Spatial Thinking in Primary Geography Education: A Design-Based Intervention in Georgia

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Abstract

Students' spatial thinking and problem-solving skills are crucial components of modern primary education. While the Georgian National Curriculum emphasises spatial representations and environmental perception skills, significant challenges exist in their practical implementation. Textbooks often lack tasks that engage students with real spatial problems and develop argumentative thinking. This article presents design research conducted in a fifth-grade class at a Tbilisi public school. The study aimed to improve students' spatial thinking and decision-making skills using the Problem-Based Learning (PBL) model. Five interventions addressed real geographical situations, including settlement planning, protected area selection, and infrastructure placement. Results showed that targeted and consistent work on spatial tasks significantly improved students' abilities to read maps, recognise spatial relationships, and make rational choices. Despite progress, certain difficulties persisted, particularly in aligning self-assessment with actual performance and developing analytical thinking components. The article examines contradictions between standards and textbooks, identifying characteristics of pedagogical practice that either facilitate or hinder spatial skills development.

Keywords: Spatial thinking, primary level, problem-based learning, standard, design research, geography education

Introduction

Spatial thinking is an essential component of human cognitive development, enabling individuals to understand relationships between objects and space while visualising, interpreting, and predicting spatial patterns (NRC, 2006). Developing these skills is particularly crucial in geography education, where spatial representations form the basis for both information analysis and decision-making. International educational research demonstrates that establishing spatial thinking foundations at the primary level is critically important for students' subsequent subject-specific and metacognitive success. However, in the Georgian educational environment, this component is insufficiently integrated into both standards and textbooks. Consequently, students often struggle with map reading and recognising spatial connections between environmental elements. This deficit undermines the teaching-learning process and hinders students' ability to solve real spatial problems. Teachers are frequently forced to develop appropriate activities independently, as existing resources provide insufficient support. This article presents a pedagogical intervention designed to develop spatial thinking competence using Problem-Based Learning (PBL) methodology. The article describes the design research process, frameworks and tools used, presents data analysis and discussion, and offers recommendations to policymakers and educators for improving instruction in this area.

Conceptual Framework

Developing effective instructional design requires robust theoretical foundations, especially when cultivating complex skills such as spatial thinking. This study relies on three primary theoretical frameworks: Problem-Based Learning (PBL), the Geographic Reasoning Framework, and Design-Based Research.

1. **Problem-Based Learning (PBL)** PBL is a constructivist approach where learning is based on real and multifaceted tasks. In this model, the student becomes an active learner who tries to define issues, find information, analyze, evaluate, and solve problems (Barrows, 1986). In geography education, PBL is particularly effective because it allows students to consider real-world geographical problems.
2. **Geographic Reasoning Framework** Gersmehl and Gersmehl (2011) propose a geographic reasoning model consisting of seven components: identifying location, analyzing spatial distribution, explaining patterns, understanding movement patterns, evaluating connections, comparing regions, and making decisions. Using this framework allows students to conduct structured spatial analysis.
3. **Design Research (DBR)** is one of the most promising methodologies in education research, especially when the goal is to solve practical problems and improve teaching. According to Arthur Bakker (2018), design research has a clear structure, theoretical basis, and practical purpose.

*Key Aspects of Design Research (*Bakker, 2018*):*

- **Problem-Oriented Approach**: Design research begins by identifying urgent educational problems. It seeks to solve real problems through innovative means rather than merely describing existing practices.
- **Interconnection of Theory and Practice**: This methodology integrates theory and practice. Products developed during research (learning materials, activities, frameworks) are built on theoretical foundations and enrich theory in return.
- **Interventionist Nature and Innovative Design**: Design research involves creating and testing interventions to improve learning environments. Interventions can include new teaching methods, structured activities, or technological tools.
- **Iterative Cycles**: The research process is characterized by repetitive cycles—design creation, testing, analysis, and revision. This enables continuous improvement and refinement in real contexts.

According to Bakker's approach, design research is a rich, theoretically grounded, and practice-oriented methodology that is particularly powerful when learning standards inadequately support student cognitive development. During this research, all three frameworks were used interactively.

Literature Review: Spatial Problem-Solving in Primary Geography Education

Spatial thinking is increasingly recognized as a fundamental competence in geography education, especially at the primary level, where it enables students to engage in critical analysis and decision-making about their environment. Research indicates the importance of creating learning experiences that are not only age-appropriate but also address shortcomings in learning standards and textbooks (Bakker, 2018; Buckley et al., 2018).

