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Development of Scientific Writing and Communication Skills in the Context of Forestry Research

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Abstract: This article is devoted to the investigation and experimental validation of a model for developing scientific writing and communication skills among students majoring in “Forestry”. The study included a scientometric analysis of scientific publications using CiteSpace software, which revealed key areas of research such as argumentation, inquiry-based writing, scientific communication, and metacognitive components. In parallel with the analytical work, a pedagogical experiment was carried out, involving students from both experimental and control groups. The skills were assessed across eight aspects: formulation of the scientific problem, text structuring, source citation, clarity and logical coherence, use of scientific vocabulary, data interpretation, visualization of results, and justification of conclusions. The results demonstrated a significant improvement (on average, 35%) in all components among students in the experimental group, while the control group showed minimal changes. This confirms the effectiveness of the practice-oriented model, integrated into the educational process through research-based tasks. The findings can be applied in the development of educational programs and methods for training forestry specialists.

Keywords: *scientific writing, scientific communication, research competencies, CiteSpace, forestry education, pedagogical experiment.*

Introduction

Relevance and problem statement

In recent years, the term “scientific writing and communication” has been increasingly used in the scientific and educational environment to refer to the set of skills necessary for the effective presentation and dissemination of research results. The development of these skills is becoming particularly important in the context of increasing demands on academic publication activity and the rapid development of the digital environment of scientific interaction.

In the context of the modernization of education and the emphasis on practice-oriented learning, the formation of students’ research competencies is becoming an integral part of staff training. It is especially important to develop students’ ability to clearly and logically present the results of scientific activity, use accepted standards of scientific design, interact with the professional community, and form analytical and reasoned texts. All this contributes not only to improving the quality of specialist training, but also to their integration into the international scientific space.

This work is aimed at studying approaches to the development of scientific writing and communication skills among students involved in research, as well as at identifying relevant areas and scientific

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clusters in this field. The research examines both pedagogical strategies (PBL, PBL, STEM, inquiry-based learning) and digital tools that contribute to the formation of written and oral scientific speech.

Despite the growing interest in the development of scientific writing and communication in general, there is a clear shortage of research on this topic in the context of forestry and the training of forestry specialists. This conclusion is confirmed by the results of a scientometric analysis of publications indexed in the Web of Science database conducted using CiteSpace software (Chen, 2006). The analysis showed that the key terms "scientific writing", "science communication", and "academic writing" are mostly found in publications related to medicine, engineering, general pedagogy, and biology. At the same time, publications related to forestry education or forest science students are presented in fragments and do not form stable scientific clusters.

In this regard, there is a need for a comprehensive analysis of existing pedagogical approaches, as well as the development and implementation of models that contribute to the effective formation of students' scientific communication skills within the framework of real research projects. This study seeks to fill the identified scientific and practical gap, relying both on scientometric analysis using CiteSpace and on experimental testing of a practice-oriented model for the formation of scientific writing among forestry students.

The state of educational programs in the field of forestry in Kazakhstan

Despite the existence of educational programs in the field of forestry in Kazakhstan, the quality of specialist training faces certain challenges. More than 100 forestry specialists graduate in Kazakhstan every year. According to the Ministry of Science and Higher Education of the Republic of Kazakhstan, about 60% of university graduates do not work in their specialty, which indicates that there is no link between personnel training and the economic needs of the region (Zakon.kz, n.d.). Those who get a job in the field of forestry are often not involved in research activities, as this is not provided for by their job responsibilities. A significant part of forestry workers do not have specialized education, which is due to low wages and lack of social support, which reduce the attractiveness of work in this industry (Ishekenova, 2024).

According to the data of the National Chamber of Entrepreneurs of the Republic of Kazakhstan "Atameken", educational programs in the direction of B079 "Forestry" are implemented in 8 universities located in 7 cities of the country (Atameken, n.d.). However, such programs are mainly focused on theoretical disciplines, and practical training is limited to short periods of academic and industrial practice.

Foreign experience in training specialists

In developed countries, educational programs in the field of forestry are based on the close integration of scientific research, practice and innovation. Students are involved in project activities, ecosystem monitoring, laboratory work, and modeling of natural processes. Special attention is paid to critical thinking, interdisciplinary approach and academic writing as part of the educational paradigm. This approach allows future specialists to be prepared for the challenges of sustainable natural resource management (University of British Columbia, 2024).

Approaches to the formation of scientific writing and communication

The development of scientific writing and communication skills is a prerequisite for the professional growth of future scientists and specialists. Effective scientific communication promotes integration into the academic community, participation in international projects and the promotion of scientific results in society (Brownell, Price, and Steinman, 2013; Faber et al., 2024).

Structured educational programs play an important role in the formation of these competencies. One example is the Scientific Communication program, which is based on the principles of high-level thinking training (HOLS) and supports the development of clear presentation and argumentation skills (Scherz, Spektor-Levy, and Eylon, 2005; Suparman and Darmawan, 2022; Juarez and Kenet, 2018). Academic writing courses are increasingly being introduced in universities, where students learn to formulate hypotheses, structure articles, and prepare scientific reports. Additionally, resources such as The Craft of Scientific Communication provide practical tools for improving academic writing skills (Harmon and Gross, n.d.).

The inclusion of such courses in undergraduate and graduate programs contributes to improving the quality of education, particularly in the context of globalizing scientific knowledge. Programs at institutions like Duke University and Stanford effectively integrate theoretical foundations with practical assignments and publication training (Willems-Jones et al., 2019; Jude, 2017).

