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Results of geoinformation system training in higher education

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ABSTRACT: The article examines the systematic use of modern methods and techniques of teaching geoinformation systems (GIS) in universities, methods of effective implementation of practical exercises, and outlines the use of the Python programming language in the ArcGIS environment. The purpose of the study was to identify the results of training in geoinformation systems in universities in view of the methods, practice and software used. The experiment involved 166 students from three universities of the Republic of Kazakhstan. Of these, 90 students formed an experimental group for which the content of the curriculum was changed and a specially compiled syllabus and a manual were used during the study. Findings indicate that the training provided to the experimental group was successful, and leads to the formation of professionals proficient in geography and information technology, who are able to use the Python programming language in creating GIS, have knowledge, skills including database skills, and who can create tables, queries and display results in the form of cartographic data within the framework of GIS.

INTRODUCTION

There is a pressing need to educate a new generation of scientists and citizens who understand how important space and place are in the real world, and who understand and can keep pace with technological advancements in the computational world [1]. Modern technologies are making significant changes to the traditional work on the compilation of cartographic materials, their analysis and use.

A geoinformation system (GIS) is a computer system that can provide all spatial and temporal orientation services with an information base at a qualitatively new level, and is able to solve a number of tasks in the field of economic, technical and natural sciences. GIS has laid the foundation for a new era of spatial and temporal data, which has not only improved people's understanding of the world, but also opened up unprecedented opportunities to solve multifaceted problems in various scientific fields.

Modern GIS is the process, systems and technology used to derive insights from geospatial data. Modern GIS uses open, interoperable and standards-based technology. It can be run locally or in the cloud and can work with many different types, velocities and scales of data [2]. GIS provides capabilities for visualising spatial patterns from large, complex, multi-layered data sets quickly and easily. It allows for alternative approaches to problems, creates opportunities to view things from a spatial perspective, and supports spatial reasoning through 3D visualisation, overlay analysis and spatial pattern analysis. There is strong evidence that GIS can help achieve some of the important goals in education, including spatial thinking, critical thinking and inquiry-based learning [3]. The field of GIS is concerned with the description, explanation, and prediction of patterns and processes on geographical scales. Therefore, GIS is not just a technology, but a science and a problem-solving methodology, using knowledge of the geoscientific reality [4].

Currently, developed countries consider the development of GIS to be a matter of state significance. GIS is being used as a search tool at the university level, in more than 100 different academic disciplines. However, when the GIS education is concerned, it can be observed that some disciplines come into prominence. Nowadays, at undergraduate and postgraduate levels, the GIS education is offered in such faculties/departments as geography, geodesy, photogrammetry, and also in ecological sciences, natural resources, forestry, civil engineering, landscape architecture, ecology, urban design and planning. In relation to the developments in computer technology, GIS has improved and the usage area has increased. The increase of available software, decrease in expenditures and usage flexibility in GIS applications made it possible to solve the problems of design and planning [5].

Currently, the effectiveness of the use of GIS technologies in education is becoming increasingly important and relevant, as it contributes to the skills development of each student. In Kazakhstan, the teaching of geoinformation systems in higher educational institutions in natural, technical, economic sciences, etc, is widely practised. GIS is very effective for analysing the quality of the education system in all regions and cities. Such an analysis should be carried out by government agencies on a systematic basis to ensure effective and affordable education for the local population, along with monitoring the quality of education. Each institution can use it to find new markets for its graduates and make decisions about opening new professions. In short, the use of GIS in education allows one to participate in the study and solve problems, display spatial patterns, connections and relationships, master the field of geography and information technology using a programming language, develop knowledge and skills, including database skills, be able to create tables, queries and map the results in creating data in the geoinformation system.

The purpose of the study was to identify the results of training in geoinformation systems in selected universities in Kazakhstan. To achieve this goal, the following tasks were set:

1) Explore the experience of the world's leading universities in creating the content of the GIS course.
2) The GIS course is aimed at teaching syllabuses and creating teaching aids and electronic resources.
3) Introduce and implement the GIS course in the elective discipline *digital technologies by industry* for natural science specialists in higher educational institutions of Kazakhstan.
4) Conduct statistical analysis of learning outcomes.

The following sections present the research model proposed for conducting GIS training in higher education: literature review, research methodology, data collection and analysis, and results and conclusions [6].