Spatial skills development begins in early childhood with topological concepts (e.g., "near," "inside," "around") and gradually progresses to more complex spatial-projective concepts such as scale, symbols, and coordinates. Research by National Geographic shows that primary school students (especially grades II-IV) begin understanding maps but still need support in interpreting spatial connections and symbols (National Geographic Society, 2016).

Cognitively, Buckley et al. (2018) emphasize that spatial skills are multifactorial and include visualization, orientation, mental rotation, and spatial perception—all directly related to academic achievement, especially in STEM disciplines. These skills develop through targeted tasks and activities such as understanding directions, creating maps, or making decisions about specific spatial problems—which directly aligns with primary geography education contexts.

Fiveable (2024) clearly states that spatial thinking extends beyond map reading to encompass a full cycle of geographical inquiry: asking spatial questions, acquiring and organizing information, analyzing connections, and making relevant decisions. This approach is compatible with problem-based learning models that promote active student engagement and encourage thinking development.

Nevertheless, spatial thinking remains incompletely integrated into primary education standards. Textbooks often emphasize memorizing facts and technical map reading rather than spatial-cognitive tasks. A learning design-based approach can address this gap, especially when linking students' real needs with evolving research strategies (Bakker, 2018).

Primary geography education focused on spatial problem-solving requires both recognizing the diversity and developmental potential of spatial skills and implementing research-based instructional design. The synthesis of various academic disciplines—cognitive psychology, educational design, and practice—creates a solid foundation for developing spatial thinking and problem-solving skills in students.

Methods and Materials

This research is based on Design-Based Research (DBR) methodology, which aims to develop innovative educational practices and test them in real contexts. DBR involves cyclical planning, implementation, evaluation, and redesign of educational interventions (Anderson & Shattuck, 2012). This approach is particularly important when developing complex skills in resource-limited conditions. The study was conducted in the academic year 2024-2025 in a fifth-grade class at Tbilisi Public School No. 51, with 23 students. Teacher Maia Madzgharashvili was involved as an equal partner and active observer. Student teachers from the training programme, Mariam Gagua and Keso Kankia, conducted the interventions. Student teacher involvement proved particularly effective, as students felt comfortable with younger facilitators, experienced less stress, and could ask questions freely. This approach promotes more active student involvement and reduces barriers between teacher and student.

Data Collection

The instruments used included:

- Standard and textbook analysis
- Analysis of student work (maps, tables, arguments for choices)
- Student self-assessment forms
- Interviews with the teacher

Intervention Design

Each intervention included the following structure, shown on the scheme

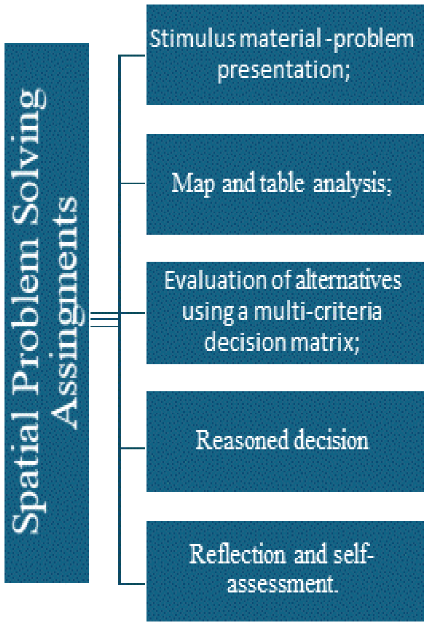

Figure 1. Design elements

The study included five interventions, each planned at three-week intervals. Each intervention was based on the PBL model and represented a task based on real geographical contexts, such as:

- Planning a prototype settlement
- Selecting the location of a protected area
- Analyzing infrastructure placement (school, clinic)
- Assessing natural disaster risk and planning routes
- Planning recreational zones considering residents' interests

Data Analysis

Data analysis divided information according to three main components:

- Map reading and spatial identification ability
- Reasoned decision-making ability
- Accuracy of self-assessment

Qualitative and quantitative data analysis was conducted using Excel. Student work was evaluated according to a rubric (satisfactory, partially improved, incompetent) and analyzed after each intervention.