Integration of students into real scientific research

The integration of students into real scientific research is a transformative educational approach that promotes deeper learning and engagement in science (Dounas-Frazer, Ríos, and Lewandowski, 2019). Programs such as Students as Researchers (STARs) enable students to conduct proactive research in both school and university settings, fostering responsibility and sustained interest in scientific work (Silverman, 2012).

Authentic forms of research—such as research internships, student-teacher-scientist partnerships, field-based practices, and participation in citizen science—facilitate student comprehension of scientific methodology, critical thinking, and data analysis skills (Okhotina and Belonogova, 2021; Edwards et al., 2007; Bailenson, 2013; Strogetskaya and Betiger, 2024; Anop and Petruk, 2014; Ovsepyan, 2019).

STEM-based strategies, integration of project activities, and experiential learning approaches further enhance student engagement and prepare them for professional scientific practice (Kanematsu and Barry, 2016; Jackson, 2013).

Using CiteSpace to analyze scientific clusters

CiteSpace software, a tool for citation analysis and visualization of scientific information, was used to identify directions and trends in the research field. This tool enables the tracking of key publications forming scientific clusters, identification of highly cited authors, and construction of co-authorship networks (Chen, 2006; Chen, 2020; Chen et al., 2010).

The conducted scientometric analysis showed that the most active research on the topic of scientific communication is concentrated in the fields of medicine, pedagogy, and engineering. Topics related to the training of forestry students are poorly represented and require further development in both research and applied aspects.

Materials and Methods

A. Data sources

For the scientometric analysis, data from the Web of Science Core Collection (WOSCC) database, an authoritative international source of scientific information, including peer-reviewed publications, was used. The sample included publications from the Science Citation Index Expanded (SCI-EXPANDED) and Emerging Sources Citation Index (ESCI), as they cover a wide range of disciplines, including education, ecology, forestry, and interdisciplinary research.

The search for publications was conducted in March 2025 through the advanced Web of Science interface. To improve the accuracy of the sample, the logical operators AND, OR, as well as a phrasal search in quotation marks "..." were used. Queries were applied to the following fields of publications: Title, Abstract, and Author Keywords. This made it possible to identify works that address the topics of scientific writing and communication in the context of forestry education.

Examples of search queries:

1. "scientific writing" OR "science communication" AND "forestry education";
2. ("academic writing" OR "research skills") AND ("forestry educatio" OR "environmental education").

The following terms were used as keywords:

scientific writing, science communication, academic writing, research skills, student engagement, forestry education, environmental education, scientific literature, publication ethics, STEM communication.

The analysis period covers 2021-2024. The data for 2025 were excluded from the analysis because they were not yet fully available in the Web of Science database at the time of the analysis.

Criteria for inclusion of publications:

- the language of publication is English;
- type of publications - original articles, reviews, editorial materials, conference abstracts, letters;
- full-text accessibility and relevance to the research topic.

As a result of applying these criteria, the analysis included 77 publications corresponding to the intersection of scientific writing and educational practices in the field of forestry. All selected publications were exported to a CiteSpace-compatible format for further analysis of scientific clusters, terms, author networks, and time trends.

B. Analysis tool

To analyze the scientific literature, *CiteSpace* software was used, which is specifically designed to visualize and analyze structural relationships between scientific publications (Chen, 2006). *CiteSpace* enables the identification of key clusters, influential authors, dominant topics, and emerging trends through co-citation and temporal analysis.

The following functions were used in the research:

- clusterization of scientific publications;
- analysis of citation spikes;
- assessment of the centrality of nodes in the network (by degree and by intermediacy);
- calculation of Sigma, a significance indicator that combines citation and centrality;
- building thematic and author networks.
- Analysis Parameters:
- type of analysis: co-citation;
- the level of analysis: document – author – keywords;
- intervals: 1 year each;
- cluster labeling method: LLC, LSI, MI;
- minimum citation threshold: 3;
- visualization is saved in PNG format.

C. Methodological justification

The application of the scientometric approach with the help of CiteSpace has allowed:

- to systematize existing publications;
- identify key clusters and missing areas;
- to assess the relevance and scientific richness of the topic;
- to substantiate the need for further research in the context of the formation of scientific research competencies among students of forestry.

Table 1. *Search queries*

Source	Web of Science Core Collection
Citation databases	SCI-EXPANDED, ESCI
Time coverage	2021 – 2025
Language	English
Document types	Article
Search stages	Search query
#1	TS = (“scientific writing” OR “academic writing” OR “science communication” OR “research writing” OR “scientific literacy” OR “publication literacy” OR “research communication” OR “writing skills” OR “presentation skills” OR “academic discourse” OR “research competence”)
#2	TS = (“forestry education” OR “forest science” OR “forest research” OR “forestry students” OR “environmental education” OR “natural resources education” OR “forest ecology” OR “sustainable forestry”)
#3	#1 AND #2

Note: #1 - the stage of literature search on scientific writing and communication;
#2 - the stage of searching for literature related to forestry and research;
#3 - a combined query to identify relevant publications at the intersection of the two directions.

Statistical analysis

The data were obtained from the Web of Science (WOS) database in the "Full Record" and "Cited References" formats in March 2025. The final sample consisted of 77 publications, which were carefully checked for duplicates, preprocessed, and then imported into CiteSpace software—an advanced platform for documentary data mining and visualization developed by the team of Chaomei Chen (Chen, 2006).

