

OPEN ACCESS

EDITED BY

Joseline Santos,
Bulacan State University, Philippines

REVIEWED BY

Dicky Arinta,
State University of Malang, Indonesia
Natalia Posada-Pérez,
Institución Universitaria Colegio Mayor
de Antioquia, Colombia

*CORRESPONDENCE

Zhanbolat Nurmagambetuly
✉ zhanbo_87@mail.ru

RECEIVED 15 December 2025

REVISED 16 February 2026

ACCEPTED 23 February 2026

PUBLISHED 13 March 2026

CORRECTED 17 April 2026

CITATION

Laiskhanov S, Nurmagambetuly Z,
Kaimuldinova K, Aliaskarov D,
Abikbaev E and Bopiyeva A (2026)
Scientific and methodological
foundations for integrating remote
sensing (RS) data into school geography.
Front. Educ. 11:1768464.
doi: 10.3389/feduc.2026.1768464

COPYRIGHT

© 2026 Laiskhanov, Nurmagambetuly,
Kaimuldinova, Aliaskarov, Abikbaev and
Bopiyeva. This is an open-access article
distributed under the terms of the
[Creative Commons Attribution License](#)
(CC BY). The use, distribution or
reproduction in other forums is
permitted, provided the original
author(s) and the copyright owner(s) are
credited and that the original publication
in this journal is cited, in accordance
with accepted academic practice. No
use, distribution or reproduction is
permitted which does not comply with
these terms.

Scientific and methodological foundations for integrating remote sensing (RS) data into school geography

Shakhislam Laiskhanov^{1,2}, Zhanbolat Nurmagambetuly^{2*},
Kulyash Kaimuldinova², Duman Aliaskarov², Erzhan Abikbaev²
and Aitolkyn Bopiyeva³

¹Department of Science and Innovations, International Educational Corporation, Kazakh Leading Academy of Architecture and Civil Engineering, Almaty, Kazakhstan, ²Department of Geography and Ecology, Abai Kazakh National Pedagogical University, Almaty, Kazakhstan, ³Institute of Natural Sciences, Kazakh National Women's Teacher Training University, Almaty, Kazakhstan

In the era of digital transformation, the application of remote sensing (RS) data in geography education and its effective integration into the teaching and learning process has become one of the pressing educational challenges, particularly in fostering students' spatial thinking competencies. The purpose of the study is to identify the possibilities of incorporating RS data into school geography, to develop an effective teaching methodology based on its application, and to test it in practice. The research employed a review of international publications, surveys, correlation and comparative statistical analysis, modeling, analysis of regulatory documents, and pedagogical experimentation. The survey involved 124 geography teachers from different regions of Kazakhstan, while the experimental study included 52 eleventh-grade students from one secondary school selected through random sampling (26 students in the experimental group and 26 students in the control group). The survey results revealed that 62% of teachers use satellite imagery during lessons; however, 69% of them utilize RS data primarily for visualization purposes. The results of the pedagogical experiment demonstrated that the average academic achievement of students in the experimental group increased by 18.2%, whereas the improvement in the control group was 3.6%. Furthermore, the use of RS data positively influenced students' geospatial thinking, research skills, and analytical abilities. The study further established that the structural-content model of RS-based teaching materials developed as a result of the research can contribute to improving existing methodologies. The proposed model is designed to modernize school geography curricula, enhance teachers' methodological capacity, improve students' learning outcomes, and promote geospatial literacy. The findings of the study demonstrate that the systematic integration of RS data into school geography education can serve as a scientific and methodological foundation for modernizing educational content, fostering students' contemporary scientific and technological competencies, and improving the overall quality of geographic education.

KEYWORDS

aerospace methods, geospatial technologies, remote sensing, school geography, teaching methodology

1 Introduction

The use of aerial photographs and satellite imagery for monitoring, modeling, and visualizing environmental change has become a key method for understanding the complex interconnections of the Earth system and addressing various issues related to sustainable development. Moreover, the development of an underutilized information source for contemporary school education is considered one of the main objectives of remote sensing didactics (Laiskhanov et al., 2025). The International Charter on Geographical Education describes geography as a subject and a source of knowledge of critical importance for people living in the 21st century. In accordance with this significance, the Charter emphasizes the necessity of incorporating the most advanced technologies for exploring the world in the process of learning geography (Commission on Geographical Education of the International Geographical Union, 2016). It has been noted that geographical education must be revised to align with the changing ways of accessing geographic information and materials in the new century (Stoltman et al., 2017). One such approach involves the integration of RS data into school geography curricula. In this context, it is important to highlight that the use of RS materials through geospatial technologies offers unique opportunities for understanding the modern world.

In recent years, many countries have developed practices for integrating RS materials into school geography education (Dannwolf et al., 2020; Dziob et al., 2020; Naumann et al., 2009; Wolf et al., 2016). RS data serve as a unique and accurate source of information about geographical objects and processes occurring within the geographic environment. In practice, RS makes it possible to observe real-time phenomena such as deforestation, wildfires, desertification, water pollution, glacial melting, and many other issues. One of the key advantages of incorporating RS materials into geographical education is their potential to enhance students' spatial thinking abilities. Overall, the benefits of using RS materials in education include greater clarity and precision compared to traditional geographic maps, a more realistic representation of the geographical environment, and the ability to reveal interrelationships among various spatial processes.

The sharp increase in the use of RS data across science, industry, and society has led to the emergence of web-based learning environments in many countries, further facilitating the integration of RS materials into school curricula. For instance, the use of satellite imagery has been incorporated into numerous school programs in Germany. Platforms such as the “BLIF” remote sensing software enable students to explore and analyze RS materials, thereby enhancing their competencies in addressing geographical and environmental issues (Wolf et al., 2016). Such digital tools not only make RS data more accessible to students but also provide them with hands-on experience in data analysis and interpretation—skills that are considered essential in geography education (Hodam et al., 2020).

The use of geoinformation technologies and methods, as well as RS materials, in geographical education is addressed in geography textbooks of Kazakhstan. For example, the 9th-grade geography textbook includes sections on “Cartography and Geographic Databases,” while the 10th and 11th-grade textbooks feature chapters on “Cartography and Geoinformatics” and “Nature Management and Geoecology” (Minister of Education and Science of the Republic of Kazakhstan, 2022). It is explicitly stated that the use of RS materials is necessary for teaching and practical exercises; however, these materials are rarely employed in some lessons beyond serving as

visualization tools for phenomena or as abstract substitutes for maps. Although printed satellite images are well suited for these purposes, this rich source of information is not utilized at an adequate level (Kerstin et al., 2009). Since the introduction of updated geography textbooks for grades 9–10 in 2019 and grade 11 in 2020, the need to acquire theoretical knowledge of digital geoinformation technologies and systems, as well as their practical application in teaching, has become increasingly relevant.

The use of RS data in school settings, due to its interdisciplinary nature, presents both challenges and opportunities. Utilizing RS data across multiple subjects, including geography, physics, and computer science, requires foundational knowledge and skills. Researchers have noted that this can be challenging even for undergraduate students (Maggioni et al., 2020). Nevertheless, this interdisciplinary approach enriches the learning process, as students acquire new knowledge and competencies beyond the traditional scope of geography.

However, the majority of studies on the use of remote sensing (RS) data in school geography are primarily limited to describing technological capabilities or demonstrating the effectiveness of individual instructional tasks. Scientifically grounded methodologies for the systematic integration of RS data into school geography, as well as structured implementation models, remain insufficiently developed. This represents one of the key unresolved challenges in this field. Moreover, empirical research focused on developing RS-based teaching methodologies is limited, and in Kazakhstan, such studies have not yet been systematically conducted at the secondary education level.

This study is aimed at identifying the scientific and methodological foundations for integrating remote sensing (RS) data into school geography and evaluating its effectiveness through pedagogical experimentation. Furthermore, the conceptual framework of the research is grounded in constructivist learning theory, the principles of inquiry-based and problem-based learning, as well as scholarly approaches focused on the development of geospatial literacy. These theoretical perspectives provide a foundation for designing an instructional model that facilitates the development of students' spatial thinking, research competencies, and analytical skills through the application of RS data.

The aim of the study is to identify the challenges and opportunities of integrating RS data into school geography, develop an effective teaching methodology based on their use, and test it in practice. In line with this goal, several research questions were formulated:

- 1 What is the significance and what are the opportunities of integrating RS data into the geography curriculum?
- 2 What is the current state of using satellite imagery in school geography: what are the achievements and barriers?
- 3 What should the structural-content model for teaching RS data in school geography include?
- 4 What results were obtained from the experimental testing of the teaching methodology for RS materials based on geoinformation technologies in school geography?

