Active online learning with remote sensing data in higher education

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ABSTRACT

The increasing popularity of online learning has created a need for effective methods to enhance educational quality. This study addresses this need by developing and evaluating an active online learning model incorporating remote sensing data (RSD). The study included a pedagogical experiment with 181 students divided into control and experimental groups. The model included an interactive database, a web portal with tools for processing and visualizing RSD, and the implementation of active learning methods. Data were collected through testing, analysis of completed projects, and questionnaires. Quantitative and qualitative analysis methods were used to process the data. The pedagogical experiment showed that the model improved students' average scores, increased the number of students with high levels of knowledge acquisition, and enhanced motivation. Thus, the use of RSD and active learning methods in online education is a promising approach to improve the quality of the educational process and foster students' digital competence.

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1. INTRODUCTION

The rapid advancement of digital technologies has revolutionized higher education, paving the way for innovative approaches to online learning. Active learning methodologies, particularly those incorporating remote sensing data (RSD), are crucial in enhancing the effectiveness of online education, fostering practical skills, and nurturing critical thinking among students. Traditional online learning methods in the field of geoinformation technologies often prove insufficiently effective in equipping students with practical skills for working with modern geoinformation systems. Therefore, developing and implementing new online learning methods that can enhance the effectiveness of the educational process and foster students' digital competence is a pressing issue. One promising avenue in this area is the use of RSD, which offers unique opportunities for visualizing and analyzing geographical data, modeling natural processes, and solving practical problems in various fields. This study delves into the realm of active online learning in higher education, focusing on the integration of interactive methods and technologies, including the utilization of RSD.

Recent years have witnessed a surge in research exploring the effectiveness of online learning and the integration of digital technologies into educational practices. Numerous studies [1]–[3] underscored the importance of establishing an interactive and stimulating online learning environment that encourages active student participation, cultivates self-reliance, and boosts motivation. The emphasis is placed on leveraging multimedia resources, virtual laboratories, online simulations, and other interactive tools [4], [5].

However, online learning also presents challenges, such as limitations in social interaction, the need for heightened self-organization among students, and potential technical difficulties [6], [7]. To address these limitations and enhance the effectiveness of online education, it is imperative to develop and implement innovative methods and technologies tailored to the specific characteristics of the digital environment. In this context, the utilization of RSD offers a promising avenue for active online learning. RSD provides a unique opportunity to visualize and analyze geographical data, model natural processes, and address practical challenges in fields such as ecology, geography, agriculture, and others [8], [9]. Integrating RSD into the educational process enables students to acquire practical skills in working with modern geoinformation technologies, cultivate spatial thinking, and enhance analytical abilities.

This study contributes to the existing body of knowledge by developing and testing a comprehensive approach to active online learning that incorporates RSD. This approach involves the creation of an interactive database and web portal for RSD analysis and research, as well as the implementation of effective interactive learning methods, such as collaborative project work, virtual discussions, and RSD data analysis. This study contributes to the existing body of knowledge by developing and testing a comprehensive approach to active online learning that incorporates RSD, specifically focusing on the integration of RSD with active learning methods [10]–[15]. This distinguishes our research from previous work that may have explored RSD in the context of traditional online learning approaches. The primary objective of this research is to develop and evaluate the effectiveness of an active online learning model utilizing RSD in higher education. To achieve this objective, the following research tasks were undertaken: i) analyze existing approaches to active online learning and the utilization of RSD in the educational process; ii) develop an interactive database and web portal for RSD analysis and research; iii) implement effective interactive learning methods incorporating RSD; and iv) evaluate the effectiveness of the developed active online learning model with RSD.

The practical significance of this research lies in the potential application of the developed model and methodological recommendations to enhance the effectiveness of online learning across various disciplines involving the use of RSD. The introduction of geographic information systems (GIS) opens up new horizons in the field of monitoring and forecasting forest fires. The development of GIS integrated with intelligent processing of aerospace data allows not only to promptly track fire sources, but also to model the dynamics of their spread taking into account meteorological conditions and topographic features of the terrain. Such a system can significantly increase the effectiveness of measures to prevent and extinguish forest fires, ensuring timely decision-making and optimization of resource use.