The CiteSpace program combines the methods of social network analysis and cluster analysis, which provides the construction of structural and thematic maps of scientific publications. The analysis examined fundamental knowledge, limitations in research, key topics, the evolution of trends, as well as networks of scientific collaboration, networks of co-authorship and citation.

To ensure reproducibility and reliability of the analysis, the network reduction and filtering parameters used (in particular, the Pathfinder method) were fixed. The CiteSpace 5.8 R1 version was used in the work, which allowed for consistent and reliable processing of the collected data.

Research Methodology

Based on the analysis of scientific literature and modern pedagogical approaches, a practice-oriented model for the formation of students' research competencies in the field of "Forestry" has been developed and tested. The model combines theoretical and practical components and is aimed at developing the skills of scientific writing, communication and independent research activities.

The model includes the following stages: organizational, theoretical, practical, final and effectiveness assessment stages. During the implementation process, the methods of field research, project work, scientific writing, as well as methods of self-reflection and expert assessment were used.

The aim of the research is to substantiate and implement a model that promotes the formation of research competencies among students in the framework of educational and scientific activities.

Objectives:

- to analyze methodological approaches to the formation of research competencies;
- to develop a step-by-step structural model;
- to integrate the model into the educational process in the field of "Forestry";
- to conduct a pedagogical experiment and evaluate its effectiveness.

Table 2. *Description of the model*

№	Stage	Contents
1	Organizational	Formation of control and experimental groups
2	Theoretical	Seminars on scientific writing, data analysis and preparation of scientific texts
3	Practical	Field trips (core collection, analysis of annual rings, visual inspection of trees)
4	Final	Conducting a scientific seminar with a presentation of the results, discussion
5	Effectiveness assessment	Scales of assessment of motivation, cognitive, procedural, practical and reflexive components are used (see below)

To strengthen the academic part, a new discipline was introduced, the work curriculum "Organization and planning of research work", in which students mastered the tools of scientific writing, methods of publication activity and the basics of research ethics.

Diagnostic and assessment methods

To assess the formation of students' research competencies, a set of diagnostic methods was used, covering motivational, cognitive, procedural, practical and reflexive components.

1. Motivational component.

To measure the level of educational and research motivation, A. Mehrabian's modified methodology was used, adapted to the educational context. It allowed us to determine the students' internal attitude towards achieving academic and scientific goals.

2. Cognitive component

The assessment of the level of intellectual development and the ability to think scientifically was carried out using a mental development test (intellectual diagnostics) aimed at identifying logical, analytical and abstract thinking.

3. Procedural and practical components

To diagnose the ability to plan and perform research activities, the following methods were used:

- expert assessment of research and project work (abstracts, reports, posters);
- results of students' participation in competitions and scientific conferences;
- monitoring the implementation of practical tasks;
- analysis of laboratory and field work results;
- special professionally oriented tests aimed at testing applied research skills.

4. Reflexive component

The level of awareness of one's own research path and self-assessment of skills was monitored using the S.A. Budassi self-assessment methodology, which includes scales of reflection and professional orientation.

Experiment

The pedagogical experiment was conducted within the framework of the scientific project AP25794101 "Study of the influence of technogenic factors and climate change on tree species growing in industrial regions of Eastern Kazakhstan using the dendroindication method" (2025–2027), implemented under the grant funding program "Zhas Galym" of the Ministry of Science and Higher Education of the Republic of Kazakhstan. The project is coordinated by postdoctoral researcher K.B. Alipina and covers both forestry and environmental aspects of sustainable nature management. The students involved in the project had the opportunity to participate in real scientific research, which ensured the practical application of the model.

The participants of the experiment

129 students participated in the experiment. The Experimental group (EG) included students involved in research and field activities. The Control group (CG) was trained according to the traditional program. The details are provided in table 3.

Table 3. *Number of students in the Experimental and Control groups*

University	Course	Experimental		Control	
		Male students	Female students	Male students	Female students
S. Amanzholov East Kazakhstan University	2	5	18	5	17
S. Amanzholov East Kazakhstan University	3	3	19	4	17
D. Serikbayev East Kazakhstan Technical University	2	9	5	11	4
D. Serikbayev East Kazakhstan Technical University	3	4	2	3	3
Total		65		64	

Stages of the pedagogical experiment

1. Ascertaining stage: determining the initial level of research competencies;
2. Formative stage: model implementation, participation in field work, seminars on scientific writing, project assignments;
3. Control stage: final diagnostics, project protection and analysis of the dynamics of competence development.

Criteria for assessing effectiveness

- motivational – interest in scientific activity;
- cognitive – knowledge and understanding of the scientific process;
- procedural – the ability to perform the stages of research;
- practical – the ability to apply research methods;
- reflexive – the ability to introspect and evaluate results.

Methods of processing the results: Student's t-test, correlation analysis (the relationship between activity level and diagnostic results).

Results and Discussion

A. Geographical distribution of publication activity in the field of scientific writing and communication

As part of this study, a scientometric analysis of publications indexed in the Web of Science Core Collection (WOSCC) database was conducted using CiteSpace software (version 6.1.R6). The sample includes publications for the period from 2021 to March 2025, corresponding to the topics "scientific writing", "academic writing", "science communication", "research skills", "forestry education" and "environmental education".