2 Materials and methods

In searching for research materials, key terms that formed the basis of the study were used. Specifically, keywords such as “remote sensing,” “aerospace methods,” “school geography,” “geospatial

technologies,” and “teaching methodology” were employed. Searches were conducted across databases including Scopus, Web of Science, ResearchGate, Taylor & Francis, ERIC, and Google Scholar. No restrictions were placed on the publication year or language of the selected scientific articles; the main criterion was the relevance of the publications to the topic under consideration. However, particular attention in the analytical review and in identifying the role and significance of satellite imagery in geographic education was given to recent publications in peer-reviewed international journals. Scientific publications of a purely technical nature, those lacking a methodological framework, or those not related to secondary education content were excluded from the analysis.

To study the use of satellite imagery in school geography, a survey method was employed. The survey was conducted using the online service crowdsignal.com. The questionnaire developed as a research tool consisted of a total of 17 questions. The content validity of the survey was established based on expert evaluations from specialists in geography education methodology, as well as in the fields of GIS and RS. The survey collected data on teachers’ frequency of using satellite imagery during lessons, their understanding and knowledge of RS data, as well as the obstacles and difficulties they encounter in its usage. A total of 124 geography teachers from urban and rural schools across various regions of Kazakhstan voluntarily participated in the study. Teachers participating in the survey were selected based on their professional engagement in geography teaching and having at least 1 year of teaching experience at a school. Respondents who did not complete the survey in full were excluded from the sample. The survey was anonymous, ensuring complete confidentiality of the participants’ names and responses. The collected data were analyzed using statistical methods. Microsoft Excel software was utilized to perform correlation, statistical, and qualitative analyses.

In the next stage of the study, an analysis of the collected materials was conducted. Classification was performed based on the titles and abstracts of the full-text sources. During this stage, we considered the relevance and applicability of the selected sources (Browning and Rigolon, 2019). Descriptive and logical, qualitative, and comparative methods were employed throughout the research. The modeling method was used to develop a structural-content model for teaching RS materials in school geography.

A pedagogical experiment was conducted to evaluate the effectiveness of the teaching methodology based on the developed structural-content model. The experiment took place in the 11th grades of School-Gymnasium No. 5 named after Zhambyl, under the Department of Education of Taraz city, Education Administration of Zhambyl Region. A total of 52 students participated in the study, with 26 students in the experimental group and 26 students in the control group. During the research, it was ensured that participants were from the same grade level, followed a comparable curriculum, and had approximately similar baseline knowledge levels. In the experimental group, modern geoinformation software such as Google Maps, EarthViewer, Google Earth, Google Earth Engine, Sentinel Hub EO Browser, USGS Earth Explorer, ArcGIS, and QGIS were actively used during lessons. The control group predominantly employed traditional teaching methods. The research materials included the State Compulsory Education Standard for Geography, school textbooks, methodological guides, as well as author-developed assignments and exercises.

The purpose of a pedagogical experiment is not limited to empirically confirming or refuting the research hypothesis and the validity

of theoretical findings; it may also be aimed at substantiating that the proposed pedagogical intervention (e.g., new content, instructional forms, teaching methods, learning materials, etc.) is more effective or, conversely, demonstrating its lower effectiveness. To achieve this, it is necessary to demonstrate that applying the intervention to at least one object (e.g., a group of students) produces outcomes different from those obtained through the use of traditional pedagogical methods. In this study, the experiment was designed to evaluate the effectiveness of the methodology for integrating RS data into school geography and to assess its impact on students’ academic achievement.

For this purpose, an experimental group is formed and compared with a control group. If these two groups, initially identical in characteristics, differ after the implementation of pedagogical interventions, the difference in the effects of these interventions is substantiated. Therefore, two comparisons must be conducted: the first comparison (before the start of the pedagogical experiment) should show that the experimental and control groups have similar characteristics, while the second comparison (after the experiment concludes) should demonstrate the differences between them (Novikov, 2004).

The experimental results were quantitatively analyzed using mathematical and statistical methods. The outcomes for the experimental and control groups were comparatively presented in diagrams and tables, followed by descriptive and inferential statistical analyses, including paired-samples and independent-samples *t*-tests. This approach enabled the evaluation of the effectiveness of the proposed methodology. Differences in learning outcomes were analyzed using quantitative indicators based on percentage changes, which facilitated the interpretation of the results.

The project research team included authors of school textbooks and teaching materials, developers of currently successful professional development programs for geography teachers, as well as a researcher-practitioner with extensive teaching experience in schools. This contributed significantly to the appropriate selection of instructional methods and the effective use of educational materials within the study.

3 Results and discussion

3.1 Literature review: the current the importance and opportunities of integrating remote sensing data into the geography curriculum

By using remote sensing data, students can deepen their understanding of spatial relationships and patterns. Studies have shown that the use of remote sensing technologies facilitates a more profound comprehension of ecological and geographical concepts and significantly enhances students’ spatial critical thinking skills (Adaktylou, 2020; Kholoshyn et al., 2019; Saputro et al., 2020). This is closely linked to geospatial literacy, which is described as the ability to work with digital spatial data through geoinformation technologies (Mísařová et al., 2022). Satellite imagery stimulates students’ interest and improves their knowledge of ongoing processes on Earth, while also fostering geospatial thinking and technical skills (Wolf et al., 2016).

It can be assumed that engaging with RS materials fosters a sense of responsibility and care for the environment among school students,

as it broadens their knowledge of global issues such as climate change, deforestation, and the expansion of urbanization (Adaktylou, 2020; Simerská, 2023). Educational programs incorporating RS data may also provide learners with opportunities to participate in discussions on sustainability and environmental protection (Kholoshyn et al., 2019). Research conducted in the Czech Republic emphasizes the importance of introducing the use of RS materials at primary and secondary school levels as an approach that combines environmental education with digital learning and interlinks the natural sciences (Simerská, 2023).

The effectiveness of using RS data in geographical education is also supported by empirical research demonstrating its impact on students' learning outcomes. For instance, studies have shown that learners working with RS materials exhibit enhanced analytical skills and improved ability to synthesize information from multiple sources (Kholoshyn et al., 2019; Saputro et al., 2020). Moreover, the application of remote sensing in the context of project-based learning has been associated with increased motivation and engagement among students, as they can observe the real-world applications of their research (Mesas-Carrascosa et al., 2019). This aligns with the broader educational objective of developing critical thinking and problem-solving skills essential for success in the twenty-first century. RS materials further offer opportunities to enhance students' spatial thinking, promote interdisciplinary learning, and transform geographical education with a stronger focus on environmental protection.

The use of digital technologies, integrated with other accessible geospatial technologies (such as GPS and geolocation data, open data, and big data infrastructures), promotes a collaborative and interdisciplinary approach in geographic education. The rapid technological advancements in remote sensing necessitate the continuous updating of educational resources and curricula to ensure learners acquire the most relevant information (Bondarenko et al., 2023).

Integrating geographic information systems (GIS) with RS materials in the school setting significantly enhances the learning of geography. This combination creates a favorable learning environment that engages students and helps develop critical analytical skills necessary for modern geographic analysis (Cheung et al., 2011).

As researchers have noted, integrating remote sensing (RS) materials into secondary school curricula supports the implementation of constructivist learning theory, which is considered an effective approach to teaching subjects within the natural science and mathematics cycle (Bada and Olusegun, 2015; Dziob et al., 2020). Voss et al. (2008) highlighted that the use of RS data in school subjects enables the introduction of new forms of instruction, identifying the key advantages in this field as follows:

- The ability to address a broad range of STEM topics in the curriculum through problem-based, integrated approaches;
- The capability to utilize both archival and newly acquired data for analyzing current and dynamic issues;
- Visualization of problems with a high degree of clarity;
- Increased motivation and engagement of learners;
- Development of learners' skills in processing remote sensing imagery (Voss et al., 2008).

Educational projects and programs provide a partial solution to the identified challenges. They are typically developed by experts in education and remote sensing through international collaborations. These initiatives offer learning materials that engage youth and

demonstrate contemporary applications integrating school education with interdisciplinary scientific knowledge.

The integration of RS materials into geography education is based on specific scientific research, including the results of international projects. For example, the goal of the "YCHANGE" (Young Scientists as Change Explorers – Students Evaluating Environmental Change in Europe with Digital Space Technologies) project, conducted by researchers from Tallinn University (Estonia), Charles University in Prague (Czech Republic), Heidelberg University of Education (Germany), and FHNW School of Education (Switzerland), was to improve the competence of teachers and students in working with satellite imagery. Within this project, a curriculum on remote sensing was developed. It included possibilities for using satellite images in organizing different types of learning activities and the sequence of their implementation. The research results showed that the vast majority of school teachers are interested in improving their qualifications in this area (Schulman et al., 2021).

