

Strategies of academic writing as a tool for developing research-oriented learning in geography teacher education

Aigerim Yespenova¹, Meruyert Tasbolatova², Gulnur Berkenova³, Shalkar Turganov⁴,
Viktor Trofimov⁵, Daulet Sartayev⁶

¹Department of History and Theory of Fine Arts, Temirbek Zhurgenov Kazakh National Academy of Arts, Almaty, Kazakhstan

²Department of Publishing, Editorial and Design Art, Al-Farabi Kazakh National University, Almaty, Kazakhstan

³Department Political Science and Political Technologies, Al-Farabi Kazakh National University, Almaty, Kazakhstan

⁴School of Design, International Educational Corporation, Almaty, Kazakhstan

⁵Department of Design and Cultural and Leisure Work, Kokshetau University named after Abay Myrzakhmetov, Kokshetau, Kazakhstan

⁶School of Construction, International Educational Corporation, Almaty, Kazakhstan

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ABSTRACT

In contemporary teacher education, academic writing is regarded as a key meta-competence reflecting students' analytical thinking and readiness for research. However, in geography teacher education, writing often remains descriptive and provides limited support for interpreting spatial processes and developing research-oriented thinking. This is problematic because future geography teachers must analyze spatial, cartographic, field-based, and socio-cultural data. The study aims to determine whether architectural terminology can serve as an interdisciplinary cognitive framework for developing research-oriented academic writing among future geography teachers. Its originality lies in integrating architectural conceptual terminology with geographic information systems (GIS)-supported academic writing instruction within a unified pedagogical framework. A mixed-methods approach combined quantitative and qualitative analyses of students' written work before and after the intervention, alongside field observations, GIS-based spatial analysis, expert evaluation, and comparative text coding. The results indicate a shift from descriptive to analytical writing, demonstrated by increased use of interdisciplinary concepts such as "structure," "scale," and "composition," stronger argumentation, and deeper interpretation of spatial processes. Expert evaluation confirmed improvements in critical reasoning and visual data presentation. The findings suggest that architectural vocabulary can function as a cognitive scaffold for higher-order thinking and research-oriented learning, contributing to the modernization of geography teacher education and competency-based academic writing instruction.

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Corresponding Author:

Daulet Sartayev

School of Construction, International Educational Corporation

Almaty, Kazakhstan

Email: d57280900@gmail.com

1. INTRODUCTION

In contemporary teacher education, the development of research competencies has become an increasingly important objective of university curricula. Future geography teachers are expected not only to possess sound disciplinary knowledge but also to critically interpret spatial phenomena, integrate diverse forms of geographical evidence, and communicate research findings through analytically grounded academic

writing. Accordingly, academic writing is increasingly recognized as a pedagogical tool that promotes critical thinking, argumentation, and evidence-based reasoning rather than merely serving as a means of presenting information. Despite this growing emphasis, academic writing in geography teacher education often remains predominantly descriptive. Students are generally capable of identifying visible characteristics of landscapes and urban environments but frequently encounter difficulties when interpreting spatial relationships, explaining causal mechanisms, and constructing coherent analytical arguments. Consequently, writing often functions as a formal academic requirement instead of supporting the development of research-oriented thinking and analytical competence.

Recent research has consistently demonstrated that academic writing promotes critical thinking, argumentation, and research competencies, while geography education increasingly emphasizes inquiry-based learning, geographic information systems (GIS)-supported analysis, and the interpretation of complex spatial data. Parallel studies in architecture and urban studies have shown that concepts such as structure, scale, composition, and node provide powerful analytical frameworks for understanding spatial organization. However, these three areas of research have developed largely independently. Studies on academic writing rarely incorporate conceptual tools derived from architecture, whereas research in geography education has paid limited attention to the role of interdisciplinary conceptual vocabulary in fostering analytical writing. Likewise, architectural terminology has primarily been examined within design and urban studies rather than as a pedagogical resource for developing research-oriented thinking. Consequently, there is still no empirically validated pedagogical model that integrates academic writing, geography education, and architectural conceptual terminology within a unified framework for developing analytical writing among future geography teachers. Accordingly, this study addresses an important research gap by examining whether architectural conceptual terminology can function as an interdisciplinary cognitive scaffold for developing research-oriented academic writing among future geography teachers.