Participant Selection for Analysis

Important Note on Sample Size: While 23 students are in the class, only 9 students attended all five interventions and were included in the final analysis. This reduction was necessary to maintain data integrity, as the cyclical nature of the interventions required consistent participation to track skill development progression.

Absenteeism poses particular challenges for this age group (fifth graders) as they are not yet independent learners. Unlike older students, fifth graders cannot effectively review missed spatial thinking activities at home, especially since these activities are not part of licensed textbooks. The hands-on, collaborative nature of the interventions—involving map work, group discussions, and guided problem-solving—cannot be replicated through traditional homework assignments. Students who missed interventions lacked the foundational skills needed for subsequent activities, making it methodologically inappropriate to include incomplete data sets in the analysis. This limitation highlights the importance of consistent attendance for cumulative skill development in primary education.

Ethical Considerations

With parental and school agreement, all students participated anonymously. Materials used contain no names and strictly adhere to confidentiality principles. The teacher and school received summarized analysis results.

Analysis of Standards and Textbooks

The Georgian National Curriculum (MoE, 2018) defines compulsory achievements for students in "Our Georgia," which includes geographical components alongside history. Although the document generally addresses spatial connections between environmental elements, it lacks specific instructions for developing spatial thinking as a separate competence.

The standard presents terms such as "recognizing spatial connections," "map reading," and "representing the environment," but these are not accompanied by relevant explanations, minimal indicators, or task typologies, increasing the risk of multiple interpretations. Consequently, teachers often remain unclear about what teaching these competencies means in practice.

Despite the Georgian National Curriculum's stated emphasis on developing spatial representations and environmental perception skills, practical implementation faces significant challenges stemming from current educational materials' shortcomings. A typical exercise from the widely used "Our Georgia" textbook (Avtandilashvili et al., 2018) asks students: "What is the location of Kartli on the map of Georgia? Which historical-geographical regions of Georgia border it? Are there more hills or plains in Kartli?" Similarly, page 52 asks students to "List, with the help of the map, which regions of Georgia border Imereti?"

These tasks, and many others like them, are purely descriptive and extractive, requiring only direct information retrieval from maps rather than fostering genuine problem-solving or analytical engagement with spatial data. This reliance on rote recall rather than critical thinking fundamentally hinders true spatial reasoning development.

The root of this issue lies in the national standard's generalized directives, which fail to compel textbook authors to create situation-based problems demanding analytical map work. For instance, within the "Space" concept, the standard merely requires students to "discuss the reasons for the diversity of landscapes characteristic of Georgia." This level of abstraction falls far short of fostering robust spatial thinking.

In contrast, by fourth grade, National Geographic's standards expect students to "analyze geographic contexts in which current events and issues occur," exemplified by tasks like describing "geographic factors that would influence the decision on where to locate a new school in the local community" (National Geographic Society, n.d.). This disparity highlights a significant competency gap, where Georgian primary students engage with spatial concepts at far less complex and practical levels than international peers, ultimately impeding their ability to apply spatial thinking to real-world scenarios.

Furthermore, comprehensive visual resources (diagrams, maps, pictures) essential for developing spatial representations are often absent in textbooks. This resource lacks forces educators to find or create materials independently, increasing teacher workload and leading to teaching quality inconsistencies.

The discrepancy between standards and textbooks was highlighted during intervention planning. It became clear that standard minimum requirements do not correspond to skills students need. For example, understanding spatial sequences between water, forest, village, and mountain objects on maps and formulating reasoned choices is required by neither the standard nor textbook tasks.

Teacher interviews revealed the need for clear guidelines for spatial task work and practical examples aligning with national curriculum goals. One educator noted: "I rarely have the opportunity or time to create spatial tasks myself. The textbook focuses more on factual knowledge."

The analysis indicates a systemic challenge—current standards and textbooks at Georgia's primary level do not ensure development of spatial thinking competencies essential for modern education. This discrepancy creates barriers to learning effectiveness and increases individual teacher workload.

Design Description and Its Use as a Problem-Solving Tool

The design developed within this study was based on the SPBL (Spatial Problem-Based Learning) model and aimed to overcome difficulties caused by the lack of spatial thinking components in standards and textbooks. The combined integration of PBL and the Geographic Reasoning Framework allowed us to create tasks based on real contexts, considering spatial relationships, natural-geographical factors, and reasoned decisions.