The potential of satellite imagery goes far beyond the scope of topics covered in general secondary education. School curricula in geography aim to develop students' ability to make decisions and evaluations based on information obtained from various sources. The decision-making process, especially in the natural sciences, is more complex than in everyday life. Assessing situations such as disasters of natural origin requires realistic and systematic analysis, critical thinking, and consideration of expert opinions and factual data. In this regard, satellite imagery serves as an effective material for developing these skills. Objects in satellite images are not always clearly visible. Their use and interpretation are based on processing this not immediately visible information and decoding data from it. Furthermore, the use of satellite imagery has high potential in terms of developing spatial orientation skills, problem-based learning, methodological competencies, assessment, as well as practical skills (Goetzke et al., 2013).

3.2 Analysis of the use of satellite imagery in school geography

3.2.1 Results

Satellite imagery serves as an effective method for enhancing geographical education in schools and for developing students' research skills. Therefore, it is important to identify teachers' perceptions regarding the use of satellite imagery in schools, to determine the barriers to using such imagery as educational materials based on the current state of schools, and to analyze the practical issues related to its implementation in the teaching process.

This section presents the results of the survey conducted among school teachers and discusses them within the framework of pedagogical theories and previous research.

According to the results of the conducted survey, 62% of teachers reported using satellite imagery during lessons, while 38% indicated that they do not use it.

Among those who use satellite imagery during lessons, 31% reported using it to develop students' research skills, while 69% indicated that they use it primarily for visual demonstration purposes. This indicates that the proportion of teachers utilizing satellite imagery for research purposes is relatively low.

Several significant barriers affect the successful integration and widespread use of satellite imagery in school lessons (Figure 1).

According to Figure 1, teachers reported that the low material and technical conditions of some schools (46.8%) and limited access to the internet or low internet speed (38.7%) negatively impact their use of satellite imagery in lessons. These factors influence the extent to which teachers can incorporate satellite imagery materials into their lessons, as well as the amount of time required to implement them effectively.

To teach students how to process, analyze, and conduct research using satellite imagery, teachers need a solid knowledge base. Although this instructional material has been used in the natural sciences for several decades, it is considered relatively new in the field of education. This creates a need for professional development courses for geography teachers.

Overall, it was found that teachers have a high level of interest (82%) in effectively using satellite imagery and GIS technologies in their lessons. However, their proficiency in using satellite imagery is low. The lack of professional development courses negatively impacts their ability to master these skills. Since the majority of teachers have little experience working with satellite imagery, using it in lessons without proper interpretation does not yield good results. Regular use of satellite imagery in geography lessons can be achieved through enhancing teachers' competencies. This is supported by the fact that 84% of teachers believe that professional development courses on the use of satellite imagery in lessons are necessary.

While maintaining teachers' interest in using satellite imagery, it is necessary to develop professional development courses and educational-methodological materials aligned with the school curriculum to help students acquire the appropriate level of knowledge. Since the use of the Internet, computers, and interactive whiteboards is a mandatory condition for utilizing satellite imagery, its implementation in schools occurs within limited time frames. This situation is further underscored by teachers' suggestions in the survey, such as: "the organization of courses on the use of satellite imagery in lessons" and "improving Internet access and the opportunity to freely explore specific software and websites."

Overall, the survey revealed that the proportion of teachers who practically use satellite imagery in geographical education is low. In order to address the question, "Does the share of non-users appear to be influenced by the age of teachers?," we conducted a correlation analysis. (Table 1).

The analysis results show that there is no correlation between Y – the proportion of non-users and X – age group ($r_{yx} = -0.20371$), indicating that age does not significantly affect the proportion of non-users. Only 4.2% of the increase in the proportion of non-users can be attributed to age, while the remaining 95.8% is due to other unaccounted factors. This may be explained by the influence of qualification-related, material and technical, and organizational factors discussed above.

3.2.2 Discussion

These findings do not align with Jordan's previous research conclusions, which suggested that older individuals tend to be less inclined to adopt computer products and may refuse to use them (Jordan, 2020).

Overall, the survey results revealed that teachers in schools demonstrate a high potential interest in the use of satellite imagery. However, the actual level of implementation in schools remains low due to material-technical or information-communication barriers. In addition, one of the main obstacles is the lack of established methodological foundations for teaching RS data in school geography, as well as the shortage of instructional and methodological materials. Such barriers limit the systematic and purposeful use of satellite data in the educational process.

The Czech researcher Simerská highlighted that the widespread integration of geospatial data into secondary education is hindered by a lack of educational resources, the fact that learning materials are primarily available only in English, and insufficient technical infrastructure (Simerská, 2023). Several researchers, based on surveys conducted with school teachers, have indicated methodological and

Barriers influencing teachers' use of satellite imagery in classroom instruction

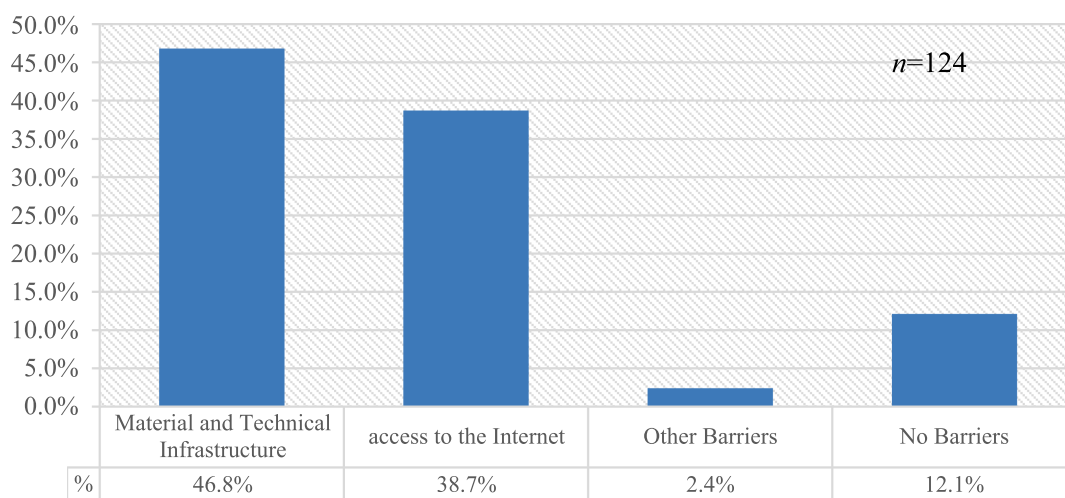


FIGURE 1
Barriers affecting teachers' use of satellite imagery in lessons.

TABLE 1 Correlation coefficient between non-use of satellite imagery and teachers' age groups.

	Y	X	R ²
Y	1		
X	−0.20371	1	0.0415

technical support deficiencies, the complexity of using geospatial data, the lack of expert knowledge among teachers, and the insufficiency of experience in this field (Ditter et al., 2012; Hodam et al., 2020). Recently graduated or newly inducted teachers in this field may be familiar with remote sensing as a subject; however, they might lack comprehensive theoretical and practical knowledge, which is often due to the limited time allocated for remote sensing instruction in universities (Hodam et al., 2020; Schulman et al., 2021).

3.3 Structural and content model for teaching GIS data in school geography

3.3.1 Results

Analyzing both domestic and international teaching practices, we have also developed a structural-content model for teaching remote sensing (RS) data in school geography (Figure 2).

The model comprises several interconnected components: goal-setting, content, technological aspects, teaching methods and approaches, professional competencies and skills, and assessment and outcomes. These components enhance the methodology of integrating RS data into geography education, facilitating effective achievement of learning objectives, improving the functional literacy of future geography specialists, and fostering the development of scientific and natural science knowledge. They also contribute to the formation of students' understanding and perspectives on the systemic relationships between nature, society, and the economy, as well as environmental and socio-economic knowledge, ultimately laying the foundation for learners to become informed about aerospace data and technologies.

Purpose: To integrate Remote Sensing (RS) data into school geography education.

Objective: To improve teaching methodology and enhance the quality of geographical education.

Content block — consists of the teaching content aimed at achieving the set purpose and objectives, including the main elements such as:

- Understanding of Remote Sensing: the operation of aerial and spaceborne platforms, spatial, spectral, temporal, and radiometric resolution of obtained images, processing of RS data, etc.
- Application of Remote Sensing in various branches of geography: *cartography and GIS* (creation and updating of topographic and thematic maps at different scales using satellite and aerial imagery, monitoring changes in land use, infrastructure, and natural objects, analysis and modeling of geographical phenomena, generation of digital terrain models, etc.); *study of natural processes and phenomena* (vegetation monitoring: assessing plant condition, identifying plant species, determining biomass and phenological changes based on spectral characteristics); *water studies* (monitoring the area, level, and quality of water resources,

studying the dynamics of glaciers and snow cover, monitoring oceans and seas); *soil cover analysis* (identification of soil types, assessment of soil moisture, detection of erosion processes and land degradation); *geological research* (study of geological structure, identification of tectonic formations, exploration of mineral resources); *meteorology and climatology* (monitoring clouds, land surface temperature, precipitation, studying climate change); *environmental monitoring* (tracking pollution of the atmosphere, water, and soil, assessing the impact of natural disasters, monitoring forest fires, detecting illegal logging); *socio-economic geography* (assessment of changes in land use, monitoring boundaries of settlements and agricultural lands); *urban studies* (analysis of the spatial structure of cities, monitoring urban growth and development, assessment of infrastructure condition); *transport geography* (evaluation of transport networks, analysis of traffic flows); *agriculture* (assessment of crop productivity, crop monitoring, planning irrigation systems); and *assessment of natural resource stocks and environmental impact* (analysis of forests, water, land, and other natural resource stocks, evaluation of the effects of economic activities on natural complexes), etc.