The key countries were identified based on the affiliations of the authors of the publications selected by an extended search query in the fields Title, Abstract and Author Keywords. Each country was ranked by the number of publications and the number of citations. The analytical sample included 77 publications that meet the search criteria. CiteSpace allowed us to identify the countries whose researchers have made the greatest contribution to the development of the topic, and automatically distributed them into thematic clusters.

The study included publications indexed in the Science Citation Index Expanded (SCI-EXPANDED) and Social Sciences Citation Index (SSCI) databases included in the Web of Science Core Collection (WOSCC). The sample includes original scientific articles, review articles, editorial materials, conference materials, and scientific notes. The Scopus database was not used in the analysis. When calculating bibliometric indicators, the citation of individual publications was taken into account, rather than journals as a whole.

Spain has demonstrated sustained activity (4 citations, cluster № 6), especially in the development of written scientific communication. Australia (3 citations, cluster № 2), Mexico and Germany (2 citations each) also demonstrated involvement in the topic related to student participation in scientific publications and educational projects. The participation of France, South Africa, Ukraine and Switzerland is interesting, each of which appears in the network as an important participant in individual clusters.

In terms of centrality, Switzerland showed the highest value (0.14, cluster № 0), which indicates its role as a link between various research topics and areas. This is followed by Germany (0.06) and Mexico (0.05), which also play an important role in the formation and dissemination of scientific information.

Index of Sigma - reflecting a combination of citation bursts and centrality - amounted to 1.00 in all the leading countries, including Switzerland, Germany, USA, Russia, China, Spain, Australia and others. This highlights the equal importance of their contributions to the subject under study.

Nevertheless, when analyzing the content of the publications, it was found that not a single study has been identified that is directly related to the development of scientific writing and communication skills specifically in the context of forestry. This indicates a clear gap in international research practice and underlines the relevance of the tasks set in this work.

Thus, the results obtained reflect global involvement in the development of academic literacy and scientific writing, but at the same time indicate the need to form a new direction focused on training specialists in the field of forestry with a high level of research and communication competencies.

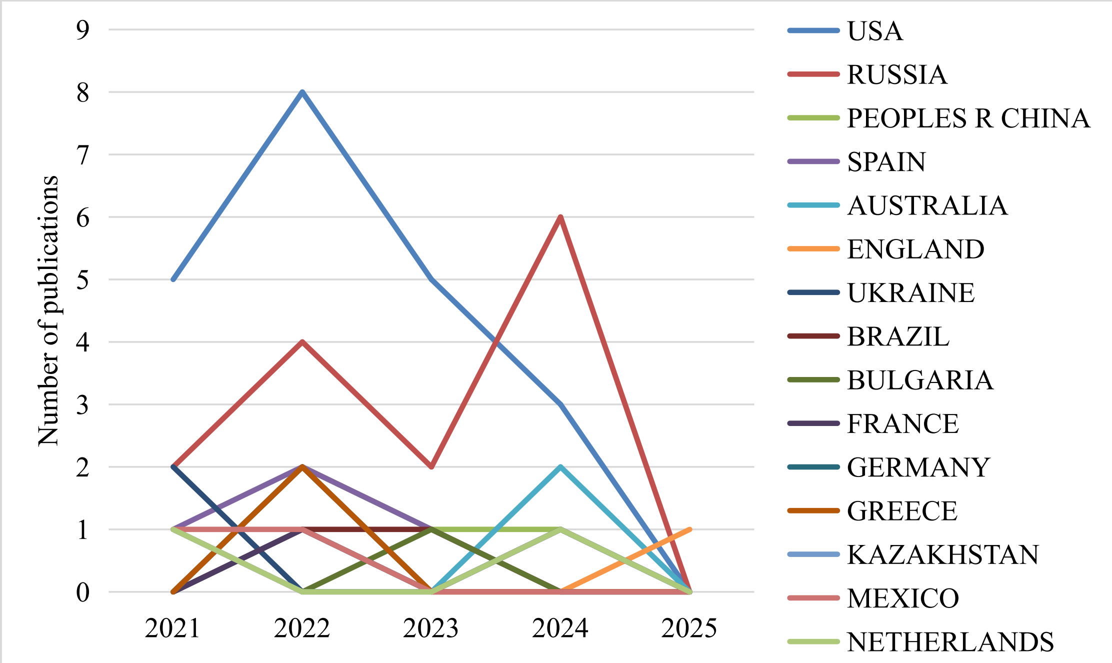

Figure 1. *Analysis of the cluster of distribution countries (Atameken, n.d.)*

B. Thematic areas related to scientific writing and communication

1) Main research directions

Figure 2 is a graph of the common occurrence of keywords, in which each node corresponds to a specific term related to scientific writing, academic and research training. The size of the nodes reflects the importance of the keywords, and the links between them indicate the frequency of their sharing in scientific publications. Cluster analysis technology using the Pathfinder pruning method was used to visualize the structure of thematic areas.

Based on the data analysis, six main clusters were identified, reflecting the dominant trends in the scientific literature. The largest cluster (cluster #0) covers keywords such as “scientific writing”, “global research”, “higher education” and “students”, which emphasizes active attention to the issues of preparing students for research activities in the context of global change. It includes 15 publications and is characterized by a high silhouette coefficient (1.0), which indicates its high coherence.

The second largest cluster (#1) is associated with the topics “scientific communication” and “plant science”, reflecting an interest in the development of scientific communication in the context of crop production and, in our case, can be interpreted as related to environmental education and popularization of climate change and forest conditions.