One main innovation was the interventions' cyclical nature. Each intervention combined problem presentation, data comprehension, map reading and spatial reasoning, alternative comparison, and reasoned decision-making. All five interventions relied on active student participation, cognitive stimulation, and self-assessment.

Each intervention followed a structured five-step process designed to guide students through comprehensive spatial problem-solving (see Fig. 1):

Step 1: Problem Presentation

Students were presented with an authentic geographical scenario that required spatial decision-making. For example, they might receive a scenario stating: "A group of early humans needs to establish a permanent settlement. As their advisor, you must help them choose the best location from three possible sites." The problem was introduced through storytelling to engage students and establish the real-world relevance of their task.

Step 2: Data Analysis

Students examined multiple information sources including topographic maps, climate data, resource availability charts, and contextual information about the geographical area. They were guided to identify key spatial elements such as water sources, elevation patterns, vegetation cover, and proximity to resources. This step required students to extract relevant information from visual and textual sources systematically.

Step 3: Alternative Evaluation

Students worked in small groups to compare multiple location options using predetermined criteria. They used evaluation matrices where each potential site was assessed against factors such as water accessibility, defensibility, resource availability, climate suitability, and transportation routes. Students assigned numerical scores to each criterion and calculated total scores for each alternative, fostering analytical thinking and systematic comparison.

Step 4: Reasoned Decision

Based on their analysis, students selected their preferred location and constructed written arguments justifying their choice. They were required to explain not only why their chosen site was optimal but also why they rejected the alternatives. This step emphasized the development of argumentation skills and required students to synthesize their spatial analysis into coherent reasoning.

Step 5: Reflection/self-assessment

Students assessed their decision-making process and outcomes through structured self-evaluation forms. They considered questions such as: "Which factors were most important in your decision?"

"What additional information would have been helpful?" and "How confident are you in your choice?" This metacognitive component helped students understand their own learning processes and identify areas for improvement in future spatial problem-solving tasks.

Tasks were designed so students genuinely considered the appropriateness of placing various objects according to specific criteria, such as where primitive humans should settle; which area is most appropriate for creating a protected area; where a school building or alpine base should be built. Tasks involved comparing several parameters—proximity to water, terrain, climate, safety, infrastructure accessibility, and others. Students worked with tables, evaluating each parameter with points, then made in-depth reasoned choices.

Another important design element was map use. Each task began with a schematic map that students needed to read to analyze spatial characteristics. Map work offered visual and analytical links between problems and environmental elements, enabling skill development in determining location, estimating distance, distinguishing directions, and establishing object connections.

Starting from the fourth intervention, students began working on spatial problems where their chosen locations were based on strong argumentation and alternative comparison. The design's consistent development was precisely the factor contributing to competency deepening. The teacher used reflection stages after each task, where students evaluated their decisions and explored how better choices could have been made.

The design solved several significant problems:

- **Gap between standard and tasks**: PBL interventions created alternative spaces for working in real geographical contexts
- **Teaching monotony**: Tasks diversified student activities
- **Teacher challenge**: The design was easily reproducible and adaptable by teachers
- **Lack of self-assessment and reflection**: Integrated self-assessment modules ensured metacognitive skills development

As a result, students not only gained better understanding of geographical concepts but also developed decision-making, argumentation, and spatial visualization skills, contributing to their overall academic development. The research clearly showed that using this design type effectively overcomes shortcomings caused by standard generality and resource scarcity at the primary level.

Results

Analysis of design research results clearly showed that students' spatial thinking and reasoned decision-making skills significantly improved as a result of interventions. This progress is reflected in student work, teacher reflections, and self-assessment forms.