- Working with online web resources that allow viewing and analyzing satellite images (NASA Worldview, USGS EarthExplorer, Sentinel Hub, Copernicus Browser, ESA, EOSDA LandViewer, Google Earth Pro, NOAA Data Access Viewer, Maxar Open Data Program, etc.);
- Practical work with remote sensing data (studying natural and anthropogenic changes in landscapes, assessing pre- and post-emergency changes, examining relief forms, data analysis and visualization, creating thematic maps and models, conducting project-based research, etc.);
- Learning aerial surveying using unmanned aerial vehicles (drones) (familiarization with operating rules and drone functions, learning to control under various weather conditions, monitoring and assessing environmental changes, etc.).

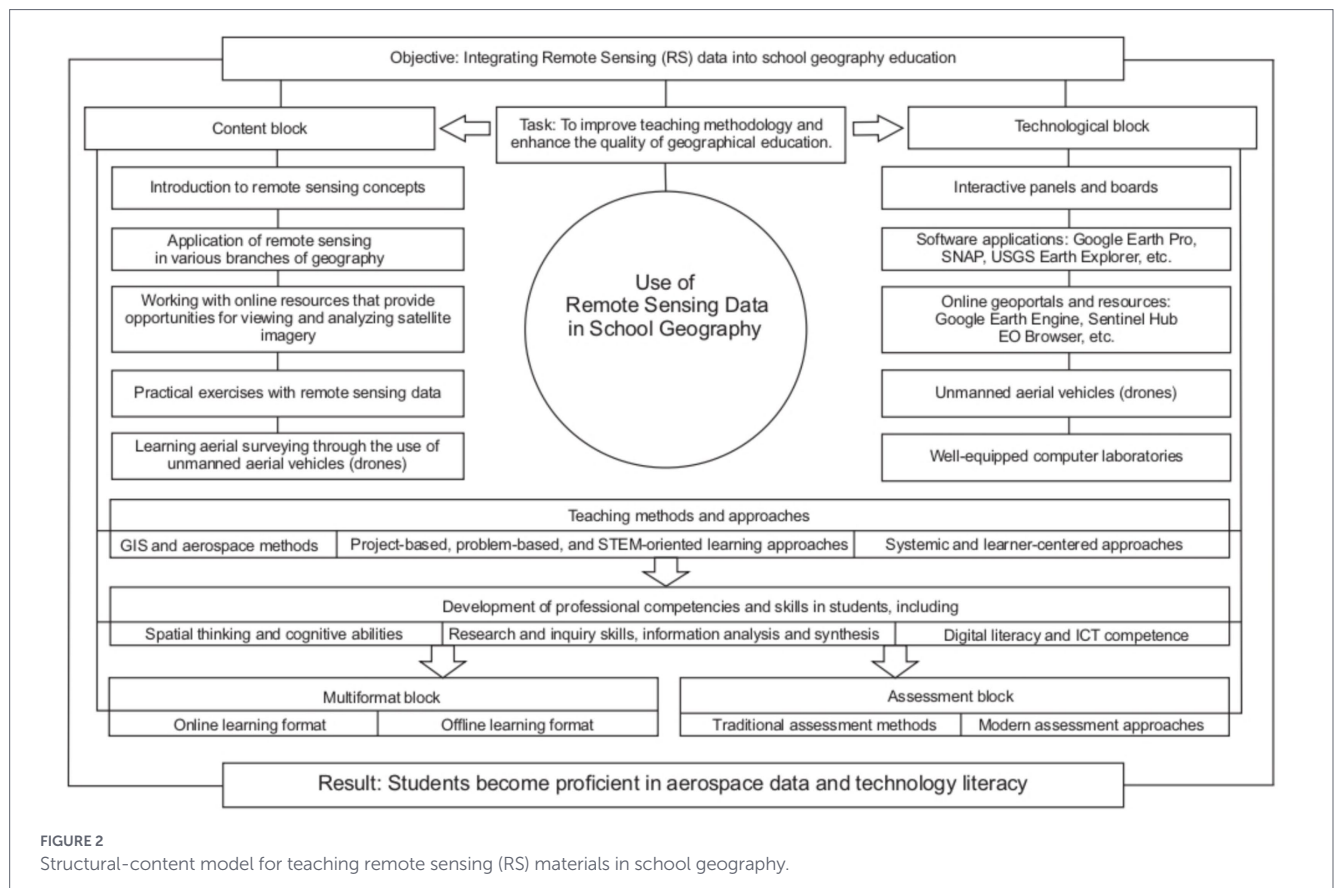
Technological block — encompasses a set of necessary tools and equipment that form the basis for the qualitative organization of the educational process:

- Interactive panels and boards;
- Software: Google Earth Pro, SNAP, USGS Earth Explorer, etc.
- Online geoportals and resources: (Google Earth Engine, Sentinel Hub EO Browser, etc.);
- Unmanned aerial vehicles (drones);
- Equipped computer classroom.

Teaching methods and approaches aim to develop students' skills in working with digital technologies based on both modern and traditional techniques. Systemic and learner-centered approaches ensure and support the self-development of learners, the realization of their personal abilities, and the growth of their unique individuality.

The structure of learners' professional competencies and skills aims to develop research competencies that involve spatial critical thinking, the ability to analyze and synthesize information, as well as the formation of skills in working with digital and information-communication technologies.

The integrated teaching of RS data in school geography consists of a **multiformat block** based on both online and offline learning formats.



The learning outcomes are evaluated using both traditional and contemporary forms of assessment. Overall, the technological map or structural-content model resulting from our research facilitates the formation of students who are knowledgeable about aerospace data and technologies, deepens their knowledge and skills, develops their research competencies, and enables them to proficiently master information technologies.

The effectiveness of the structural-content model was evaluated through the results of a pedagogical experiment. The statistically significant improvement in learning outcomes observed in the experimental group demonstrates the practical effectiveness of the model. Compared to traditional teaching approaches, the model is distinguished by its systematic integration of RS data and its focus on developing geospatial literacy.

3.3.2 Discussion

Kazakhstan's strategic development plan identifies enhancing the global competitiveness of education and science, as well as fostering the development and education of individuals based on universal human values, as one of its key priorities (Government of the Republic of Kazakhstan, 2022). The systematic organization of the educational process is directly related to the course content and its structural components (Bakhisheva et al., 2022). In pedagogical and instructional methodology research, this is commonly referred to as a structural-content model (Tambovtseva, 2023). Domestic studies in the field of pedagogy demonstrate that structural-content models contribute to the development of future professionals' soft skills (Bülbül et al., 2023), research activity (Amanbaeva, 2017), and cognitive competence (Kasymova, 2021).

Although the structural-content model is similar to STEM integration models, it incorporates a specialized methodological framework aimed at the systematic integration of RS data. The target block is focused on defining learning outcomes, while the content block is aligned with the geography curriculum. The technological block is based on the implementation of digital geospatial tools, and the assessment block enables the measurement of educational outcomes.

Activities involving the use of RS data contribute to the development of geoinformation literacy (Misařová et al., 2022), the acquisition of aerospace methods (Naumann et al., 2009), the expansion of problem-oriented STEM topics as one of their key advantages (Voss et al., 2008), and the implementation of problem-based learning approaches (Mesas-Carrascosa et al., 2019). In recent years, global educational transformation has increasingly shifted toward the application of theoretical knowledge in practical contexts.

The scientific novelty of the proposed model lies in its consideration as an integrated methodological system that combines pedagogical, technological, and competency-based components for incorporating RS data into geography education. This distinguishes it from existing educational models.

3.4 Conducting a pedagogical experiment in schools

3.4.1 Results

A pedagogical experiment was conducted to determine the impact of the instructional and methodological materials developed based on the structural-content model created in our research, their role in improving the teaching methodology, and their effectiveness

in enhancing the quality of geographical education among school teachers and students. The obtained results are examined in terms of their effectiveness in improving the quality of geographic education, as well as from the perspectives of inquiry-based and problem-based learning, and the theoretical foundations of geospatial literacy.