Cluster #2 is associated with supporting the development of students’ research skills, especially in biomedical sciences, which resonates with the environmental aspects of adaptation of living organisms to external influences, including technogenic factors.

Cluster #6 also deserves attention, which includes such important aspects as “critical thinking”, “communication skill” and “argument driven inquiry” - the skills necessary to analyze the effects of climate and anthropogenic changes on tree ecosystems, especially in the process of preparing research students.

The cluster analysis data indicate that topics related to scientific writing, critical thinking, student research, and forestry are actively developing and are of high importance in the context of modern scientific research. This underlines the importance of developing an interdisciplinary approach in teaching the integration of methods of analyzing climatic and technogenic factors into the educational process, especially in the framework of training specialists in the field of forestry.

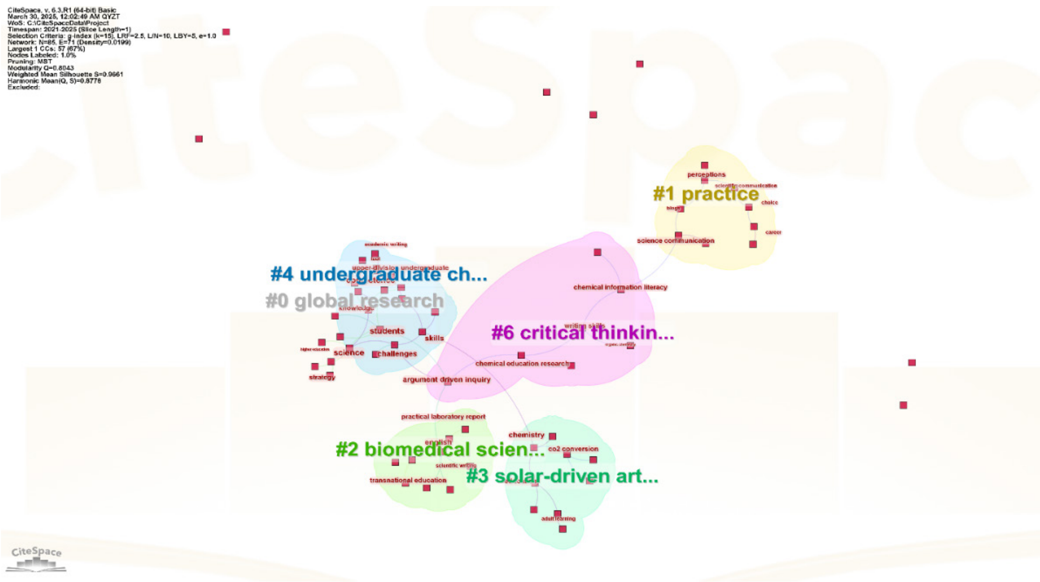

Figure 2. *Keyword network based on articles published between 2021 and 2025 (Chen et al., 2010)*

C. The intellectual structure of scientific writing and communication

To visualize the intellectual structure of the area under study, CiteSpace software was used, based on the methods of analyzing the citation and co-authorship of scientific literature indexed in the Web of Science Core Collection database for the period 2021-2025.

Despite the stated time interval, the analysis covers only publications for 2021-2024. This is due to the fact that at the time of the search (March 2025), publications for 2025 that meet the selection criteria were not fully presented in the WOSCC database. Thus, the results reflect the intellectual picture of the research area as of the end of 2024, which should be taken into account when interpreting the obtained clusters and trends.

Each time “slice” was based on the publications of the corresponding year. The network was cleaned using the Pathfinder algorithm, which reduced information noise and increased visualization clarity. The resulting map demonstrates the evolution of this field and identifies key thematic areas and research fronts.

Each node on the graph represents a cited article, and the lines between them represent cases of their joint citation. The size of the nodes corresponds to the frequency of citations, and the purple ring indicates a high degree of betweenness centrality, which indicates the importance of the publication as a bridge between different topics. The red rings indicate “citation bursts”, i.e. periods of active attention to the source.

As a result of the analysis, 6 main clusters were identified, each of which represents a separate area in the field of scientific writing and communication. The clusters were labeled using the methods LLR (log likelihood ratio), LSI (latent semantic indexing) and MI (mutual information). Cluster silhouette values range from 0.883 to 1.0, which indicates a high consistency of themes within each cluster. Table 4 provides a summary of the selected clusters.

Table 4. *Main clusters of co-cited sources*

№ clusters	Size	Contour	Label (LSI)	Label (LLR)	Label (MI)	Year
1	9	0.90	L1 and L2 writing learning technologies	Argumentative structuring	Argumentative structuring	2021
2	9	0.974	Systematic review	Research-based writing learning	Courses	2022
3	8	0.982	Argumentation research	Science	Foreign language	2023
5	7	0.899	Constructive approach	Argumentation-based learning	Argumentative structuring	2022
6	7	1.00	Laboratory classes in chemistry	Chemistry laboratories for students	Teaching	2021
7	7	0.883	Digital literacy and metacognition	Metacognitive component	Metacognitive component	2024

Figure 3 shows a cluster map of co-authorship of scientific literature on the topic of developing scientific writing and communication skills. Each cluster displays interconnected publications grouped by thematic proximity. The color difference indicates the difference in research directions, and the cluster sizes reflect the amount of scientific activity in the corresponding area.