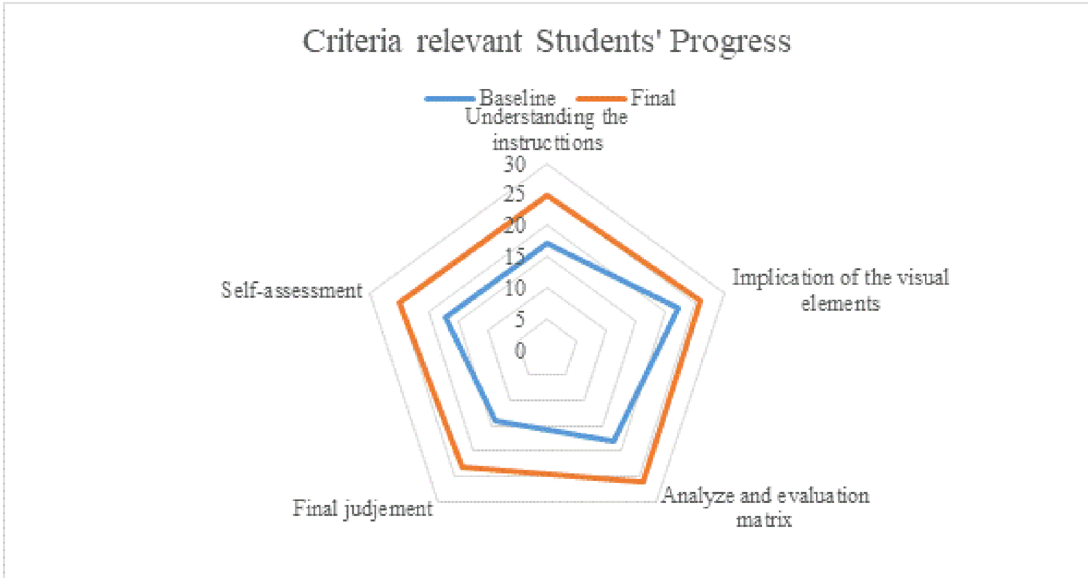

Figure 2. Competency development from preliminary to final stages

Figure 2 shows evaluation results comparing preliminary and final stages across key competencies. This clearly demonstrates that students made progress in each competence. Of these competencies, the least progress was recorded in visual elements use, indicating that students had already developed this competence substantially and could use it as needed.

Understanding instructions for multi-stage tasks was initially problematic. Textbook analysis showed that most tasks were one or two-stage, preventing students from concentrating on topics for extended periods. Therefore, incomplete or unsuccessful task completion initially raised questions about whether this was due to student competence deficiencies or instruction comprehension problems. Thus, explaining instructions and presenting tasks was critically important.

Figure 3 presents the progression of student performance across all five interventions, showing steady improvement in spatial reasoning abilities. The data shows the evaluation results of 9 students, as only 9 students attended all interventions. Under conditions of incomplete attendance, drawing conclusions based on participants' competencies becomes difficult. In general, absenteeism is a problem that reduces the effectiveness of planned and implemented activities. In the Georgian reality, such a study, which examines the impact of absenteeism in this context, does not exist.

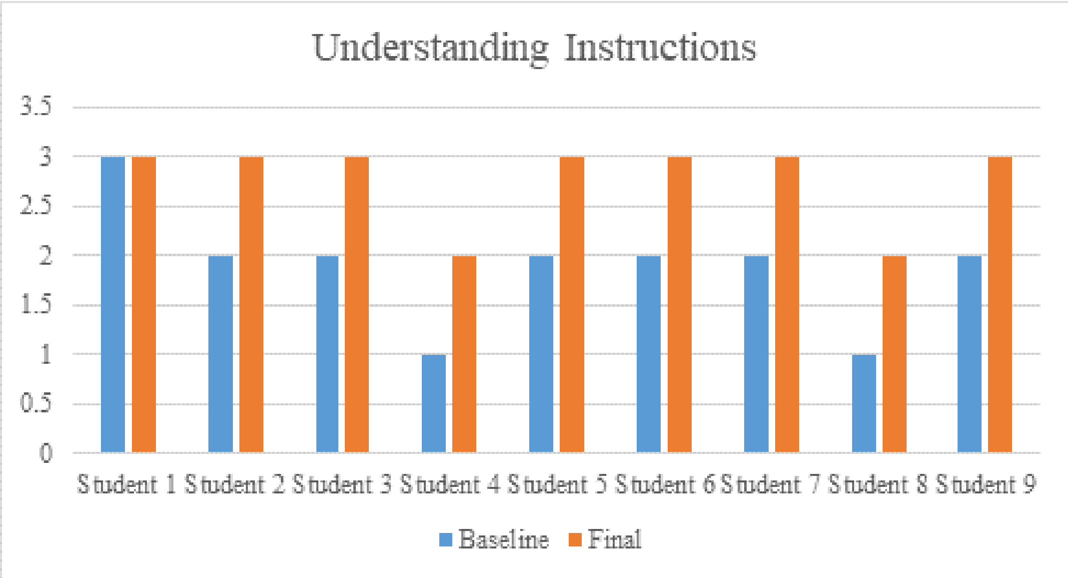

Figure 3. Student performance progression across interventions

Self-assessment data showed that most students initially assessed their work with maximum scores, despite errors. However, by the fifth intervention, as a result of active teacher feedback and group discussions, students' self-assessments aligned with actual performance in over 70% of cases. This indicates progress in metacognitive skills—students learned how and why to assess their own learning.