The object of the experiment was the 11th-grade classes “A” (natural science and mathematics focus) and “B” (natural science and mathematics focus) of the communal state institution “Zhambyl Regional Education Department of the Taraz City Education Division, School-Gymnasium No. 5 named after Zhambyl.” The 11th-grade students were divided into two groups: 26 students in the control group (11th grade “A” class) and 26 students in the experimental group (11th grade “B” class). The purpose was to test the effectiveness of the proposed teaching methodology. The duration of the experiment was 4 weeks (3 h per week) (kundelik.kz, 2023).

For the 11th grade “Geography” subject (Kaimuldinova et al., 2019), according to the sections “Cartography and Geoinformatics” and “Nature Use and Geoecology,” the learning objectives corresponding to the lesson topics are as follows:

11.2.1.1 – Utilizing the capabilities of electronic cartographic resources according to the topic (reading digital maps, determining, describing, and analyzing the location of geographic objects and areas using them, as well as their quantitative and qualitative indicators) (2 h);

11.2.2.1 – Explaining the characteristics of remote sensing methods;

11.2.2.2 – Explaining the characteristics of geoinformation methods and geographic information system (GIS) technologies, as well as their connections with other sciences and industries;

11.2.2.3 – Creating a geographic database related to the topic using computer software;

11.2.2.4 – Creating thematic map layouts related to the topic using computer software;

11.3.2.1 – Classifying anthropogenic changes in the environment (2 h);

11.3.2.2 – Classifying indicators of environmental quality (2 h);

11.3.2.3 – Assessing the impact of polluted environments on human life (including additional consideration of local/regional components) (2 h).

At the end of each section, two practical assignments are included, aimed at developing learners’ skills to apply their learning outcomes in practice.

The effectiveness of the course was evaluated in three stages: diagnostic, formative, and evaluative. To assess the levels of knowledge, 11th-grade students from both the control and experimental groups were given 15 assessment tasks (questions) aligned with the cognitive levels of Bloom’s taxonomy—namely, remembering, understanding, applying, analyzing, synthesizing, and evaluating. The final results were assessed, and the collected data were processed.

The experimental research consisted of diagnostic, formative, and evaluative stages. At each stage, the students’ responses to the assessment tasks were analyzed, and graphical models were constructed accordingly.

3.4.2 Diagnostic research stage

During the diagnostic research stage, assessment tasks were administered to determine students’ levels of subject-specific and interdisciplinary competencies in the sections “Cartography and Geoinformatics” and “Nature Management and Geoecology.” The results enabled the identification of students’ competency levels (Table 2; Figure 3).

Overall, the analysis of the results from the diagnostic (preliminary) phase of the experiment revealed the extent to which students had acquired key concepts such as the use of online web resources for viewing and analyzing satellite imagery, understanding the features of remote sensing methods, and recognizing their connections with other scientific disciplines and fields of production.

The analysis of the results of the control and experimental groups during the diagnostic phase of the pedagogical experiment showed that the students in the experimental group performed 5.8% higher on tasks at the *knowledge* and *comprehension* levels compared to the control group, while their performance on tasks at the second level — *application* and *analysis* — was 9.2% lower, and on tasks at the third level — *synthesis* and *evaluation* — was 6.2% lower. These results indicate that although students demonstrated a relatively higher level of performance in knowledge and comprehension tasks, higher-order cognitive skills - particularly analysis and evaluation - were insufficiently developed. From this perspective, the quality of knowledge in the experimental group was comparatively lower than that of the control group in terms of conceptual depth and analytical complexity.

3.4.3 Formative research stage

The aim of the formative stage of the research was to enhance the effectiveness of teaching, to develop students’ subject-specific and cross-curricular competencies, and to identify the expected positive changes in teaching geographical research and cartographic methods.

For the 11th grade Geography course, tasks were assigned based on the sections “Cartography and Geoinformatics” and “Environmental Management and Geoecology,” targeting the *understanding*, *application*, *analysis*, *synthesis*, and *evaluation* levels. The analysis of students’ responses provided a basis for drawing several conclusions (Table 3; Figure 4).

According to the analysis results, it was identified that students faced difficulties in completing tasks related to the practical application of geographical research and cartographic methods. However, the

TABLE 2 Results of the analysis of responses to control tasks obtained during the diagnostic experiment.

Group	Distribution by levels			Average indicator
	Level 1 (max – 5 points)	Level 2 (max – 10 points)	Level 3 (max – 15 points)	
Control group	65.2%	62.7%	56.5%	61.4%
Experimental group	71%	53.5%	50.3%	58.2%
Difference	+5.8%	−9.2%	−6.2%	−3.2%

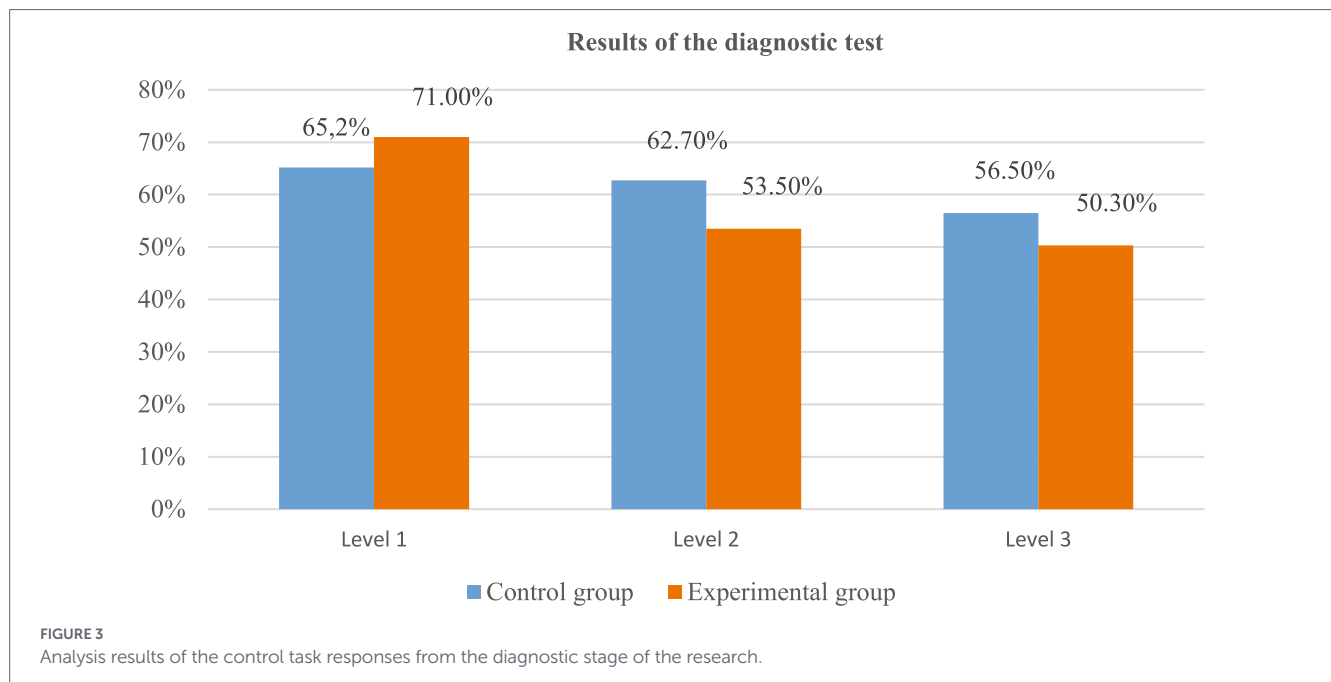


TABLE 3 Results of the formative stage of the pedagogical experiment.

Group	Distribution by levels			Average indicator
	Level 1 (max – 5 points)	Level 2 (max – 10 points)	Level 3 (max – 15 points)	
Control group	67.8%	65.6%	61.8%	65%
Experimental group	78.5%	74.8%	76.1%	76.4%
Difference	+10.7%	+9.2	+14.3%	+11.4%

tasks at the knowledge and comprehension levels were performed at a relatively higher level. Compared to the control group, the experimental group outperformed by 10.7% in Level 1 tasks, by 9.2% in Level 2 tasks, and by 14.3% in Level 3 tasks.

During the evaluative phase of the research, the average score of the control group was 61.4%, while the experimental group scored an average of 58.2%. At this stage, the control group's average increased to 65%, whereas the experimental group's average rose to 76.4%. Overall, by the end of the experiment, the control group showed an improvement of 3.6%, while the experimental group demonstrated a significant increase of 18.2% (Figure 5).