Unlike previous studies that have investigated academic writing, geography education, or interdisciplinary learning separately, the present research integrates these dimensions within a unified pedagogical model combining academic writing, GIS-supported spatial analysis, field observation, and architectural conceptual vocabulary. The originality of this study lies in the integration of architectural conceptual terminology with GIS-supported academic writing instruction within a unified interdisciplinary pedagogical framework. This research provides a novel methodological contribution by demonstrating how conceptual tools traditionally associated with architecture can be applied to strengthen analytical writing, spatial reasoning, and research-oriented learning in geography teacher education. The study aims to determine how the integration of architectural terminology into academic writing tasks contributes to the development of research-oriented learning among future geography teachers. Specifically, it investigates changes in students' analytical writing, spatial interpretation, interdisciplinary conceptualization, and expert evaluations following an interdisciplinary pedagogical intervention. By addressing this question, the study contributes both to the theoretical understanding of research-oriented learning and to the development of interdisciplinary pedagogical practices in geography teacher education.

2. LITERATURE REVIEW

The theoretical foundation of this study lies at the intersection of spatial theory, academic writing, and research-oriented teacher education. Studies in geography, architecture, and education suggest that interdisciplinary conceptual frameworks can enhance analytical thinking; however, these perspectives have rarely been integrated into academic writing instruction for future geography teachers. The first line of research concerns space as a socially constructed and analytically interpretable phenomenon. Lefebvre's concept of the production of space established a basis for interpreting urban environments as products of social practices rather than merely physical settings [1]. This perspective was expanded through space syntax and configurational theory [2], [3], urban systems perspectives [4], [5], and urban morphology [6], [7]. These approaches demonstrate that structure, form, scale, composition, and spatial configuration provide analytical tools for understanding complex urban systems [8]. Such categories allow spatial relationships to be interpreted analytically rather than through description of individual urban elements. Similarly, several studies broaden the interpretation of relationships among spatial organization, physical form, landscape, human activity, and social processes [9]–[13]. Together, these perspectives suggest that architectural concepts may offer an analytical language capable of supporting geographical interpretation beyond traditional descriptive observation.

The second line of research highlights the role of academic writing in developing higher-order thinking. Academic writing enables students to construct arguments, interpret evidence, and develop disciplinary reasoning [14], [15]. Research on academic argumentation and literacy further emphasizes evidence-based reasoning and disciplinary knowledge construction [16], [17]. Studies linking teaching, learning, and research indicate the value of engaging students with research and inquiry [18], [19].

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These issues are particularly relevant in geography education, where students may experience difficulties constructing written arguments while integrating multiple geographical materials [20]. Geography education emphasizes interactions between geographical knowledge and educational practice [21], while interdisciplinary learning enables students to engage with analytical perspectives from different disciplinary contexts [22]. This integration can broaden how students organize and communicate geographical knowledge. The third line of research focuses on analytical and research competencies in geography education. Contemporary geography education emphasizes GIS3 supported learning and spatial analysis for developing geographical knowledge, spatial thinking, and inquiry skills [23]. Teacher education research also emphasizes effective professional preparation [24]. Integrating physical, human, and GIS geographies provides opportunities for comprehensive interpretations of geographical environments [25]. Studies of pre-service geography teachers highlight the importance of pedagogical content knowledge [26]. Academic writing contributes to disciplinary identity and academic knowledge practices [27], while digital learning environments can support information literacy and critical thinking [28]. Challenges remain in transforming academic geographical knowledge into competency-based school geography [29] and integrating disciplinary knowledge with its pedagogical representation [30].

Taken together, the literature demonstrates progress in understanding academic writing, interdisciplinary learning, and geography education. Nevertheless, these fields have largely developed in parallel, leaving an important research gap. Little empirical evidence exists on whether architectural terminology can function as a cognitive scaffold supporting the transition from descriptive writing to research-oriented analytical discourse among future geography teachers. Addressing this gap, the present study develops and evaluates an interdisciplinary pedagogical model integrating architectural conceptual vocabulary, GIS-supported spatial analysis, field observation, and academic writing within a unified research-oriented learning framework.