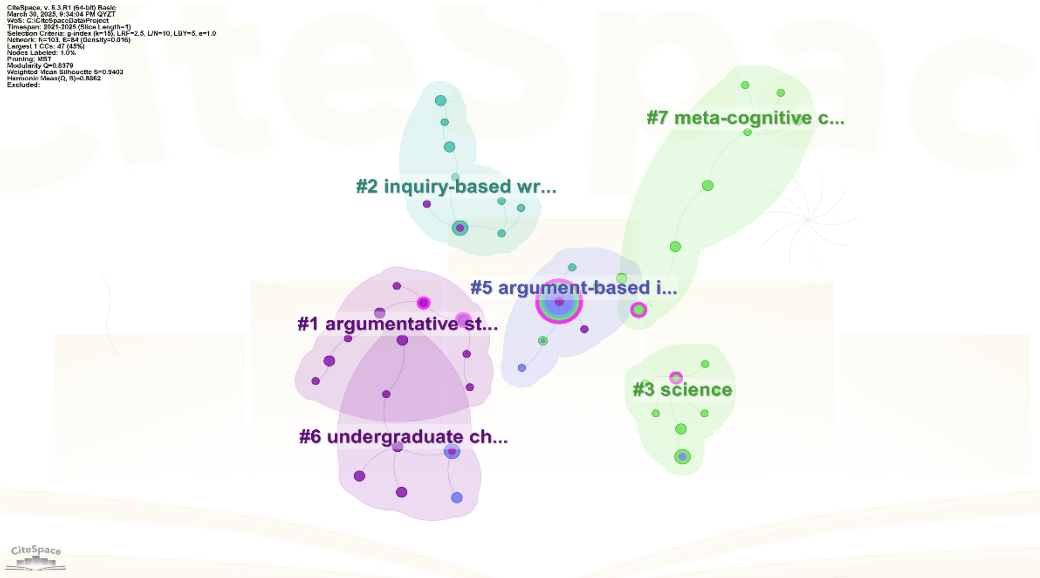

Figure 3. *Cluster map of co-authorship of scientific literature in the field of scientific writing and communication (Chen et al., 2010)*

Most of the clusters shown in Figure 4 are homogeneous, which is confirmed by the high contour values. The cluster labels were assigned based on keywords extracted from the titles of the cited articles. Cluster № 1 is devoted to argumentative structuring and reflects students' interest in metacognitive aspects and the formation of rhetorical writing skills. Cluster № 2 includes systematic reviews on the issues of teaching writing based on a research approach.

Cluster № 3 focuses on the use of scientific argumentation in writing, especially in the context of interdisciplinary and multilingual education. Cluster № 5 focuses on instructional strategies and the use of models of learning through argumentation. Clusters № 6 and № 7 are related to laboratory practice and the development of digital literacy and metacognitive abilities of students in the process of learning writing, especially in teaching foreign languages.

Thus, the identified clusters form the intellectual basis of the modern trend in the research of scientific writing and communication, allowing us to trace its evolution, main directions and development prospects.

D. Analysis of betweenness centrality

Betweenness centrality is a measure of the importance of a node in a network, reflecting the number of shortest paths passing through a given node. Nodes with high centrality play the role of connecting elements between different parts of the network and facilitate the transfer of information between clusters (Chen, 2006)

In this research using CiteSpace, eight key nodes with the highest centrality have been identified, which play a structurally important role in cluster unification. These nodes are critically necessary for linking individual clusters and forming an integrated intellectual structure in the field of scientific writing and communication development.

As shown in Figure 4, the highest value of intermediary centrality belongs to the node "argument driven inquiry" (0.38), which is part of cluster № 2, which is dedicated to teaching writing based on a research approach. This is followed by ZOHAR A (0.25) from cluster № 7, and HYLAND K (0.23), also in cluster № 2. Nodes from clusters № 3 (for example, "students" and "science") and № 4 ("scientific writing" and "practical laboratory report") are of particular interest, since they perform a connecting function between educational practice, cognitive strategies and scientific communication.

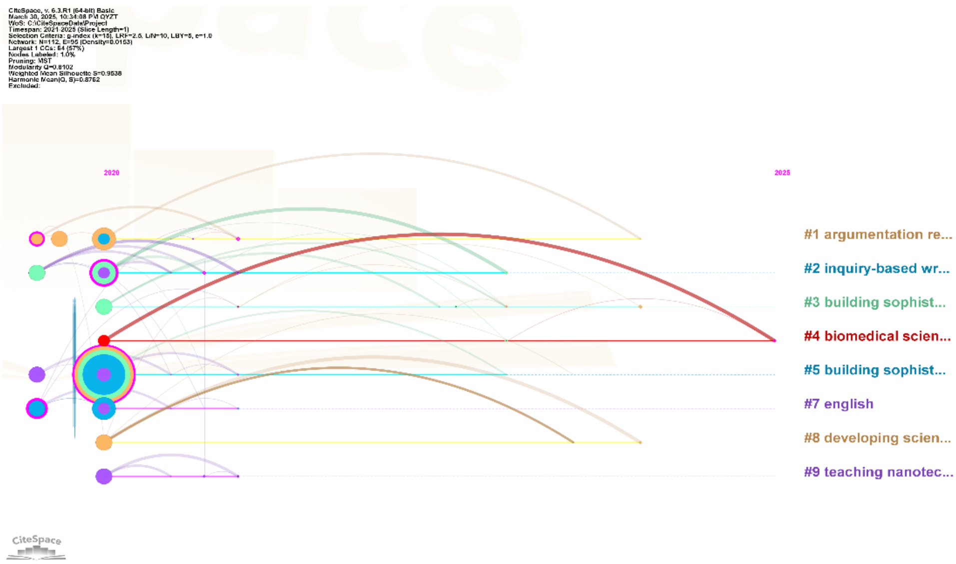

Figure 4. *Chronology of co-citation clusters (Chen et al., 2010)*

Thus, nodes with high centrality demonstrate not only quantitative significance (citation frequency), but also qualitative significance in the context of their ability to connect key research areas in the field of academic writing, argumentation, and interdisciplinary learning.