The graphically presented results of the formative research phase make it possible to assess that significantly higher indicators were achieved across all diagnostic criteria of the study. A paired-samples *t*-test was employed to determine changes in the academic achievement of students in the experimental group. The analysis revealed a statistically significant difference between the mean scores before the experiment ($M = 58.20$) and after the experiment ($M = 76.40$) ($p < 0.05$). In addition, the final results of the experimental and control groups were compared using an independent-samples *t*-test. The findings indicated that the academic achievement of students in the experimental group was statistically significantly higher than that of the control group ($p < 0.05$). These results demonstrate the positive impact of the implemented methodology on learning outcomes and on improving the quality of geographic education.

The quality of the knowledge, skills, and competencies acquired during the study of the “Cartography and Geoinformatics” and “Environmental Management and Geoecology” units was determined based on the evaluation of students’ completed tasks. Learners were required to provide written responses to analysis-level tasks that involved applying knowledge and skills in academic contexts. In order to conduct a comparative analysis of the results, the tasks were directly related to the topics covered within the “Cartography and Geoinformatics” and “Environmental Management and Geoecology” units.

From the very first day of the experiment, lessons were conducted for the class using a new modern pedagogical approach. To achieve the learning objectives, the instruction went beyond theoretical knowledge and textbook exercises, incorporating methods and techniques for using cartographic services, geoportals, and remote sensing materials applicable in geographic education, as well as utilizing online web resources during the lessons (Table 4).

The control group, on the other hand, was taught using traditional teaching methods. That is, the educational process was carried out using textbooks, maps (paper maps) depicting geographical objects and phenomena, their properties and characteristics, as well as tools such as a globe, compass, planimeter, engraving instruments, special rulers, palettes, protractors, compasses, curvimeters, and other similar instruments.

In conclusion, students in the experimental group demonstrated the highest level of performance in completing all tasks during the

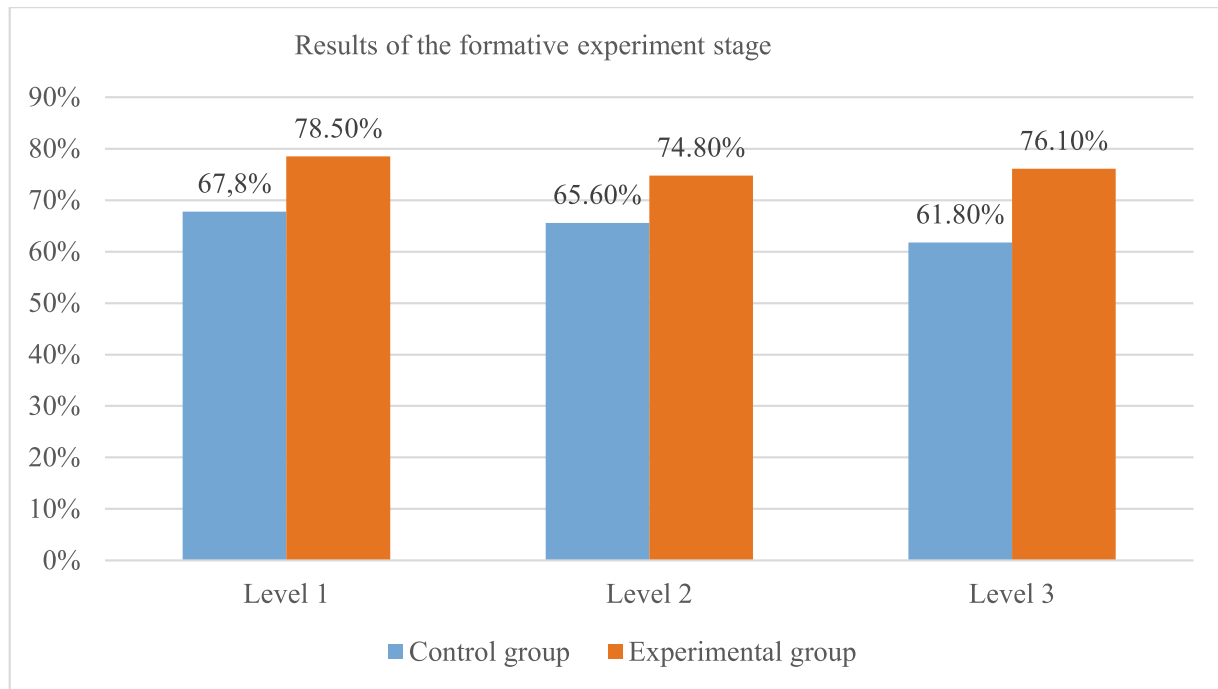


FIGURE 4
Final results of the formative stage of the research.

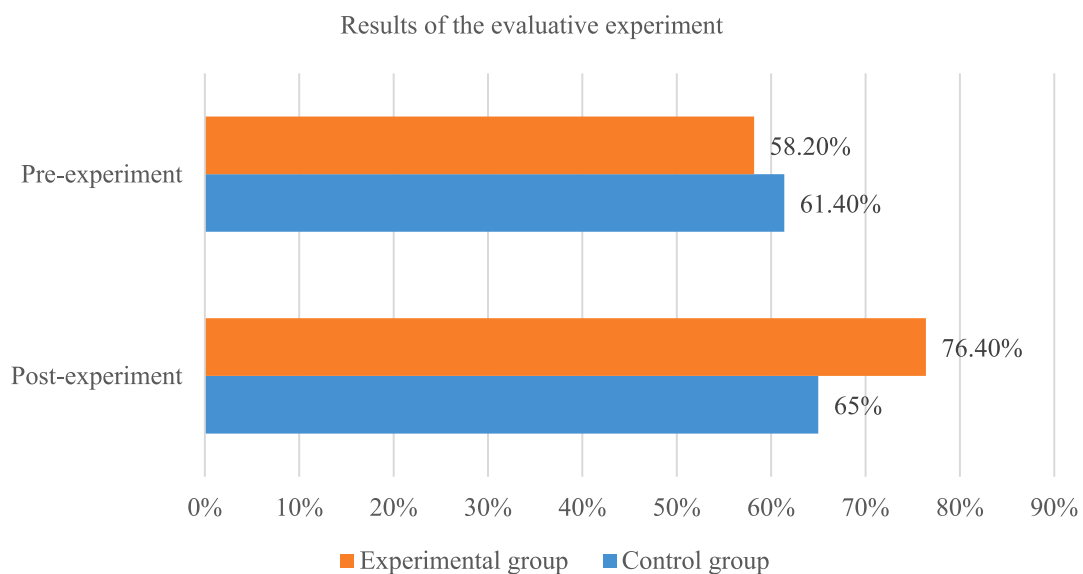


FIGURE 5
Final results of the evaluative experiment.

instruction of the “Cartography and Geoinformatics” and “Nature Management and Geoecology” sections.

During the course of the experiment, we identified the following challenges:

- the low proficiency levels of geography teachers in mastering the necessary software and online geospatial portals and resources for integrating remote sensing data into teaching;
- students’ inability to fully utilize applications such as Google Earth

Engine, Sentinel Hub EO Browser, USGS Earth Explorer, and ArcGIS.

As observed, by the end of the experiment, the use of remote sensing data in geography education significantly improved students’ quality of knowledge, contributing greatly to effective teaching and fostering independent learning.

During the course of this experiment, psychological-pedagogical and methodological literature was reviewed, knowledge about remote

TABLE 4 The process of conducting lessons for the experimental group.

Lesson topic	Learning objective	Knowledge and skills acquired in the lesson	Expected outcome
Modern cartographic methods	11.2.1.1 – use the capabilities of electronic cartographic resources (reading digital maps, identifying and analyzing the location, quantitative and qualitative characteristics of geographical objects and territories)	Using Google Maps, EarthViewer, and Google Earth to read digital maps and determine spatial and quantitative characteristics of geographical objects and territories	Ability to use Google Maps, EarthViewer, and Google Earth servers
Geo-information research methods	11.2.2.1 – explain the features of remote sensing methods	Understanding the features of remote sensing methods through online geoportals (Google Earth Engine, Sentinel Hub EO Browser, etc.)	Ability to recognize and describe elements from true-color satellite images
	11.2.2.2 – explain the features of GIS technologies and their connections with other sciences and industries	Analysis of the application of Google Earth Engine and Sentinel Hub EO Browser in agriculture, urban growth monitoring, ecology, mineral exploration, and natural disaster prevention	Ability to work with global, regional, and local geoportals
Geographic databases	11.2.2.3 – construct a geographic database using computer programs	Creating a database by entering tabular data into ArcGIS, QGIS, or Google Earth Pro and generating point/polygon layers	Ability to collect data, transfer them to a table and map, and understand database structures (point–line–polygon)
Visualization of geographic data	11.2.2.4 – create thematic maps using computer programs	Creating thematic maps based on satellite imagery and temporal changes, using GIS applications and online resources, with group work tasks	Ability to compare true-color and false-color images, identify and describe main elements
Anthropogenic changes in the environment	11.3.2.1 – classify anthropogenic environmental changes	Working with satellite images (USGS Earth Explorer, Sentinel Hub EO Browser), analyzing causes and consequences of changes through group and individual tasks	Ability to analyze data, explain and conclude beyond viewing satellite images
Environmental quality	11.3.2.2 – classify indicators of environmental quality	Classifying environmental quality (water, vegetation, air, soil) using true- and false-color visualizations and band combinations in Sentinel Hub EO Browser	Ability to analyze and classify satellite imagery, calculate indices
	11.3.2.3 – assess the impact of polluted environments on human life (including local/regional aspects)	Evaluating the possibilities and limitations of remote sensing for environmental pollution assessment, through group and individual tasks	Understanding advantages/limitations of RS in detecting pollution, integrating theoretical and practical data

sensing was systematized within the educational process, and the methodology for integrating remote sensing data into school geography education was investigated.