The development of a geoinformation system for monitoring and forecasting the spread of forest fires with intelligent processing of aerospace data is a pressing task of modern science and technology. The use of machine learning methods and big data analysis allows creating highly accurate forecasting models that can be used for rapid response to emergency situations. The integration of such a system with the educational process will allow students to gain practical skills in working with advanced technologies in the field of geoinformatics and remote sensing of the earth.

2. METHOD

2.1. Study design

The study employed a mixed-methods approach. It involved a literature review, development of online resources, and a pedagogical experiment. The experiment included 181 students from two specialties (Geodesy and Remote Sensing; and Cartography and Geoinformatics) who were randomly divided into control and experimental groups. The experiment included 181 students from two specialties (Geodesy and Remote Sensing; and Cartography and Geoinformatics). Students were randomly selected from those in 2nd to 4th years of study who had completed basic courses in geoinformation technologies [16]–[20]. The control group used traditional online learning methods, including video lectures, PowerPoint presentations, and independent work with educational materials posted in the distance learning system. The experimental group used the developed model of active learning using RSD, which included:

- Access to an interactive database with RSD containing satellite images of various territories, aerial photographs, laser scanning data, and digital elevation models.
- Work with a web portal that provides tools for processing and visualizing RSD, such as tools for image classification, spectral characteristics analysis, creation of thematic maps, and 3D models. The web portal developed for this study provided a suite of tools for processing and visualizing RSD. These tools included functionalities for image classification, spectral analysis, thematic map creation, and 3D model generation. The platform also facilitated access to the interactive RSD database, enabling students to readily utilize diverse datasets in their learning activities.
- Carrying out group projects related to RSD analysis, such as land use dynamics analysis, vegetation assessment, identification of ecological risk zones.
- Participation in online forum discussions dedicated to discussing RSD analysis results, sharing experiences, and solving problematic tasks.

The pedagogical experiment spanned a semester and involved weekly online sessions for both groups. The control group engaged in traditional online learning activities, such as attending video lectures, reviewing PowerPoint presentations, and completing independent assignments using educational materials posted on the distance learning system [21]–[25]. The experimental group utilized the developed active online learning model with RSD, participating in interactive database exploration, web portal exercises for RSD processing and visualization, collaborative group projects, and online forum discussions.

2.2. Data collection tools

The tools provided a comprehensive view of the impact of the training on students' learning and engagement. The combination of quantitative and qualitative data collection methods ensured a robust evaluation of the training's effectiveness. Several tools were used to assess the effectiveness of the training:

i) Testing on the material covered. The test consisted of 20 questions, including tasks on choosing the correct answer, establishing a match, and solving problems. Examples of test tasks:
   - What type of satellite images are used to study vegetation? (Answer options: panchromatic, multispectral, radar)
   - Match the types of RSD with their application (e.g. aerial photographs-creating topographic maps, thermal images-monitoring forest fires).
   - Calculate the area of a forest massif from a satellite image using the tools of the web portal.

ii) Evaluation of group projects by criteria. The project evaluation criteria included: quality of RSD data analysis; validity of conclusions; originality of the solution to the problem; quality of project presentation design; and level of group interaction.

iii) Student survey to assess the level of motivation and satisfaction with the learning process. The survey included questions with Likert scale response options (e.g., “how interesting was it for you to study the material using RSD?”) and open-ended questions (e.g., “what difficulties did you experience when working with RSD?”).

2.3. Data processing

Quantitative data (test results, project evaluations) were processed using descriptive statistics, t-test for independent samples, and ANOVA to compare the indicators of the control and experimental groups [26]–[30]. The results are presented in Figure 1 and Tables 1-6. Qualitative data obtained from the questionnaires and student reviews were analyzed using content analysis to identify the main themes and assess the level of motivation and satisfaction with learning.