3. METHOD

This study employed an exploratory mixed-methods design to investigate whether the integration of architectural conceptual terminology supports the development of research-oriented academic writing among future geography teachers. A mixed-methods approach was considered the most appropriate because the study sought to examine both measurable educational outcomes and the cognitive processes underlying students' analytical writing. Quantitative data were used to identify overall changes in students' writing performance before and after the pedagogical intervention, whereas qualitative data provided a deeper understanding of how students' analytical reasoning, interdisciplinary conceptualization, and research reflection evolved throughout the learning process. The study followed a convergent mixed-methods design, in which quantitative and qualitative evidence was collected during the same pedagogical intervention and integrated during data interpretation. Data triangulation was achieved through comparative text analysis, expert evaluation, and descriptive quantitative indicators. This methodological triangulation strengthened the credibility of the findings and enabled a comprehensive interpretation of the educational effects of the intervention. In particular, the study sought to determine whether interdisciplinary architectural terminology could function as a pedagogical and cognitive scaffold supporting research-oriented analytical thinking among future geography teachers. The primary purpose of this exploratory mixed-methods study was to examine the processes underlying students' analytical writing development rather than to estimate population-level effects or test predefined statistical hypotheses. Therefore, quantitative indicators were used to describe patterns of change and were interpreted together with qualitative evidence obtained from comparative text analysis and expert evaluation.

3.1. Participants

The study involved 50 master's students enrolled in the "geography and education" program, who voluntarily agreed to participate and complete both field-based and writing tasks. All participants possessed basic academic writing skills and had prior experience working with geographical data. Students were fully informed about the aims and procedures of the study and retained the right to withdraw at any stage. Participants were selected through purposeful sampling because they represented the target population for which the proposed pedagogical model was specifically designed. The sample size of 50 students was considered appropriate for an exploratory mixed-methods study, where the primary objective is to obtain an in-depth understanding of educational processes rather than to achieve statistical generalization.

Furthermore, the combination of students' written assignments, GIS analyses, and field observations provided a sufficiently rich dataset for triangulating quantitative and qualitative findings. For the final assessment, an expert panel consisting of 12 specialists—architects, geographers, and educators with experience in interdisciplinary research and teacher training—was established. The interdisciplinary

composition of the expert panel was particularly important because the study focused not only on the quality of academic writing itself but also on the integration of spatial analysis, architectural conceptualization, and research interpretation within students' texts. The interdisciplinary composition of the expert panel enabled student work to be evaluated from complementary disciplinary perspectives, including analytical writing quality, spatial interpretation, methodological rigor, and the application of architectural conceptual terminology. Expert evaluation therefore constituted an important element of methodological triangulation, complementing the quantitative indicators and qualitative analysis of students' written work.

3.2. Research setting and procedure

The study was conducted within the framework of practical training courses related to geographical research methodology over a period of eight weeks. The field component took place in the urban environment of Almaty, while classroom-based tasks were carried out in academic laboratories and through online platforms (Google Workspace, ArcGIS Online, and QGIS). The urban environment of Almaty was selected because of its spatial diversity, contrasting urban morphology, transport infrastructure, public spaces, and socio-spatial complexity, which created favorable conditions for interdisciplinary spatial analysis and analytical writing. To select the research object, each student was required to identify a specific urban site using Google Maps, such as a neighborhood block, park, transport hub, or another significant urban area. Following site selection, participants produced an initial written description of the environment, which served as a diagnostic baseline indicator of their analytical writing level, as shown in Figures 1 and 2. The initial tests revealed that most students relied predominantly on descriptive observation and lacked analytical interpretation of spatial relationships, compositional structure, and socio-spatial dynamics. This confirmed the relevance of the pedagogical problem identified in the Introduction and justified the implementation of the interdisciplinary pedagogical intervention.



Figure 1. Selected urban sites analyzed by students



Figure 2. Framework of the interdisciplinary pedagogical intervention model

3.3. Research procedure and stages

The study consisted of three main stages. During the diagnostic stage, students were asked to produce a brief written description of a selected urban site using cartographic services. These texts were predominantly descriptive in nature and contained little to no architectural or interdisciplinary terminology. Most texts demonstrated fragmented observation, weak analytical organization, and limited interpretation of spatial processes. Students mainly focused on listing visible urban elements without explaining functional, compositional, or socio-spatial relationships.

During the pedagogical intervention stage, the study implemented a sequence of instructional modules aimed at developing students' research and writing competencies. The pedagogical intervention was conceptualized as an interdisciplinary educational model integrating academic writing, GIS-supported spatial analysis, architectural conceptual vocabulary, and field-based observation within a research-oriented learning framework. This stage comprised a linguistic module and a practice-oriented analytical module. The intervention was designed to gradually increase the complexity of analytical tasks and promote deeper engagement with spatial interpretation.