LITERATURE REVIEW

Educational research is a project of a university Bachelor's course aimed at introducing students of geographical specialties to computing and computer thinking. Climate change modelling with geoinformation systems is used as a context for an in-depth understanding of computational concepts [7]. Previous research on education in geoinformation systems (GIS) claims that the study of GIS contributes to the development of spatial thinking of students [8].

Today's view of the development of GIS suggests the possibility of a completely new approach based on globes, rather than maps, and taking into account positional uncertainty. The use of hierarchical data structures for the globe from the very beginning makes it possible to overcome the limitations of computing technology of the 1960s, while maintaining the advantages of congruent geography at different scales. However, modern GIS still partially reflect the limitations of that time [9].

ArcGIS is a new generation of software developed by the Environmental System Research Institute (ESRI), and is one of the most widely used GIS in the world. GIS software, a comprehensive, perfect, scalable GIS software platform, whether on the desktop, server, Internet or field operation, can be built through ArcGIS. ArcGIS spatial analysis has the function of extracting and transmitting spatial information. As the basis of various comprehensive geological analysis models, spatial analysis provides a basic tool for the establishment of complex models.

The geoinformation system can be used in such areas as education, health, construction, economics, ecology, transport, tourism, law, etc. Currently, due to the sharp growth of settlements, GIS is resorted to get to the area, order anything with time savings, solve tourist problems, master cars, get ambulance services, solve criminal problems, etc. All these processes are used in daily lives. The geoinformation system is designed for training in higher educational institutions, in any industry, and the development of information technology as a result of training and the establishment of interdisciplinary connections.

RESEARCH METHODOLOGY

The practical work was carried out with 166 students of the *L.N. Gumilyov* Eurasian National University, *K. Zhubanov* Aktobe Regional State University and *Kh. Dosmukhamedov* Atyrau University, all in Kazakhstan. The study examined geography and information technology, with the use of a programming language for the development of GIS.

Research forecast: if the teaching methodology using the Phyton programming language in the ArcGIS environment were implemented in the teaching of geoinformation systems, then the proficiency level of creating databases and groups, managing, publishing and updating elements, performing complex visualisations and data analysis, and management in the ArcGis environment in creating a geoinformation system would increase, and students would have a higher degree of knowledge, skills and abilities in creating a geoinformation system. The Pearson chi-square criterion was used to pinpoint this assumption:

$$\chi^2 = \sum(Э - Т_{кр})^2 / Т_{кр} \quad [10] \tag{1}$$

Where: H_0: - null hypothesis
H_1: - alternative hypothesis
Df = (R-1) x (C-1)

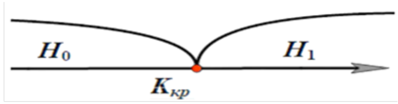

Figure 1: The null hypothesis - acceptance/rejection.

The participants were students in the 2nd year of studies aged between 18 and 20, and the gender was not taken into account. The discipline *application of digital technologies by industry* was traditionally taught without changes in the curriculum of students in the control group. In the experimental group, the content of the curriculum was changed and a specially compiled syllabus and a manual were used during the study. In both groups, the results of the initial and final formative tests were compared. At the time of the determinant testing, there was no difference in knowledge levels in both groups.

Various GIS training programmes are widely used in education. Currently, the leaders in the educational areas of GIS software are: ArcGIS, Autodesk AutoCAD Map 3D, QGIS, Google Earth Engine, MapInfo Professional, GRASS GIS, OpenLayers, Mapbox Education, MapInfo, Panorama, Neva. Using ArcGIS in the learning process allows students to visualise geoinformation analysis, model, and use data within specific areas of their interest in natural sciences. This tool contributes to a deeper understanding of the material and the development of skills in using geoinformation technologies in research.

As part of this study, an analysis was conducted of the world's best and the Republic of Kazakhstan higher education institutions by Quacquarelli Symonds (QS) university ranking using GIS technologies, and an indicator of the programmes they provide was obtained. These universities included: Massachusetts Institute of Technology, US; Stanford University, US; Harvard University, US; University of Oxford, UK; Imperial College London, UK; and from Kazakhstan, *Al-Farabi* Kazakh National University and *LN. Gumilyov* Eurasian National University.