As can be seen from Table 6, the most effective methods of active learning are the project method and discussions, which received the highest rating (5 points). This is due to the fact that these methods contribute to the greatest activation of students' cognitive activity, the development of their independence and creative thinking. The least effective method is the video lecture (2 points), which is due to its passive nature and lack of interactivity.

Thus, a set of methods was used to conduct this study, including literature analysis, pedagogical experiment, development of an interactive database and web portal, implementation of interactive teaching methods, and evaluation of effectiveness [31]–[35]. The combination of these methods allowed us to obtain objective data on the effectiveness of the developed model of active online learning using RSD. The next section will present the results obtained and their analysis.

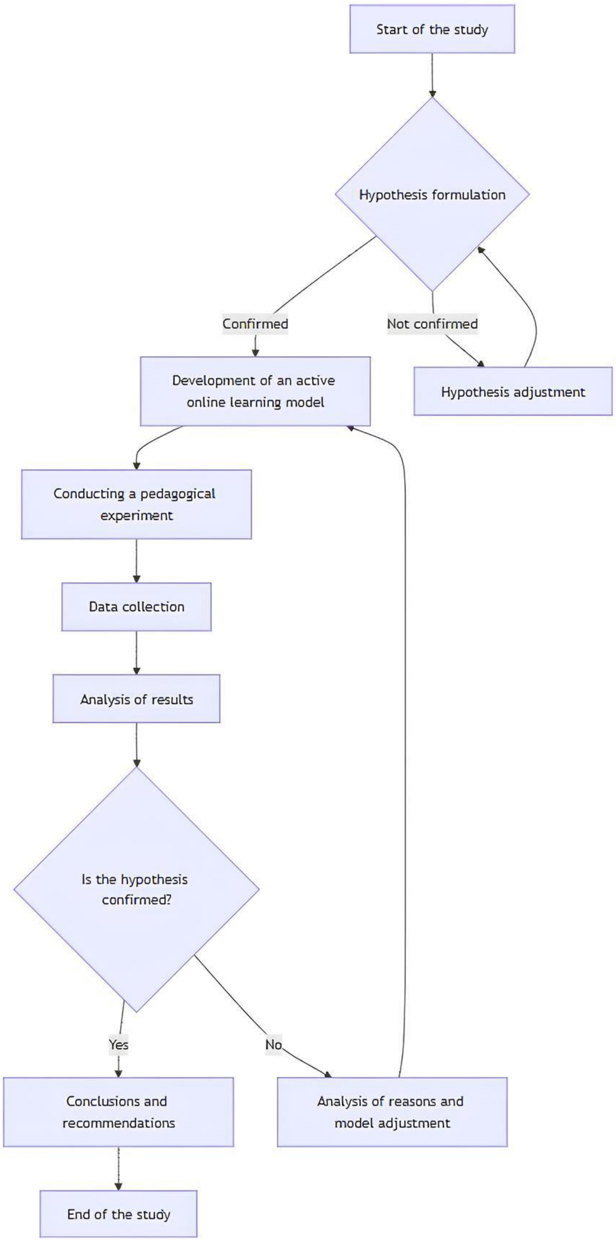

Figure 1. Research scheme

Table 1. Number of undergraduate and graduate students by groups and active online learning methods in the 2020-2021 academic year

No.	Institute, group	Active online learning methods
Number of students (people)	Project method (people)	Work in small groups (people)
Bachelors		
1	Institute of Space Engineering and Technologies, 211 group	30
2	Institute of Space Engineering and Technologies, 221 group	12
3	Institute of Space Engineering and Technologies, 231 group	27
4	Institute of Computer Engineering and Software, 311 group	20
5	Institute of Space Engineering and Technologies, 331 group	20
6	Institute of Computer Engineering and Software, 421 group	18
7	Institute of Space Engineering and Technologies, 431 group	18
Masters		
8	Institute of Space Engineering and Technologies, 111 group	12
9	Institute of Computer Engineering and Software, 221 group	17
Total	181	-