3.4. Linguistic module

Architecture instructors introduced and explained key architectural concepts (e.g., "structure", "scale", "composition", "node", "axis") and demonstrated their application in the analysis of urban environments. The purpose of the linguistic module was not limited to terminology acquisition. Instead, architectural concepts were introduced as analytical cognitive tools capable of restructuring students' interpretation of spatial processes and supporting the transition from descriptive observation to analytical reasoning. The emphasis was placed not on rote memorization of terminology but on its meaningful integration into analytical writing. Students also participated in guided discussions and text-analysis activities to practice the contextual use of these concepts in academic discourse.

3.5. Practice-oriented analytical module

Students were engaged in a series of progressively structured tasks that included micro-scale fieldwork involving observation diaries, GPS tracking, and photographic documentation of key spatial points. They also conducted GIS-based analyses, including object vectorization, transport accessibility analysis, and the assessment of green space distribution. In addition, students completed scenario-based case studies focused on reconstructing urban transformations over several decades, prepared narrative essays following the "fact–interpretation–conclusion" structure to link empirical observations with analytical reasoning, and presented the results of their research in public presentations. Each task required the application of architectural terminology to support the conceptual interpretation of processes occurring within the urban environment. The gradual increase in task complexity was intended to stimulate the development of analytical reasoning, interdisciplinary interpretation, and research reflection. The integration of GIS, field observation, and conceptual terminology enabled students to combine visual-spatial analysis with written analytical interpretation. Furthermore, regular instructor feedback encouraged students to refine their analytical arguments and strengthen the coherence of their written texts.

3.6. Control stage

During the final stage, students repeated the writing tasks. These texts were compared with the baseline submissions to identify changes in the use of interdisciplinary terminology, the level of argumentation, and the depth of analysis. Particular attention was paid to the emergence of analytical structures within students' texts, including causal interpretation, spatial reasoning, socio-ethical reflection, and the use of interdisciplinary conceptual categories. In addition, all materials were evaluated by an expert panel. The results of this comparison provided evidence regarding the effectiveness of the pedagogical intervention in fostering research-oriented academic writing.

3.7. Expert evaluation stage and assessment criteria

An interdisciplinary expert panel composed of architects, geographers, and educators evaluated the students' work according to five key criteria: the clarity of research question formulation, the completeness and accuracy of data handling (including maps, diagrams, photographs, and GIS-based analysis), the depth of interpretation and coherence of argumentation, the level of mastery and correct use of architectural and interdisciplinary terminology, and the quality of written expression and visual presentation. Each criterion was assessed using a four-point scale ranging from a basic to an advanced level. For the quantitative analysis, the proportion of student assignments meeting each predefined evaluation criterion was calculated and expressed as percentages before and after the pedagogical intervention. These percentages were used to summarize changes in students' analytical writing performance and are presented in Figure 3.