3.4.4 Discussion

Currently, the science of cartography is undergoing a new stage of development and is becoming increasingly in demand over time. It is known that humans receive up to 80%, and according to some data, up to 90% of information through visual perception. Through maps, a geographer demonstrates geographical patterns and establishes spatial relationships between phenomena. The famous geographer-economist Baransky (1980) once said, “There is no geography without maps,” and these words remain relevant today. RS data are widely used in modern cartographic production, and in some cases, they can be applied directly through image interpretation without the need for map creation.

As a modern approach to geographical work, satellite imagery can complement maps and serve as a visual source of information, contributing to the diversification of teaching tools and enriching the overall content of geography lessons (Bachmann and Möller, 1995; Brucker, 1976; Haversath, 1981; Siegmund and Wolf, 2006).

One of the key priorities in the current process of informatizing society is the informatization of education. According to Kreider (2005), this refers to the process of equipping the field of education with the methodology and practice for developing and optimally applying new information technologies aimed at achieving the psychological and pedagogical goals of teaching and upbringing.

The use of digital geospatial platforms does not automatically lead to improved learning outcomes in the educational process (Bednarz and Lee, 2019; Viehrig, 2014). The effectiveness of these technologies depends on their pedagogically sound organization and the instructional methods employed. Student-centered teaching approaches contribute to enhancing learners’ motivation, subject knowledge, environmental literacy, spatial thinking abilities, and the practical relevance of geographic education (Goetzke et al., 2013). The results obtained in this study provide scientific support for these assumptions. The proposed structural-content model establishes a systematic methodological framework for integrating RS data into geography education and offers a conceptual scientific contribution by integrating technological, pedagogical, and competency-based components.

However, despite the positive results, several limitations should be considered when interpreting the findings of the study. The relatively small number of participants and the fact that the study was conducted within a specific regional context limit the broader generalizability of the results. In addition, teachers' preparedness levels and infrastructural challenges influenced the research outcomes. Further studies are required to test the proposed model in diverse educational settings and to evaluate its long-term impact on the development of students' geospatial competencies.

4 Conclusion

The results of the conducted research, by achieving the stated objective, made it possible to identify the scientific and methodological foundations for integrating RS data into school geography.

Firstly, the analysis of international practices and literature review on the importance of using RS materials in school geography demonstrated that the integration of RS materials into geography education provides significant opportunities for enhancing the learning process, developing practical competencies, and fostering comprehensive skills aligned with 21st-century educational goals.

Secondly, the research results on geography teachers' use of satellite imagery in schools revealed a number of issues. The proportion of teachers who use RS materials in their lessons was 62%, while 38% reported not using them. However, among those who do use satellite imagery, the majority (69%) apply it solely for illustrative purposes, whereas only 31% utilize it for research-oriented activities. This indicates a lack of experience among teachers in using RS materials for inquiry-based learning and highlights the need for professional development programs focused on this area. Teachers expressed a strong interest in using satellite imagery effectively in their lessons. Nevertheless, various challenges were identified, including ICT-related and infrastructural barriers, insufficient teacher qualifications in RS, and a shortage of teaching and methodological resources. These findings substantiate the need to develop dedicated instructional materials and expand pedagogical practice in the future. As a result of this research, a structural-content model for teaching remote sensing materials in school geography was developed. The interconnected components of the model contribute to enhancing the methodological foundation for integrating RS into geography lessons, allowing for more effective achievement of educational objectives and fostering the development of scientific thinking. This model and its components also served as the basis for the development of instructional and practice-oriented tasks.

Thirdly, the results of the experimental work conducted in a school setting demonstrated the effectiveness of the methodology for integrating RS data into geography lessons. The use of modern geoinformation technologies and resources that allow for viewing and analyzing satellite data significantly improved students' academic performance, contributed to high-quality instruction, and promoted independent learning. Furthermore, compared to traditional teaching methods, the new approach enhanced students' research competencies and increased their cognitive engagement. However, the study has several limitations. The limited number of students and teachers involved in the empirical research restricts the generalizability of the findings. Furthermore, as the study was conducted within the school context of a specific region, the results are primarily applicable

to educational institutions with similar infrastructural conditions.

Overall, the research findings, alongside the increasing importance of spatial geoinformation in the current digital era, clearly demonstrate the necessity of integrating RS data into school geography. Integrating RS data into the geography curriculum contributes to the modernization of educational content, the development of students' modern scientific and technological competencies, and the enhancement of the quality of geographical education to a new level. Moreover, further research aimed at improving the structural-content model for teaching RS materials in school geography could contribute to the development of competencies in working with satellite imagery, thereby supporting the advancement of geospatial literacy among students. Investigating the long-term effects of using RS materials in school geography and expanding research to include different regions and educational institutions represent important directions for future studies.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

Ethical approval was not required for the studies involving humans because this study was based on an anonymous survey and a pedagogical experiment conducted among adult participants (geography teachers). No personally identifiable data were collected, and informed written consent was obtained from all participants. In accordance with national legislation and institutional requirements, ethical committee approval was not required for this type of educational research. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

SL: Writing – original draft, Writing – review & editing. ZN: Writing – original draft, Writing – review & editing. KK: Writing – review & editing. DA: Writing – review & editing. EA: Writing – review & editing. AB: Writing – review & editing.

Funding

The authors declare that financial support was received for the research and/or publication of this article. This study was funded by the Ministry of Science and Higher Education of the Republic of

Kazakhstan under grant project IRN AP23487595, entitled ‘Preparation of methodological developments aimed at developing skills in the use of remote sensing (RS) materials in school geography.’ The article processing charge (APC) was also funded by this grant.

Conflict of interest

The author(s) declared that this work was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Correction note

A correction has been made to this article. Details can be found at: [10.3389/feduc.2026.1832274](https://doi.org/10.3389/feduc.2026.1832274).