Table 2. Application of active online learning methods in classes on disciplines related to the use of RSD data

No.	Lesson topic	Active learning methods
1	Visualization of RSD data	Brainstorming, virtual online laboratory
2	Processing of RSD images	Flipped classroom, discussion, video lecture, colloquium
3	Classification of objects on RSD	Case method, project method, virtual online laboratory
4	Deciphering RSD	Discussion, colloquium, brainstorming
5	Creating thematic maps using RSD	Working in small groups, brainstorming, project method, online virtual laboratory
6	Analysis of RSD time series	Lecture for two, project method, brainstorming, virtual online laboratory
7	Application of RSD to solve practical problems	Case method, discussion, brainstorming, colloquium, virtual online laboratory
8	Preparing a report on the results of RSD analysis	Lecture for two, project method, discussion, online virtual laboratory

Table 3. Average student scores by type of learning activity and active online learning methods (%)

Active methods and types of activities	Control group	Experimental group	Difference
Working in small groups	72	85	+13
Project method	75	88	+13
Case method	70	82	+12
Brainstorming	68	80	+12
Colloquium	73	86	+13
Business game	71	83	+12
Solving situational problems	69	81	+12
Flipped classroom	74	87	+13
Discussion	76	89	+13
Socratic method	70	82	+12
Lecture for two	72	84	+12
Video lecture	75	88	+13

Table 4. Application of active online learning methods in open lessons in different faculties

Faculty	Discipline	Open lesson topic	Active learning methods
Faculty of Information Technologies	Geoinformation systems	Creating thematic maps from RSD data	Working in small groups, project method
Faculty of Natural Sciences	Ecology	Assessment of environmental pollution based on RSD data	Case method, discussion
Faculty of Geography	Cartography	Deciphering aerial photographs	Brainstorming, colloquium

Table 5. Distribution of students by levels of knowledge acquisition (%)

Level of knowledge acquisition	Control group	Experimental group	Other methods
High	55	75	Observation, self-assessment, peer-assessment
Medium	30	20	-
Low	15	5	-

Table 6. Evaluation of the effectiveness of active online learning methods

Method	Description	Active learning level (scale from 1 to 5)
Work in small groups	Students work on projects in small groups using RSD and web portal tools	4
Project method	Students complete projects related to the analysis and interpretation of RSD	5
Case method	Students analyze real situations and problems related to the use of RSD	3
Brainstorming	Students generate ideas for solving problems related to RSD	4
Colloquium	Students discuss issues related to RSD in the format of an educational conference	3
Business game	Students simulate real situations related to the use of RSD	4
Solving situational problems	Students solve practical problems related to the analysis and interpretation of RSD	4
Flipped classroom	Students study the material independently before the class, and during the class they discuss it and solve problems	4
Discussion	Students discuss problems and issues related to RSD	5
Socratic method	The teacher asks questions that encourage students to independently search for answers	3
Lecture for two	Two students prepare and deliver a lecture for their classmates	3
Video lecture	Students watch video lectures on topics related to remote sensing	2

3. RESULTS AND DISCUSSION

This study aimed to develop and evaluate the effectiveness of a model for active online learning using RSD in higher education. The results demonstrate the impact of this model on student learning outcomes and motivation.

3.1. Effectiveness of active online learning methods

To assess the effectiveness of active online learning methods, a comparison was made between the learning outcomes of the control and experimental groups [36]–[39]. The control group was taught using traditional online learning methods (lectures, seminars, independent work), while the experimental group was introduced to the developed active online learning model with RSD, an interactive database, and a web portal, as presented in Table 7.