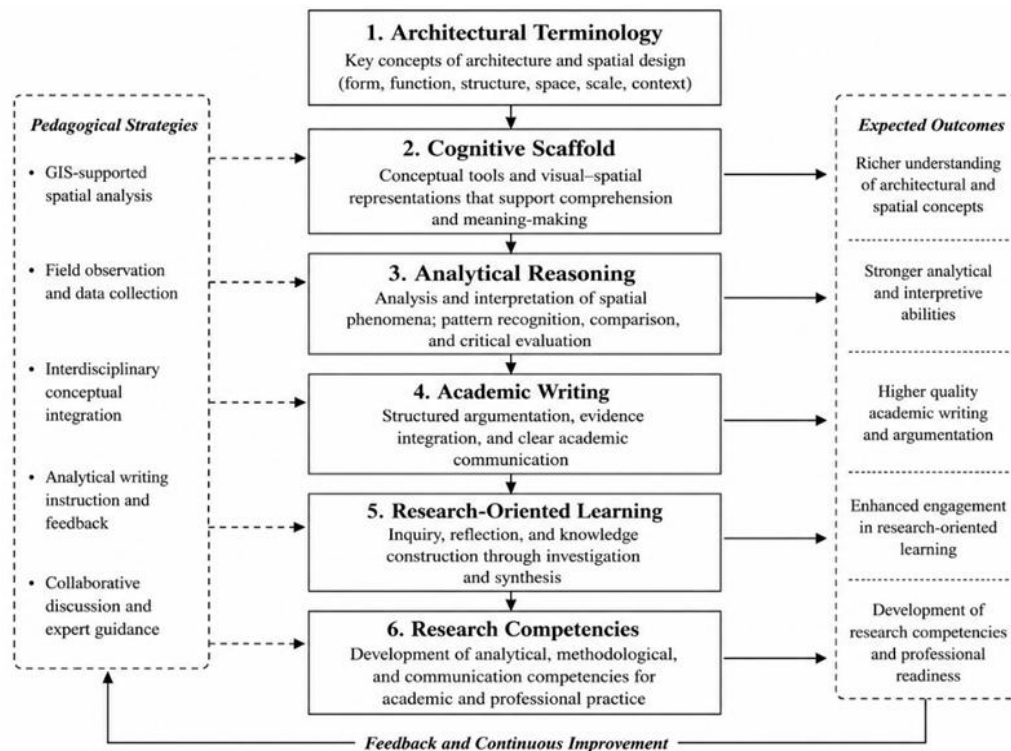


Figure 3. Conceptual framework illustrating the interdisciplinary pedagogical intervention model

4. RESULTS AND DISCUSSION

4.1. Results

A comparison between the texts produced at the initial stage and those completed after the eight-week course revealed a clear transition from the descriptive listing of observable features to the analytical interpretation of spatial processes through interdisciplinary concepts. At the baseline stage, students primarily described visible characteristics of urban environments, such as buildings, green spaces, and transport infrastructure, with limited interpretation of spatial relationships or functional organization. Following the pedagogical intervention, students demonstrated substantial improvements in their academic writing by interpreting the spatial organization of the studied areas, identifying structural elements of the urban fabric, and relating them to functional and social processes. Table 1 presents representative examples demonstrating this transition from descriptive to analytical academic writing following the pedagogical intervention. The examples presented in Table 1 illustrate a clear transition from descriptive observation to analytical interpretation. Rather than serving merely as additional vocabulary, architectural concepts supported more coherent explanation of spatial relationships and urban processes.

Table 1. Changes in students' academic writing before and after the pedagogical intervention

Research stage	Excerpt from student text	Use of interdisciplinary terminology	Expert comment
Before	The area is built up with residential buildings, there is a green zone and a road leading to the school.	×	General description without analytical detail.
After	A square is located in the center of the block, surrounded by buildings.	×	Observation is recorded, but lacks a conceptual framework for analysis.
After	The planning structure of the area is organized around a central axis connecting the transport hub and residential blocks.	✓ (“structure”, “axis”)	Architectural terminology is applied; the text has become more analytical.
After	The composition of the built environment emphasizes the scale of the main street, while green spaces create visual accents on the periphery.	✓ (“composition”, “scale”)	A more complex description emerges, linking form and function.
After	Nodal points coincide with transport stops, which explains the concentration of people and movement flows.	✓ (“nodes”)	Terminology supports the interpretation of social processes.

4.2. Transformation of spatial interpretation and research-oriented thinking

The changes observed in students' written work were also reflected in quantitative indicators. The quantitative analysis confirmed that the pedagogical intervention produced not only qualitative stylistic changes but also measurable improvements in research-oriented analytical competencies. The proportion of texts receiving positive expert evaluations increased from 46% to 82%. The share of assignments incorporating socio-ethical interpretations of the urban environment also rose significantly, from 18% to 59%. Furthermore, there was a substantial expansion in both thematic scope and conceptual repertoire: the proportion of texts that included interdisciplinary terminology increased from 32% to 67%.

These results indicate a clear shift from a predominantly descriptive approach to a more analytical mode of writing as shown in Figure 4. Figure 4 summarizes the changes in the key indicators observed before and after the pedagogical intervention. The dynamics in Figure 4 demonstrate improvements across several dimensions, including analytical reasoning, conceptual interpretation, socio-spatial reflection, and research-oriented writing. The distribution of expert evaluations also demonstrates an overall improvement in students' research competencies. The most significant progress was observed in data handling and the use of visual materials, the accurate application of interdisciplinary terminology, and the structural organization of written texts. At the same time, the criteria related to the depth of interpretation and the construction of argumentation showed improvement but still require further development as shown in Table 2.