References

- Adaktylou, N. (2020). Remote sensing as a tool for phenomenon-based teaching and learning at the elementary school level: a case study for the urban heat island effect. *Int. J. Educ. Methodol.* 6, 517–532. doi: 10.12973/ijem.6.3.517
- Amanbaeva, M. B. (2017). *Methodology for the formation of research activities in prospective biology teachers* a dissertation submitted for the degree of doctor of philosophy (PhD) in the specialty 6D011300 – biology. Almaty: Abai University.
- Bachmann, M., and Möller, C. (1995). “Satellitenbildauswertung im Unterricht – Ergebnisse und Erfahrungen aus einem bundesweiten,” in *Erderkundung leichtgemacht: Ein Ratgeber für Satellitendirektempfang und Bildauswertung als neues Medium im fächerübergreifenden Unterricht*, eds. A. Bludau-Hary, M. Bachmann and W. P. Steinborn (Gotha).
- Bada, O. S., and Olusegun, S. (2015). Constructivism learning theory: a paradigm for teaching and learning. *J. Res. Method Educ* 5, 66–70.
- Bakhisheva, S., Kinzhikova, R., and Kemeshova, A. (2022). Model of learning in the age of digital society: instructional design of blended learning. *J. Educ. Sci.* 73, 62–75. doi: 10.26577/JES.2022.v73.i4.06
- Baransky, N. N. (1980). *Selected Works: The Formation of Soviet Economic Geography*. Moscow: Mysl.
- Bednarz, R., and Lee, J. (2019). What improves spatial thinking? Evidence from the spatial thinking abilities test. *Int. Res. Geogr. Environ. Educ.* 28, 262–280. doi: 10.1080/10382046.2019.1626124
- Bondarenko, O. V., Hanchuk, O. V., Pakhomova, O. V., and Varfolomyeyeva, I. M. (2023). Digitalization of geographic higher education: problems and prospects. *J. Phys. Conf. Ser.* 2611:012015. doi: 10.1088/1742-6596/2611/1/012015
- Browning, M. H. E. M., and Rigolon, A. (2019). School green space and its impact on academic performance: a systematic literature review. *Int. J. Environ. Res. Public Health* 16:429. doi: 10.3390/ijerph16030429
- Brucker, A. (1976). Satellitenbilder Im Geographieunterricht. *Geogr. Rundsch.* 28, 378–380.
- Bülbul, H. I., Bekbolat, M. S., Berkimbayev, K. M., and Meirbekova, G. P. (2023). The structural-content model of forming the soft skills of future specialists. *Bull. Karaganda Univ. Pedagog. Ser.* 111, 152–159. doi: 10.31489/2023ped3/152-159
- Cheung, Y., Pang, M., Lin, H., and Lee, C. K. J. (2011). Enable spatial thinking using GIS and satellite remote sensing - a teacher-friendly approach. *Procedia Soc. Behav. Sci.* 21, 130–138. doi: 10.1016/j.sbspro.2011.07.014
- Commission on Geographical Education of the International Geographical Union (2016). International charter on geographical education, 2016. Official translation into Russian. Available online at: <https://www.igu-cge.org/publications/2016-charter/> (Accessed March 30, 2025).
- Dannwolf, L., Matusch, T., Keller, J., Redlich, R., and Siegmund, A. (2020). Bringing earth observation to classrooms-the importance of out-of-school learning places and e-learning. *Remote Sens.* 12:3117. doi: 10.3390/RS12193117
- Ditter, R., Michel, U., and Siegmund, A. (2012). “Neue Medien-Möglichkeiten Und Grenzen,” in *Geographiedidaktik: Theorie-Themen-Forschung*. (Braunschweig: Westermann), 214–235.
- Dziob, D., Krupiński, M., Woźniak, E., and Gabryszewski, R. (2020). Interdisciplinary teaching using satellite images as a way to introduce remote sensing in secondary school. *Remote Sens.* 12:2868. doi: 10.3390/RS12182868
- Goetzke, R., Hodam, Henryk, Rienow, Andreas, and Voß, Kerstin. (2013) “Tools and learning management functions for a competence-oriented integration of remote sensing in classrooms.” In *GI-Forum 2013. Creating the GISociety – Conference Proceedings*, 458–462. Heidelberg: Herbert Wichmann Verlag.
- Government of the Republic of Kazakhstan. (2022). Concept for the development of education in the Republic of Kazakhstan for 2022–2026. Available online at: <https://adilet.zan.kz/kaz/docs/P2200000941/links> (Accessed August 11, 2025).
- Haversath, J.-B. (1981). Satellitenbild-Transparente - Unterrichtliche Auswertung in Der 6. Jahrgangsstufe. *Praxis Geogr.* 1, 10–14.
- Hodam, H., Rienow, A., and Jürgens, C. (2020). Bringing earth observation to schools with digital integrated learning environments. *Remote Sens.* 12:345. doi: 10.3390/RS12030345
- Jordan, P. W. (2020). *An Introduction to Usability*. London: CRC Press.
- Kaimuldinova, K., Abdimanapov, B., and Abilmazhinova, S. (2019). *Geography. Textbook for the 11th Grade of a Comprehensive School in the Natural and Mathematical Direction*. Almaty: Almaty School.
- Kasymova, G. K. (2021). *Development of students' cognitive competence based on the E-learning educational system* a dissertation submitted for the degree of doctor of philosophy (PhD) in the specialty 6D010300 – pedagogy and psychology. Almaty: Almaty School.
- Kerstin, V., Roland, G., and Henryk, H. (2009) “Einbindung Fernerkundlicher Methoden in Den Erdkundeunterricht—Das Beispiel Der Klassifikation Und ChangeDetection.” In *Proceedings of the Fourth 'Learning with Geoinformation' Conference; Result of the Conference, Held within the Framework of AGIT and Organised in Co-Operation with the HERODOT Network as Well as the GI-Forum*, Salzburg, Austria, 8–10
- Kholoshyn, I. V., Varfolomyeyeva, I. M., Hanchuk, O. V., Bondarenko, O. V., and Pikilnyak, A. V. (2019). Pedagogical techniques of earth remote sensing data application into modern school practice. *CEUR Workshop Proc.* 6, 391–402. doi: 10.55056/cte.399
- Kreider, O. A. (2005). The information environment for the use of GIS technologies in education. *Geoinformatics* 4, 49–52.
- kundelik.kz. (2023). “Эксперимент Кезеңінің Нәтижелері.” Available online at: <https://schools.kundelik.kz/v2/reports/default?school=1000004092355&report=progress-group&year=2023&group=2120174941053491035&repPeriod=2120170731985521840> (Accessed December 17, 2023).
- Laishkanov, S. U., Nurmagambetuly, Z., and Gönençgil, B. (2025). The current state and possibilities of using space imagery in school geography. *Sci. J. Pedagog. Econ.* 415, 146–161. doi: 10.32014/2025.2518-1467.957
- Maggioni, V., Girotto, M., Habib, E., and Gallagher, M. A. (2020). Building an online learning module for satellite remote sensing applications in hydrologic science. *Remote Sens.* 12:3009. doi: 10.3390/RS12183009
- Mesas-Carrascosa, F. J., Pérez Porras, F., Triviño-Tarradas, P., de Meroño Larriva, J. E., and García-Ferrer, A. (2019). Project-based learning applied to unmanned aerial systems and remote sensing. *Remote Sens.* 11:2413. doi: 10.3390/RS11202413
- Minister of Education and Science of the Republic of Kazakhstan (2022) Order no. 399 of the minister of education and science of the Republic of Kazakhstan dated September 16, 2022, on the approval of model curricula for general education subjects, elective courses for primary,

Generative AI statement

The author(s) declared that Generative AI was not used in the creation of this manuscript.

Any alternative text (alt text) provided alongside figures in this article has been generated by Frontiers with the support of artificial intelligence and reasonable efforts have been made to ensure accuracy, including review by the authors wherever possible. If you identify any issues, please contact us.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

basic secondary, and general secondary education in general education organizations. Available online at: <https://uba.edu.kz/qaz/metodology/4> (Accessed August 7, 2025).

Misařová, D., Svobodová, H., Maštnerová, V., Durna, R., Hercik, J., Šimáček, P., et al. (2022). *Koncepce Rozvoje Geoinformačních Dovedností ve Výuce Na Základních a Středních Školách*. Brno: Masarykova univerzita.

Naumann, S., Siegmund, A., Ditter, R., Haspel, M., and Jahn, M. South Korea (2009). "Remote sensing in school – theoretical concept and practical implementation," in *E-Learning Tools, Techniques and Applications*. eds. G. König and H. Lehmann (Potsdam: ISPRS).

Novikov, D. A. (2004). *Statistical Methods in Pedagogical Research (Typical Cases)*. Moscow: MZ-Press.

Saputro, Rudy, Liesnoor, Dewi, Setyowati, and Hardati, Puji. (2020). "The students spatial critical thinking skill by using map and remote sensing imagery on geography lesson." In *Proceedings of the International Conference on Science and Education and Technology (ISET 2019)* Atlantis Press.

Schulman, K., Fuchs, S., Hämmerle, M., Kisser, T., Laštovička, J., Notter, N., et al. (2021). Training teachers to use remote sensing: the YCHANGE project. *Rev. Int. Geogr. Educ. Online* 11, 372–409. doi: 10.33403/rigeo.708754

Siegmund, A., and Wolf, A. (2006). "Satellitenbilder Im Unterricht–Eine Internationale Vergleichsstudie Zum Schulischen Fernerkundungseinsatz." In *Veröffentlichungen des AK Fernerkundung*, eds. U. Michel and K. Behncke Osnabrück, 137–148.

Simerská, D. (2023). The importance of remote sensing in geography education. *Geografie* 128, 419–435. doi: 10.37040/geografie.2023.015

Stoltman, J. P., Lidstone, J., and Kidman, G. (2017). The 2016 international charter on geographical education. *Int. Res. Geogr. Environ. Educ.* 26, 1–2. doi: 10.1080/10382046.2017.1272849

Tambovtseva, A. O. (2023). Structural and content-based modeling of the formation of students' interdisciplinary foundations of research culture in the educational process. *Hum. Capital* 6, 189–196. doi: 10.25629/HC.2023.06.21

Viehrig, K. (2014). *Exploring the Effects of GIS Use on Students' Achievement in Geography*. Heidelberg: University of Education Heidelberg.

Voss, K., Goetzke, R., and Hodam, H. (2008). Learning modules—a way to integrate remote sensing methods in school education. *Int. Arch. Photogramm. Remote. Sens. Spat. Inf. Sci.* 34.

Wolf, N., Fuchsgruber, V., Riembauer, G., and Siegmund, A. (2016). An adaptive web-based learning environment for the application of remote sensing in schools. *Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci.* 41, 53–56. doi: 10.5194/isprsarchives-XLI-B6-53-2016