The integration of new teaching methods in the educational process in higher educational institutions of the Republic of Kazakhstan was considered, as well as attention paid to topical issues and problems reflecting the latest trends in science and society [11]. Each technology brings unique capabilities that, when harmonised, result in more sophisticated and versatile systems capable of handling complex tasks and producing advanced results [12].

Geographic information systems and science are taught to undergraduates across many disciplines, and researchers evaluate how this contributes to critical spatial thinking [13].

In relation to the study outlined in this article, a textbook has been developed to teach students digital technologies in natural sciences using geoinformation systems. This educational and methodological support has been developed taking into account modern educational standards and provides students with valuable knowledge and practical skills in programming, analysis and visualisation of spatial data. The project was aimed at creating an effective educational environment conducive to a deep understanding and successful application of geoinformation technologies in scientific research and practical activities of students in the context of the university. The training manual, as shown in Table 1, includes 15 theoretical and 15 practical sections.

Table 1: Content of the training manual.

No.	Theoretical content
1	Geoinformation systems
2	The ArcGIS environment
3	ArcMap, ArcCatalog, ArcGlobe and ArcScene applications
4	Using Python in the ArcGIS environment
5	The ags ru package, the IDLE integrated development environment (Python GUI)
6	Geographical layers
7	The form of files in the geographic information system
8	Functions, classes, modules of ArcPy
9	The ArcGIS database
10	Geographical atlas and album
11	Working with tables in geographic information systems
12	2D and 3D objects in ArcGIS Pro
13	Creating the basis for spatial analysis
14	Spatial statistics, patterns, data distribution
15	GIS functions in the transport system
Content of the practical part	
1	Installing ArcGIS
2	Working with the ArcGIS environment
3	Working in the ArcMap, ArcCatalog environment
4	ArcPy work. Using the Python programming language
5	Working with IDLE in ArcPy

6	Getting started with the ArcPy layer
7	The form of files in the geographic information system. Mapping in ArcGIS
8	A set of Python tools in ArcGIS
9	Working with numerical aggregate data
10	Working with the map with Python in ArcGIS
11	ArcPy attributes and working with tables
12	Creating 2D and 3D objects in ArcGIS Pro
13	Building a spatial analysis model
14	Working with spatial statistics, patterns and data
15	Planning and preparation of spatial analysis for the city of Astana, Kazakhstan

A training manual for students of natural sciences titled *Creating a geographic information system using the Python programming language* has been developed and released. Digital educational resources *Geoinformation system* have also been prepared for students, and a copyright-protected certificate has been obtained.

L.N. Gumilyov Eurasian National University has introduced and implemented the GIS course as part of the elective discipline for natural science specialists *application of digital technologies by industry*. The discipline allows students to choose training courses according to their interests and needs, flexibly form the curriculum and deepen their knowledge of GIS. In the context of the course of geoinformation systems as an elective discipline, students can expand their skills and knowledge in spatial analysis, programming and the application of geoinformation technologies.

As mentioned above, a total of 166 students took part in the study, with 76 students in the control group and 90 students in the experimental group. Out of the 166 participants, 90 students were of the educational programmes *6B05208-Ecology and nature management* and *Ecological zoning and remote sensing* of *L.N. Gumilev* Eurasian National University, 51 of the educational programme *6B01506-Geography* of *K. Zhubanov* Aktobe Regional University, and 25 of the educational programme *6B01510-Teacher of geography and history* of *Kh. Dosmukhamedov* Atyrau University (Table 2).

Table 2: Higher educational institutions where the experiment took place.

No.	University name and specialty	Number of students	Experimental group	Control group
1	*L.N. Gumilyov* Eurasian National University, educational programme *6B05209 - Geography*	68	68	-
2	*L.N. Gumilyov* Eurasian National University, educational programme *6B05208 - Ecology and nature management*	22	22	-
3	*K. Zhubanov* Aktobe Regional University, educational programme *6B05209 - Geography*	51	-	51
4	*Kh. Dosmukhamedov* Atyrau University, educational programme *6B01510 - Geography and history teacher*»	25	-	25
Total		166	90	76

The study examined the field of geography and information technology with the use of the Python programming language to develop GIS. The focus of the study was on development of knowledge, skills and abilities of students in working with databases, the ability to compile tables, formulate queries and present results in the form of cartographic data within a geoinformation system.