Expert evaluations were conducted using a four-point assessment scale (1=low, 2=medium, 3=good, and 4=advanced). For the quantitative analysis, the proportion of student assignments satisfying each predefined evaluation criterion established by the interdisciplinary expert panel was calculated and expressed as percentages before and after the pedagogical intervention. These percentages are presented in Figure 4. Table 2 reports the mean scores assigned by the interdisciplinary expert panel for each evaluation criterion. The expert evaluations presented in Table 2 demonstrate consistent improvements across all assessment criteria. The highest scores were observed for data handling and visual-spatial presentation, whereas comparatively lower scores for interpretation and argumentation indicate that these competencies require further pedagogical development. Overall, the expert assessment corroborates the quantitative findings and confirms the effectiveness of the proposed pedagogical intervention.

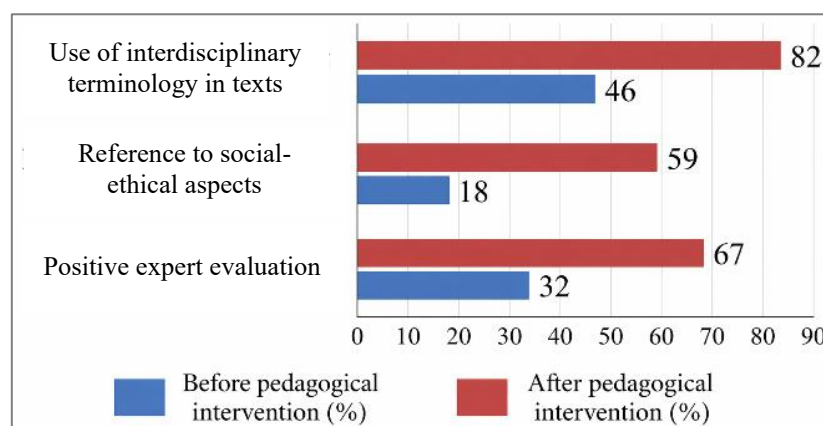


Figure 4. Percentage of student assignments meeting the predefined evaluation criteria before and after the pedagogical intervention

Table 2. Mean expert assessment scores across evaluation criteria (4-point scale)

Evaluation criterion	Mean score	Interpretation
Clarity of research question formulation	3.1	Good
Completeness and accuracy of data handling (maps, diagrams, photographs, and GIS analysis)	3.5	Good-advanced
Depth of interpretation and argumentation	3.2	Good
Correct use of architectural and interdisciplinary terminology	3.0	Good
Quality of written expression and visual presentation	3.3	Good-advanced

4.3. Discussion

The findings of the present study provide empirical evidence that integrating architectural conceptual terminology into academic writing instruction can support the development of research-oriented learning among future geography teachers. The improvements observed in students' writing quality, spatial

interpretation, and expert evaluation suggest that the pedagogical intervention influenced not only the structure of written texts but also the underlying processes of analytical thinking. In particular, the transition from predominantly descriptive writing toward more analytical academic discourse indicates that architectural conceptual vocabulary functioned as a cognitive scaffold, enabling students to organize observations, interpret spatial relationships, and construct more coherent research-based arguments. Rather than serving merely as an additional disciplinary language, concepts such as structure, scale, composition, axis, and node provided students with analytical categories for interpreting complex urban environments.

These findings extend previous research emphasizing the role of academic writing in developing higher-order thinking skills. Hyland [14] argues that academic writing supports disciplinary reasoning and analytical thinking, while Lea and Street [15] conceptualize writing as a socially situated process of knowledge construction. The present study supports these perspectives by demonstrating that analytical writing can be further strengthened when students employ interdisciplinary conceptual frameworks during the interpretation of geographical phenomena. The observed improvements therefore appear to result not only from increased writing practice but also from the availability of conceptual tools that facilitate analytical reasoning.

The findings also reinforce previous studies highlighting the importance of argumentation in academic writing. Wingate [16] emphasizes that effective academic writing requires students to construct and justify arguments rather than simply reproduce information, whereas Lillis and Curry [17] stress the importance of authentic academic genres for developing critical evaluation and analytical reasoning. Consistent with these studies, participants in the present research demonstrated stronger text organization, more coherent argumentation, and greater integration of interdisciplinary concepts after the pedagogical intervention. These changes suggest that architectural terminology supported not only vocabulary development but also the organization of evidence and analytical interpretation. An important contribution of this study concerns the relationship between academic writing and geography teacher education. Previous research has emphasized the educational value of integrating field observations, maps, GIS analyses, and spatial narratives into geography instruction [23].