E. The results of the pedagogical experiment

As part of the pedagogical experiment, the effectiveness of the proposed model for the formation of research competencies among students studying in the field of "Forestry" was evaluated. The results of the control stage demonstrated a statistically significant increase in the level of formation of target competencies among the participants of the experimental group. In particular, more than 35% of EG students demonstrated stable skills in scientific writing, basic data analysis, and the application of field and laboratory research methods.

The total sample of the research consisted of 129 2nd-3rd year undergraduate students from two higher education institutions in East Kazakhstan:

- S. Amanzholov East Kazakhstan University, Department of Biology, Higher School of IT and Natural Sciences;
- D. Serikbayev East Kazakhstan Technical University, Higher School of Earth Sciences.

Two groups were formed:

- Experimental group (EG) - 65 students (21 boys, 44 girls) who participated in research activities;
- Control group (CG) - 64 students (23 boys, 41 girls) studying according to the standard program without additional research practice.

The pedagogical experiment was conducted in 2025 as part of the implementation of the scientific project AP25794101 to study the influence of technogenic factors and climate change on tree species growing in the industrial regions of Eastern Kazakhstan using the dendroindication method, funded by the Ministry of Science and Higher Education of the Republic of Kazakhstan under the grant program "Zhas Galym" (2025-2027). The project was coordinated by postdoctoral researcher K.B. Alipina. and it provided for the active involvement of students in the stages of field and laboratory research.

The students of the experimental group were trained in the discipline "Organization and planning of research work", which includes:

- fundamentals of scientific writing and publication compilation;
- research design and planning;
- ethical aspects of scientific activity;
- participation in field trips, core collection, analysis of annual rings.

The assessment of the formation of scientific research competencies among students was carried out in three stages: ascertaining, forming and controlling, in accordance with the developed model. The diagnosis included five components previously described in the methodology section: motivational, cognitive, procedural, practical, and reflexive. At the same time, the main attention at the control stage was paid to the dynamics of the growth of indicators in the experimental group compared with the control group. The data obtained indicate significant differences in all components, especially in practical and motivational ones, which indicates the effectiveness of the implemented model.

The statistical analysis was performed manually based on the calculation of the Student's t-test and the Pearson correlation coefficient using formulas in spreadsheets. Graphs and tables built in Microsoft Excel were used to visualize the results.

The assessment of the development of scientific writing and communication skills was carried out in a number of key aspects reflecting the structure and content of the scientific text. The following components were selected as evaluation criteria:

1. Formulation of a scientific problem - the ability to clearly and reasonably present the problem under study;
2. Text structuring - logical and consistent design of scientific work sections;
3. Citation of sources - the correctness of the use of scientific sources and the observance of academic integrity;
4. Clarity and logic of presentation - consistency of argumentation and clarity of presentation of the material;
5. Use of scientific vocabulary - proficiency in terminology and style of academic writing;
6. Data interpretation - the ability to analyze the results obtained and draw informed conclusions;
7. Visualization of results - the ability to present information in the form of graphs, tables, and other visual forms;
8. Justification of conclusions - the logical conclusion of the study based on the data obtained.

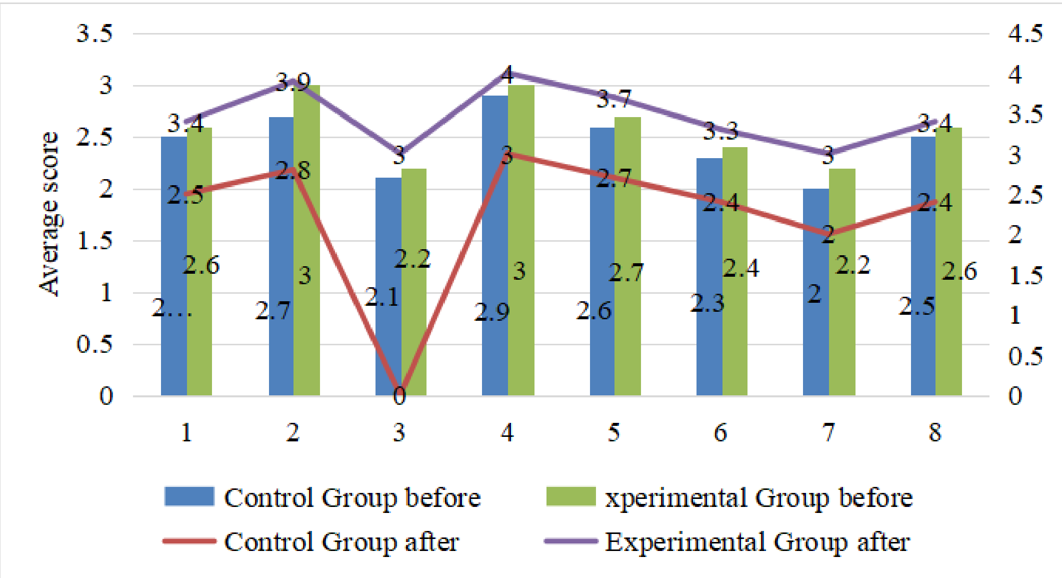

Figure 5. *Comparison of scientific writing and data analysis skills development*

In the control group, progress in all aspects was insignificant or minimal - from 0% to 4%, which indicates the absence of targeted pedagogical influence.