Figure 4 illustrates the alignment between student self-assessment and actual performance across the intervention period.

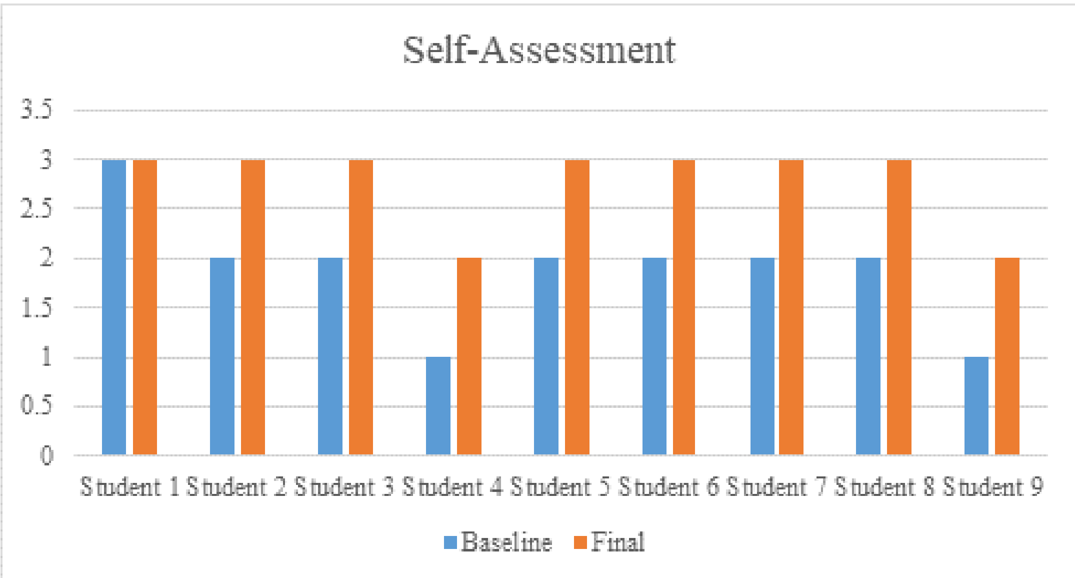

Figure 4. Convergence of self-assessment and actual performance

Data confirms that with design progress, students' approaches to tasks and instruction understanding changed. While the first intervention was characterized by template-based perception and difficulty in functional map use, from the third intervention students began better perceiving information and reasoning. For example, on given map territories, they evaluated not only geographical factors but also environmental impact (e.g., roads running through forests requiring maintenance).

According to the teacher, student engagement significantly increased during proposed tasks when decisions depended on them rather than just finding correct answers. This reflects PBL approach effectiveness—interest and motivation increase when students are responsible for thinking and choice.

Analysis also revealed several challenges, as represented in figure 5. For some students, map orientation remained problematic—especially correctly reading scale and symbols. However, the main challenge was argumentation, the clear, academic formulation of their results. These difficulties indicate that teaching spatial thinking should include not only problem-solving but also consistent work on developing appropriate domain-specific vocabulary and argument formation.