The present findings extend this body of knowledge by demonstrating that architectural conceptual tools can function as a bridge between empirical observation, GIS-supported spatial analysis, and academic writing. Students increasingly interpreted urban environments not only as physical settings but also as socio-spatial systems characterized by functional relationships, movement patterns, and social interactions. This development is consistent with the theoretical perspectives of Massey [11] and Jacobs [13], who conceptualize urban space as a dynamic product of social relations rather than merely a physical environment. Another important finding concerns the mechanism through which the pedagogical intervention appears to have been effective. The combination of field observation, GIS-supported analysis, interdisciplinary conceptual terminology, and structured academic writing required students to repeatedly connect empirical evidence with conceptual interpretation. This iterative learning process may explain the observed improvements in analytical writing and research-oriented thinking, as students were encouraged to move beyond descriptive observation toward evidence-based explanation and conceptual reasoning. The comparatively lower expert scores for argumentation indicate that developing advanced analytical writing remains a gradual process requiring continued practice and feedback, even when interdisciplinary conceptual tools are incorporated into instruction.

From a practical perspective, the proposed pedagogical model may be implemented in geography teacher education through analytical writing assignments, GIS-supported investigations, interdisciplinary seminars, and field-based research projects. Because the model integrates conceptual analysis with empirical observation, it may also be adapted to other disciplines involving spatial interpretation, urban studies, environmental education, and interdisciplinary research. Overall, the study contributes to the literature in three important ways. First, it extends current understanding of research-oriented learning by demonstrating that architectural conceptual terminology can function as a cognitive scaffold supporting analytical academic writing. Second, it provides methodological evidence for integrating academic writing, GIS-supported spatial analysis, field observation, and interdisciplinary conceptual tools within a unified pedagogical framework. Third, it offers empirical evidence that interdisciplinary conceptual vocabulary can facilitate the transition from descriptive writing to analytical and research-oriented academic discourse among future geography teachers. Collectively, these findings suggest that interdisciplinary conceptual frameworks represent a promising direction for strengthening analytical thinking, spatial reasoning, and research competencies in contemporary teacher education.

4.4. Limitations of the study

The present study has several limitations. First, the sample consisted of 50 master's students from a limited number of higher education institutions in Kazakhstan, which may restrict the generalizability of the findings to other educational contexts. Second, the pedagogical intervention lasted only eight weeks, making

it difficult to assess the long-term sustainability of the observed changes in analytical writing and research competencies. Third, although expert evaluation was employed to enhance the reliability of the assessment process, some degree of subjectivity may remain inherent in qualitative judgment. In addition, the effectiveness of the intervention may have been influenced by students' initial level of academic and analytical preparation. Furthermore, the quantitative findings were based on descriptive indicators rather than inferential statistical analysis. Therefore, the reported percentages should be interpreted as illustrative trends supporting the qualitative findings rather than as evidence of statistically verified effects. Although the quantitative component demonstrated clear patterns of improvement, inferential statistical procedures were not applied because the study was designed as an exploratory mixed-methods investigation emphasizing qualitative transformation rather than statistical generalization. Future studies involving larger samples and repeated measurements may incorporate inferential statistical procedures to further validate the reported findings.

5. CONCLUSION

The findings of this study support the proposed hypothesis that integrating architectural conceptual terminology into academic writing instruction facilitates the transition from descriptive to analytical and research-oriented writing among future geography teachers. Rather than functioning solely as an interdisciplinary vocabulary resource, architectural concepts served as cognitive scaffolds that supported students' analytical reasoning, spatial interpretation, and organization of research-based academic discourse. The study makes several important contributions. Theoretically, it extends current understanding of research-oriented learning by demonstrating that interdisciplinary conceptual systems can strengthen analytical writing through cognitive support for spatial interpretation. Methodologically, it proposes and evaluates an interdisciplinary pedagogical model that integrates academic writing, GIS-supported spatial analysis, field observation, and architectural conceptual terminology within a unified learning framework. Empirically, the findings provide evidence that this approach enhances students' analytical writing, research competencies, and ability to interpret complex spatial phenomena. From a practical perspective, the proposed model may be applied in geography teacher education to strengthen analytical writing, critical thinking, and evidence-based interpretation of spatial data. More broadly, the approach may also be adapted to other disciplines that require the integration of empirical observation, conceptual analysis, and research communication.