In the experimental group, there is a steady increase in education in all aspects from 35% to 37%, which reflects the effectiveness of the implemented model of scientific writing and communication based on research activities.

The greatest increase was recorded in terms of indicators:

- citation of sources;
- interpretation of data;
- formulation of a scientific problem.

This suggests that the integration of research activities into the learning process significantly enhances the academic and communicative competencies of students.

The effectiveness of the pedagogical experiment in each aspect of scientific writing and communication according to formulas:

$$Growth\ index = \left(\frac{X_{до} - X_{после}}{X_{до}}\right) * 100\%$$

$$Growth\ index_{avg.} = \left(\frac{3.4625 - 2.7125}{2.7125}\right) * 100\% = 27{,}65\%$$

The participants of the experimental group improved their scientific writing and communication skills by 27.65% compared to the baseline level. This indicates the high effectiveness of the applied teaching methodology, as target competencies have been strengthened by almost a third.

Net efficiency = (Growth in EG) - (Growth in CG)

Net efficiency = 0.75 - (2.475 - 2.575) = 0.75 - (-0.1) = 0.85

The net increase in results in the experimental group exceeded the control group by 0.85 points, which confirms that the positive changes were caused precisely by the experimental intervention, and not by external factors.

$$C_E = \frac{X_{EG\ after} - X_{EG\ before}}{X_{CG\ after} - X_{CG\ before}}$$

$$C_E = \frac{3.4625-2.7125}{2.7125-2.7125} = \frac{0{,}75}{-0{,}1} - 7{,}5$$

Although the coefficient turned out to be numerically negative, this is due to the fact that there was a deterioration in the results in the control group. In such cases, the negative value of E is interpreted as a strong positive effectiveness of the experiment, since the EG improved the results, and the CG, on the contrary, decreased.

The pedagogical experiment turned out to be successful and effective: the growth of scientific writing and communication skills in the experimental group was significant, the improvements were confirmed by objective calculations, and the dynamics of the control group excluded external influence.

These findings align with international research emphasizing the value of integrating scientific writing with ecological and project-based learning. For example, Septriana, Suwandi, and Sumarwati (2025) demonstrated that project-based learning combined with ecological literacy significantly improves students' scientific writing competencies.

Similarly, Hajdarpasic, Brew, and Popenici (2015) stressed that involving students in authentic research activities strengthens their academic engagement and scientific reasoning. This reinforces the observed gains in our experimental group, particularly in motivation and the formulation of scientific arguments.

Moreover, Zimmerman et al. (2006) found that visual and animated communication tools enhance public understanding of forestry practices, supporting our use of graphs and visual data presentations in student projects.

Finally, the effectiveness of applied and community-oriented forestry education was confirmed in the work of Parajuli et al. (2020), where practical engagement strategies helped participants better understand sustainable forest-based economic models. These international parallels confirm the relevance and adaptability of the proposed model in forestry education contexts.

Conclusion

This study comprehensively examined the formation of scientific writing and communication skills among forestry students through a dual methodology: (1) a scientometric analysis of international publication trends, and (2) an experimental application of a pedagogical model within two universities in Kazakhstan. The bibliometric analysis using CiteSpace software identified key thematic clusters and geographical activity areas in research on academic communication, emphasizing a gap in forestry-related contexts. Despite global engagement with scientific writing and STEM pedagogy, forestry education remains underrepresented in this domain, indicating the novelty and necessity of the current work.

To address this gap, a practice-oriented model integrating scientific writing, field research, and interdisciplinary learning was developed and piloted. The pedagogical experiment demonstrated statistically significant improvements in students' competencies, especially in the formulation of scientific problems, data interpretation, and academic writing conventions. The average improvement of 27.65% and a net effectiveness of 0.85 points confirm the success of the intervention.

These findings contribute to the growing body of literature on research-based learning and underscore the need for curriculum modernization in forestry education, especially in Kazakhstan. Future research should explore longitudinal impacts of such pedagogical approaches, as well as their integration into broader environmental education frameworks. Additionally, international collaborations could enhance the scalability and contextual adaptability of the model.

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Within the framework of this project, students participated in practice-oriented research, which created favorable conditions for the development of their scientific writing and academic communication in a real research context.

Conflict of interests

The authors declare no conflict of interest.

Author Contributions

Conceptualization, K. Alipina; methodology, K. Alipina; supervision, K. Alipina; writing—original draft preparation, K. Alipina; project administration, Zh. Tergenbayeva; writing—review and editing, Zh. Tergenbayeva and Z. Dautova; validation, Zh. Kabatayeva; data curation, K. Alipina and Zh. Kabatayeva; formal analysis, Z. Bolatbekovna; visualization, Z. Bolatbekovna; investigation, N. Amangeldi; resources, N. Amangeldi; proofreading and English language editing, Z. Dautova. All authors have read and agreed to the published version of the manuscript.

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