International Journal for Geographic Information and Geovisualization,* vol. 47, no. 1, pp. 18-28, 2012. https://doi.org/10.3138/carto.47.1.18

[10] B. Zhong, X. Liu, and X. Li, "Effects of reverse engineering pedagogy on students' learning performance in STEM education: The bridge-design project as an example," *Heliyon,* vol. 10, no. 2, p. e24278, 2024. https://doi.org/10.1016/j.heliyon.2024.e24278

[11] B. Kelgembayeva, S. Kumarbekuly, O. Aliya, A. Alimkhan, K. Kaldybay, and B. Kadirov, "Development of the academic policy of universities in Kazakhstan through the strategy of authentic assessment of students' educational achievements," *Journal of Ecohumanism,* vol. 3, no. 7, pp. 3353-3367, 2024. https://doi.org/10.62754/joe.v3i7.4458

[12] K. Kaldybay, S. Kumarbekuly, A. Sharipkhanova, Z. Dautova, I. Afanasenkova, and M. Tarlaubay, "Identifying the factors that influence students' academic performance as a function of teaching qualities in Ahmed Yasawi International Kazakh-Turkish University," *Journal of Ecohumanism,* vol. 3, no. 6, pp. 859-868, 2024. https://doi.org/10.62754/joe.v3i6.4056

[13] A. Ng, S. Kewalramani, and G. Kidman, "Integrating and navigating STEAM (inSTEAM) in early childhood education: An integrative review and inSTEAM conceptual framework," *Eurasia Journal of Mathematics, Science and Technology Education,* vol. 18, no. 7, p. em2133, 2022. https://doi.org/10.29333/ejmste/12174

[14] J. Wai, D. Lubinski, and C. P. Benbow, "Increasing math and science learning by improving spatial thinking," *Journal of Educational Psychology,* vol. 101, no. 4, pp. 817–835, 2009.

[15] D. H. Uttal, D. I. Miller, and N. S. Newcombe, "Exploring and enhancing spatial thinking: Links to achievement in science, technology, engineering, and mathematics?," *Current Directions in Psychological Science,* vol. 22, no. 5, pp. 367-373, 2013. https://doi.org/10.1177/0963721413484756

[16] T. R. Baker and S. Witham Bednarz, "Lessons learned from reviewing research in GIS education," *Journal of Geography,* vol. 102, no. 6, pp. 231-233, 2003. https://doi.org/10.1080/00221340308978554

[17] J. J. Kerski, "The role of GIS in digital earth education," *International Journal of Digital Earth,* vol. 1, no. 4, pp. 326-346, 2008. https://doi.org/10.1080/17538940802420879

[18] K. Cairns, "Mapping futures, making selves: Subjectivity, schooling and rural youth," Doctoral Dissertation University of Toronto, 2012.

[19] E. H. Chapman, "Review of the book The image of the city, by K. Lynch," *Journal of Aesthetics and Art Criticism,* vol. 21, no. 1, p. 91, 1962. https://doi.org/10.2307/427643

[20] H. E. Gruber, "The life space of a scientist: The visionary function and other aspects of Jean Piaget's thinking," *Creativity Research Journal,* vol. 9, no. 2-3, pp. 251-265, 1996. https://doi.org/10.1080/10400419.1996.9651176

[21] L. S. Vygotsky and M. Cole, *Mind in society: The development of higher psychological processes*. Cambridge, MA: Harvard University Press, 1978.

[22] M. J. Egenhofer and D. M. Mark, "Naive geography," in *International Conference on Spatial Information Theory,* 1995.

[23] S. Sjøberg and E. Jenkins, "PISA: A political project and a research agenda," *Studies in Science Education,* vol. 58, no. 1, pp. 1-14, 2022. https://doi.org/10.1080/03057267.2020.1824473

[24] K. Eriksson, O. Helenius, and A. Ryve, "Using TIMSS items to evaluate the effectiveness of different instructional practices," *Instructional Science,* vol. 47, no. 1, pp. 1-18, 2019. https://doi.org/10.1007/s11251-018-9473-1

[25] A. D. Morton, "Review of the book Spaces of global capitalism: Towards a theory of uneven geographical development, by D. Harvey," *Contemporary Political Theory,* vol. 6, no. 3, pp. 381–382, 2007. https://doi.org/10.1057/palgrave.cpt.9300296

[26] S. W. Bednarz, "Geographic information systems: A tool to support geography and environmental education?," *GeoJournal,* vol. 60, no. 2, pp. 191-199, 2004. https://doi.org/10.1023/B:GEJO.0000033574.44345.c9

[27] M. Meenar, N. Afzalan, and A. Hajrasouliha, "Analyzing Lynch's city imageability in the digital age," *Journal of Planning Education and Research,* vol. 42, no. 4, pp. 611-623, 2022. https://doi.org/10.1177/0739456X19844573

[28] QGIS Development Team, "QGIS geographic information system (Version 3.x) computer software," QGIS Association, 2021. https://www.qgis.org

[29] R. Bednarz and J. Lee, "What improves spatial thinking? Evidence from the spatial thinking abilities test," *International Research in Geographical and Environmental Education,* vol. 28, no. 4, pp. 262-280, 2019. https://doi.org/10.1080/10382046.2019.1626124

[30] R. Al Fauzi, E. O. Dewi, A. Rizara, R. Ridwana, and A. Yani, "Comparison ArcGIS with google my maps to help learn geographic information systems," *Jurnal Pendidikan Geografi Undiksha,* vol. 10, no. 2, pp. 186-196, 2022. https://doi.org/10.23887/jjpg.v10i2.46378