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This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
Aigerim Yespenova	✓	✓		✓	✓	✓	✓	✓	✓	✓				
Meruyert Tasbolatova		✓	✓	✓	✓	✓		✓		✓	✓			
Gulnur Berkenova	✓	✓		✓	✓	✓	✓			✓				
Shalkar Turganov	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Viktor Trofimov		✓		✓		✓	✓			✓		✓	✓	
Daulet Sartayev	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

C : **C**onceptualization

M : **M**ethodology

So : **S**oftware

Va : **V**alidation

Fo : **F**ormal analysis

I : **I**nvestigation

R : **R**esources

D : **D**ata Curation

O : Writing - **O**riginal Draft

E : Writing - Review & **E**diting

Vi : **V**isualization

Su : **S**upervision

P : **P**roject administration

Fu : **F**unding acquisition

CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest.

INFORMED CONSENT

We have obtained informed consent from all individuals included in this study.

ETHICAL APPROVAL

The research related to human use has been complied with all the relevant national regulations and institutional policies in accordance with the tenets of the Helsinki Declaration and has been approved by the authors' institutional review board.

DATA AVAILABILITY

Derived data supporting the findings of this study are available from the corresponding author [DS] on request.

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BIOGRAPHIES OF AUTHORS



Aigerim Yespenova    holds a Ph.D. and a master's degree in Art Studies and is a senior lecturer at the Department of History and Theory of Fine Arts, Temirbek Zhurgenov Kazakh National Academy of Arts (Republic of Kazakhstan). She holds a master's degree in Art Studies and has extensive teaching experience in higher education. Her research interests include art theory and history, art education, visual culture, and contemporary approaches to teaching art-related disciplines. She is particularly focused on developing students' research skills and implementing innovative teaching methods. She can be contacted at email: Aespenova@mail.ru.



Meruyert Tasbolatova    is a master's degree holder and senior lecturer at the Department of Publishing, Editorial and Design Art, Al-Farabi Kazakh National University (Republic of Kazakhstan). She has an academic background in publishing and design and experience in higher education teaching. Her research interests include editorial practice, graphic design, visual communication, and modern technologies in publishing. She focuses on developing students' professional competencies and implementing practice-oriented teaching methods. She can be contacted at email: meirkhanova.meirkhanova@mail.ru.



Gulnur Berkenova    is a master's degree holder and senior lecturer at the Department of Publishing, Editorial and Design Art, Al-Farabi Kazakh National University (Republic of Kazakhstan). She holds a master's degree and has teaching experience in design and publishing. Her research interests include graphic design, visual communication, typography, and contemporary approaches to training specialists in the creative industries. She actively works on improving educational methodologies and fostering students' creative potential. She can be contacted at email: neilyneily@mail.ru.



Shalkar Turganov    is a Ph.D. in Education, associate professor, Department of Fine Arts Education, Faculty of Arts, Abai Kazakh National Pedagogical University, Almaty, Republic of Kazakhstan. He is actively involved in the training of future art teachers and in the development of contemporary approaches to art and design education in higher education. His professional and research interests include art education, pedagogy of creativity and visual arts, methods of teaching fine arts and design, the integration of artistic practices into general education, and the development of students' aesthetic culture and creative competencies. He is committed to improving the quality of teacher education and practice-oriented approaches to education. He can be contacted at email: shaizadanovaagulnar@mail.ru.



Viktor Trofimov    is a lecturer and researcher in the field of Architecture and Design at Kokshetau University named after Abay Myrzakhmetov (Republic of Kazakhstan). He has experience in both practical and research activities. His research interests include architectural design, urban environments, spatial analysis, and modern digital technologies in architecture. He is involved in developing educational programs and implementing innovative approaches in professional training. He can be contacted at email: janelgulder@mail.ru.



Daulet Sartayev    is a candidate of Technical Sciences, holds a master's degree, and is a senior lecturer at the School of Construction, International Educational Corporation, Almaty (Republic of Kazakhstan). He has experience in teaching and research in the field of construction and architecture. His research interests include construction technologies, sustainable development, architectural and urban design, and improving the efficiency of urban infrastructure. He actively contributes to the development of practice-oriented education and the implementation of innovative solutions in the educational process. He can be contacted at email: d57280900@gmail.com.