Table 7. Comparative analysis of the effectiveness of traditional and active online learning methods

Indicator	Control group (traditional methods)	Experimental group (active methods+RSD)
Average score on the final test (%)	78	89
Number of students with a high level of knowledge acquisition (%)	55	75
Average score for project activities	72	85
Motivation level (based on survey results)	60	85

Description of data acquisition:
- Average score on the final test: calculated by dividing the sum of the scores of all students in the group by the number of students in the group. The final test included questions on theoretical material and practical tasks for RSD analysis.
- Number of students with a high level of knowledge acquisition: determined based on the results of the final test. Students who scored more than 80% were categorized as having a high level of knowledge acquisition.
- Average score for project activities: calculated by dividing the sum of the scores received by students for completing projects by the number of students in the group. As part of the project activities, students worked on solving practical problems using RSD and web portal tools. Project evaluation was carried out according to the following criteria: completeness of analysis, correctness of interpretation of results, and quality of presentation.
- Motivation level: assessed through student surveys. The questionnaire included questions about how interesting and useful the training was, how students assess their motivation to study the discipline.

As can be seen from Table 7, the use of active online learning methods in the experimental group led to a significant improvement in all indicators. This indicates that active learning methods, combined with the use of RSD, allow for a more effective and motivating learning environment for students.

3.2. Impact of RSD on the effectiveness of online learning

To assess the impact of RSD on the effectiveness of online learning, an analysis of the results of the project activities of students in the experimental group was conducted. As part of the project activities, students worked on solving practical problems using RSD and web portal tools. The examples of projects are: i) analysis of land cover changes using multispectral imagery; ii) assessment of vegetation condition based on RSD data; iii) monitoring of natural phenomena (floods, fires, earthquakes) using RSD. Results of the analysis of project activities: students demonstrated good command of RSD processing and analysis tools; and most students successfully coped with solving the assigned practical tasks.

In their feedback on project activities, students noted that working with RSD was interesting and useful, and also helped them better understand the theoretical material. Analysis of the project activities revealed that students in the experimental group effectively utilized the RSD processing and analysis tools. While most students successfully completed the assigned practical tasks, some challenges were observed in accurately interpreting complex spatial patterns and selecting appropriate analysis techniques for specific research questions. The use of RSD enhanced the quality of projects by enabling students to conduct more in-depth analyses and present their findings in a visually compelling manner. The use of RSD in online learning contributes to the development of practical skills in working with geoinformation systems, increasing motivation and interest in learning, as well as the formation of spatial thinking and analytical skills.

3.3. Evaluation of the effectiveness of the developed model of active online learning with RSD

Results of the survey of students in the experimental group. A survey was conducted to assess students' satisfaction with the developed learning model. The questionnaire included questions about how interesting and useful the training was, how students assessed their motivation to study the discipline, which teaching methods they liked the most, as seen in Figure 2. To assess the motivation level, a student survey was administered. The survey included Likert-scale questions (e.g., “how interesting was it for you to study the material using RSD?”) and open-ended questions (e.g., “what difficulties did you experience when working with RSD?”). Quantitative analysis of Likert-scale responses and qualitative analysis of open-ended responses using content analysis were conducted to identify key themes and evaluate students' motivation and satisfaction with the learning process. Description of data acquisition [40]–[42]. Data for plotting the diagram were taken from Table 7 (average score for the final testing in the control and experimental groups).

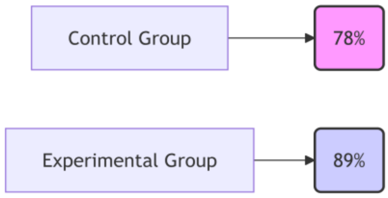

Figure 2. Comparison of the average scores of students in the control and experimental groups on final test

To assess student satisfaction with the developed learning model, a survey was conducted. The questionnaire included questions about how interesting and useful the training was, how students assess their motivation to study the discipline, what teaching methods they liked the most. The survey results were: i) 90% of students noted an increased interest in the discipline being studied due to the use of RSD and active learning methods; ii) 85% of students believe that working on projects using RSD helped them better understand the material; and iii) 80% of students expressed a desire to use RSD and the web portal in further education.