[31] L. McInnes, J. Healy, and J. Melville, "Umap: Uniform manifold approximation and projection for dimension reduction," *Journal of Open Source Software,* vol. 3, no. 29, p. 861, 2018. https://doi.org/10.21105/joss.00861

[32] R. M. Bender, "From snaps to maps: Using literature, mobile applications, and mapping software to design an engaging L2 curriculum," *Hispania,* vol. 104, no. 4, pp. 557-570, 2021. https://doi.org/10.1353/HPN.2021.0126

[33] T. C. Patterson, "Google Earth as a (not just) geography education tool," *Journal of Geography,* vol. 106, no. 4, pp. 145-152, 2007. https://doi.org/10.1080/00221340701678032

[34] M. Iqbal *et al.*, "Using google form for student worksheet as learning media," *International Journal of Engineering & Technology,* vol. 7, no. 3.4, pp. 321-324, 2018.

Appendix A.
Configuration for Monitoring Metrics.

```
{
 "groups": [
   {
     "name": "server-monitoring",
     "rules": [
       {
         "alert": "HighMemoryUtilization",
         "expr": "node_memory_Active_bytes / node_memory_MemTotal_bytes > 0.9",
         "for": "5m",
         "labels": { "severity": "warning" },
         "annotations": {
           "summary": "Memory utilization is over 90%",
           "description": "Active memory usage is above threshold on {{ $labels.instance }}"
         }
       },


               {
         "alert": "HighProcessCount",
         "expr": "node_procs_running > 300",
         "for": "5m",
         "labels": { "severity": "warning" },
         "annotations": {
           "summary": "Process count high",
           "description": "More than 300 processes running on  {{ $labels.instance }}"
         }
       },
       {
         "alert": "FileSystemFull",
         "expr": "node_filesystem_usage_bytes / node_filesystem_size_bytes > 0.9",
         "for": "5m",
         "labels": { "severity": "critical" },
         "annotations": {
           "summary": "File system usage above 90%",
           "description": "File system nearly full on {{ $labels.instance }}"
         }
       },
       {
         "alert": "HighDiskUtilization",
         "expr": "rate(node_disk_io_time_seconds_total[5m]) > 0.9",
         "for": "5m",
         "labels": { "severity": "warning" },
         "annotations": {
           "summary": "Disk utilization high",
           "description": "High disk I/O usage on {{ $labels.instance }}"
         }
       },
       {
         "alert": "HighCPUUtilization",
         "expr": "100 - (avg by(instance) (rate(node_cpu_seconds_total{mode=\"idle\"}[5m])) * 100) > 90",
         "for": "5m",
         "labels": { "severity": "warning" },
         "annotations": {
           "summary": "CPU usage over 90%",
           "description": "CPU usage is high on {{ $labels.instance }}"
         }
       },
       {
         "alert": "HighTemperature",
         "expr": "node_hwmon_temp_celsius > 80",
         "for": "2m",
```

```
    "labels": { "severity": "critical" },
    "annotations": {
      "summary": "Temperature above 80°C",
      "description": "Server temperature is high on {{ $labels.instance }}"
    }
  },
  {
    "alert": "ServerUnreachable",
    "expr": "up == 0",
    "for": "1m",
    "labels": { "severity": "critical" },
    "annotations": {
      "summary": "Server is unreachable",
      "description": "Prometheus cannot reach {{ $labels.instance }}"
    }
  },
  {
    "alert": "ServerUnresponsive",
    "expr": "probe_success == 0",
    "for": "1m",
    "labels": { "severity": "critical" },
    "annotations": {
      "summary": "Server not responding",
      "description": "Health check failed for {{ $labels.instance }}"
    }
  },
  {
    "alert": "HighRequestRate",
    "expr": "rate(http_requests_total[1m]) > 1000",
    "for": "2m",
    "labels": { "severity": "warning" },
    "annotations": {
      "summary": "High request rate",
      "description": "Over 1000 requests/sec on {{ $labels.instance }}"
    }
  },
  {
    "alert": "VulnerabilitiesDetected",
    "expr": "vuln_scan_vulnerabilities_total > 0",
    "for": "1m",
    "labels": { "severity": "critical" },
    "annotations": {
      "summary": "Security vulnerabilities detected",
      "description": "One or more vulnerabilities found on {{ $labels.instance }}"
    }
  },
  {
    "alert": "OldHardwareDetected",
    "expr": "node_hw_age_days > 1825",
    "for": "1m",
    "labels": { "severity": "info" },
    "annotations": {
      "summary": "Hardware is over 5 years old",
      "description": "Consider replacing old hardware on {{ $labels.instance }}"
    }
  },
  {
    "alert": "OutdatedPackages",
    "expr": "package_outdated_total > 0",
    "for": "1m",
    "labels": { "severity": "warning" },
    "annotations": {
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```

```
          "description": "{{ $value }} outdated packages on {{ $labels.instance }}"
        }
      },
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        "alert": "LowUptime",
        "expr": "node_time_seconds - node_boot_time_seconds < 300",
        "for": "1m",
        "labels": { "severity": "info" },
        "annotations": {
          "summary": "Server rebooted recently",
          "description": "Uptime is less than 5 minutes on {{ $labels.instance }}"
        }
      },
      {
        "alert": "OSVersionMismatch",
        "expr": "os_version != 'expected_version_string'",
        "for": "1m",
        "labels": { "severity": "info" },
        "annotations": {
          "summary": "Unexpected OS version",
          "description": "Running unsupported OS version on {{ $labels.instance }}"
        }
      }
    ]
  }
 ]
}
```