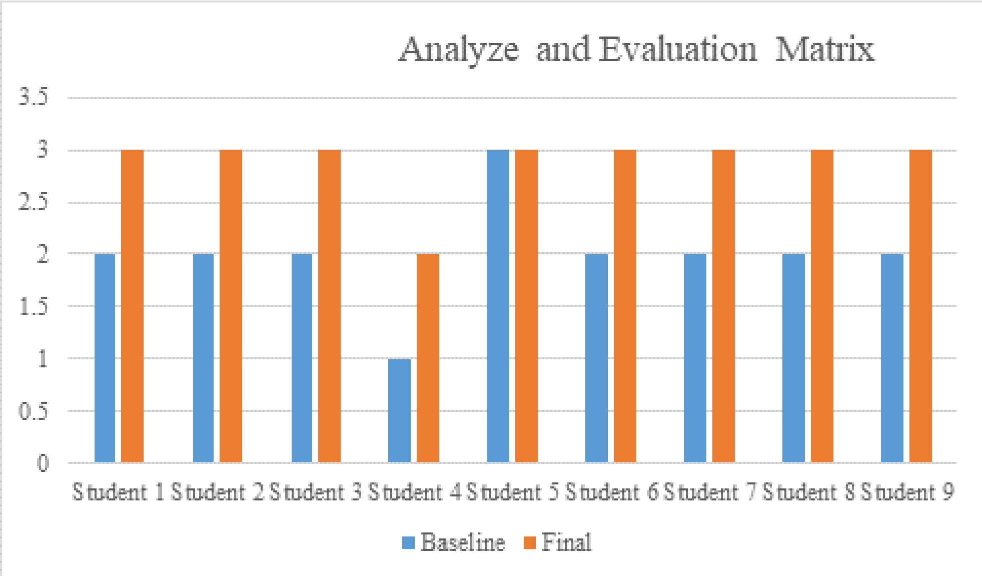

Figure 5. Comparison of how the analytical competence developed

According to the teacher's assessment, students who had self-confidence deficits in teamwork struggled with analysis and justifying their positions, but over time, they began formulating arguments better. This confirms that, under supportive environment conditions and consistent stimulation, spatial thinking competence is accessible to a wide range of students.

The intervention's consistent nature proved to be an important success factor. While first tasks were based on simpler scenarios, each subsequent intervention increased demands—parameter numbers became more complex, conflicting choices were added, and argumentation required refinement. Thus, progress was conditioned not by one-time activities but by structured and adapted intervention sequences.

The ability to make reasoned choices, which initially was based primarily on single-sentence evaluations (e.g., "It's a good place"), gradually evolved into multi-factorial reasoning: "The selection of this territory is due to its proximity to water, high elevation, and forest protection, which creates a safe environment for a primitive settlement."

Finally, analysis clearly shows that through effectively planned and consistent interventions, it is possible to develop complex skills that empower students not only in subject knowledge but also in general thinking and self-reflection. This research demonstrates that, given appropriate design, students begin to think spatially—not mechanically, but consciously, critically, and argumentatively.

Conclusion

The main findings clearly demonstrate that developing spatial thinking and problem-solving skills at the primary level is possible if teaching is based on problem-based, consistent, context-oriented design. The interventions revealed students' increasing progress not only in map reading and identifying spatial relationships but also in argumentation quality, decision-making processes, and self-assessment accuracy.

Findings:

• Clear discrepancy exists between standards and practice—standards are general and do not define minimum levels for spatial skill competencies

• Textbooks are dominated by superficial, descriptive tasks that induce neither critical thinking nor reasoned choice

• Problem-based interventions create learning environments that develop spatial thinking with both subject-specific and metacognitive components

• Student engagement significantly increases when they are allowed to work on real problems and make decisions independently

• Teacher support and professional development are critically important for designing tasks that meet students' evolving needs

Recommendations:

For Policy Makers:

• Revise the National Curriculum to include clear formulation of spatial thinking competencies and definition of key indicators; develop frameworks to measure spatial reasoning rather than factual recall

• Create platforms for schools to exchange experiences and design examples based on practical interventions

For Publishers:

• Include age-appropriate examples of problem-based, multi-factorial tasks in textbooks, along with maps and visual analytical resources

• Develop supplementary materials that support spatial thinking development

For Teacher Training:

• Prioritize intervention strategies based on design research foundations and SPBL model mastery in teacher training programs

• Support teachers in developing skills for creating and adapting spatial problem-solving tasks

For Schools:

• Ensure all students have access to visual materials and opportunities to practice spatial interpretation skills; create supportive environments for spatial problem-solving

• Address absenteeism issues that particularly affect cumulative skill development

This research confirms that spatial thinking-based learning is possible; it requires only the right approach, consistent intervention, and strong theoretical foundations that provide subject-oriented and critical thinking-oriented teaching and learning.

Competing interests

The authors declare that they have no competing interests.

Authors' contribution

M.R. conceived the study, designed the research methodology, and took the lead in writing the manuscript. **M.M.** facilitated the implementation of the research intervention and assisted in the data validation process. Both authors have read and approved the final manuscript.

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