The high appreciation of the developed learning model by students confirms its effectiveness and practical significance. To determine the statistical significance of the observed differences between the control and experimental groups, independent samples t-tests were conducted for the average scores on the final test and project activities. The results indicated statistically significant differences ($p<.05$) in favor of the experimental group for both measures. The use of RSD and active learning methods allows for a more interesting and motivating learning environment that contributes to a deep understanding of the material and the development of practical skills.

3.4. Discussion

The results of the study demonstrate the effectiveness of the developed active online learning model incorporating RSD. The model contributed to improving the quality of the educational process and fostering students’ digital competence. These results are consistent with the several previous findings [23], [43]–[46], which also showed a positive impact of RSD on students’ academic achievement. However, unlike the other studies [47]–[49], our work focused on integrating RSD into active online learning methods.

Despite the positive results, some limitations of the study should be noted. First, the sample size was relatively small and included students from only two majors. Second, the study was conducted over a limited period of time. Future studies should increase the sample size and include students from different majors, as well as conduct a long-term study to assess the sustainability of the results. Despite the positive results, several limitations should be acknowledged. In addition to the relatively small sample size and limited study duration, the online learning environment may have presented challenges for some students, potentially influencing their engagement and performance. Additionally, the specific focus on two majors within the geoinformation technology domain may limit the generalizability of findings to other disciplines. Future research should address these limitations by incorporating a larger and more diverse student population, employing a longitudinal design to assess long-term impacts, and exploring the applicability of the model across various disciplines.

The results obtained have practical implications for educators and online course developers. The integration of RSD and active learning methods can contribute to improving the effectiveness of online education in various disciplines related to geoinformation technologies. It is recommended to develop interactive learning materials using RSD, implement group projects and discussions, and provide students with access to tools for processing and visualizing RSD. In further research, it is advisable to study the impact of the developed model on the development of other student competencies, such as critical thinking and problem-solving skills. It is also of interest to develop methodological recommendations for the use of RSD in online learning for various academic disciplines.

4. CONCLUSION

This study's findings unequivocally demonstrate the effectiveness of integrating RSD and active learning methods in online education within the geoinformation technology domain. The developed model significantly improved student learning outcomes, fostered practical skills and analytical abilities, and enhanced motivation and engagement. This underscores the potential of active online learning with RSD to transform the educational experience and equip students with the digital competencies necessary for success in the 21st century. The key findings of the study are: i) Active online learning methods, combined with the use of RSD, significantly enhance student learning outcomes. This was evidenced by increased average scores on the final test, a higher number of students achieving a high level of knowledge acquisition, and improved performance in project activities; ii) RSD effectively contributes to the development of practical skills, spatial thinking, and analytical abilities, as well as increased student motivation and interest in learning. This was observed through the analysis of student project activities and their feedback; and iii) The developed model of active online learning with RSD proved to be effective in improving the quality of the educational process. This was supported by the quantitative and qualitative data collected throughout the study.

The practical significance of this research lies in its potential to enhance online learning across various disciplines involving the use of geoinformation technologies. The developed model and the interactive RSD database and web portal can serve as valuable resources for both students and educators. Future research directions include expanding the study to a larger and more diverse student population, developing new interactive learning materials and tasks, and investigating the influence of various factors on the effectiveness of the model. The findings of this study have practical implications for educators and curriculum developers seeking to enhance online learning in various disciplines. Integrating RSD and active learning methods, providing access to interactive databases and web-based analysis tools, and designing collaborative projects can significantly improve the quality of online education. Further research is recommended to explore the broader applicability of this model and to develop specific pedagogical strategies for diverse learning contexts. In conclusion, this study demonstrates the effectiveness and potential of integrating RSD and active learning methods in online education. The developed model can be used to improve the quality of the educational process and foster the development of students' digital competence.

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AUTHOR CONTRIBUTIONS STATEMENT

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C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest.

DATA AVAILABILITY

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

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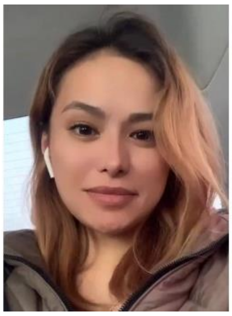

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