Using Google Drive for data comparison, a survey of the 166 students was conducted at the beginning of the academic year, and after mastering the educational and methodological complexes for the educational programme built into the experimental group, at the end of the academic year, a final survey of 90 students of the experimental group was also conducted. Within the framework of the study, two methods were identified that allow obtaining qualitative and quantitative information from the survey for data collection. The survey included questions regarding motivation level, technological level and content level.

Table 3: Questions by levels.

Motivational questions	Content questions	Technical questions
The motivational component - There is an interest in the development of the geoinformation systems industry.	*The content component - Mastering theoretical knowledge in geoinformation systems.*	*The technological component - The ability to work with geospatial databases to create a map using the Python programming language in ArcGIS.*
Do you think that the use of a geographic information system (GIS) is relevant nowadays?	Do you know the Python programming language? What is GIS?	What is a layer? What is ArcPy?

Do you think it is advantageous to use a geographic information system in the learning process? Have you tried the GIS program? How effective is the GIS program support? Do you want to learn how to create GIS programs?	What GIS data models do you know? In what area is GIS used? Have you tried using Python in the ArcGIS environment?	Is it possible to make a request in ArcPy? Which command do we use to change the color of countries in ArcPy? What query do we use when adding layers to ArcPy?

A model of integrating geoinformation systems into the educational process aimed at teaching digital technologies has been developed. The research methods and tools used include theoretical analysis, empirical research and statistical analysis. The forms of study included lectures, practical exercises and independent work of students. Teaching methods included the use of storytelling, discussions, project-based learning and distance learning.

RESEARCH RESULTS

The participants of the experimental group acknowledged that using ArcGIS contributes to improving their spatial thinking and deeper mastery of the subject area.

In the process of reconciling empirical data with theoretical frameworks, the use of chi-square criterion becomes the main method. The statistical approach, recognised as a tool of psychological and pedagogical research, plays a crucial role in the applied analytical system. The authors of this article treat it as a reliable link that has increased the depth and reliability of the analysis, contributing to an accurate and systematic comparison of expected and observed results.

Theoretically, the expectation was that the frequencies would be distributed equally, i.e. the frequency would be distributed proportionally between both groups. To check that a table of theoretical frequencies was constructed, with the row amount multiplied by the column amount and the resulting number divided by the total amount (n) (Table 4 to Table 6, and Figure 2, next page).

Table 4: Results by motivational level.

Table of distribution of theoretical frequencies				
Groups	Low level	Average level	High level	Total
C	(76 × 33):166 = 15.01	(76·× 79):166 = 36.16	(76·× 54):166 = 24.72	76
E	(90·× 33):166 = 17.89	(90·× 79):166 = 42.83	(90·× 54):166 = 29.27	90
Total	33	79	54	n = 166

Table 5: Results by content level.

Table of distribution of theoretical frequencies				
Groups	Low level	Average level	High level	Total
C	(76·× 38):166 = 17.39	(76·× 84):166 = 38.45	(76·× 44):166 = 20.14	76
E	(90·× 38):166 = 20.60	(90·× 84):166 = 45.54	(90·× 44):166 = 23.85	90
Total	38	84	44	n = 166

Table 6: Results by technical level.

Table of distribution of theoretical frequencies				
Groups	Low level	Average level	High level	Total
C	(76·× 36):166 = 16.48	(76·× 89):166 = 40.75	(76·× 41):166 = 18.77	76
E	(90·× 36):166 = 19.51	(90·× 89):166 = 48.25	(90·× 41):166 = 22.23	90
Total	36	89	41	n = 166

To compare the empirical data with the theoretical ones, the Pearson's chi-square criterion was used, which is one of the most universal criteria in psychological and pedagogical research, regardless of the number and difference of research topics.

df = (R-1) x (C-1), in the case presented here, the degree of freedom in number
df = (R-1) x (C-1)=(3-1)(3-1)=4,* the significance level that one wants to keep is 0.05. The critical table shows the value of the chi-square criterion below:

$\chi^2_{кr}$=9.488.

The importance of control in this case:

$\chi^2_{mot} = 7.49$
$\chi^2_{con} = 8.12$
$\chi^2_{tech} = 8.7$
$\chi 2_{cr} = 9.488$.

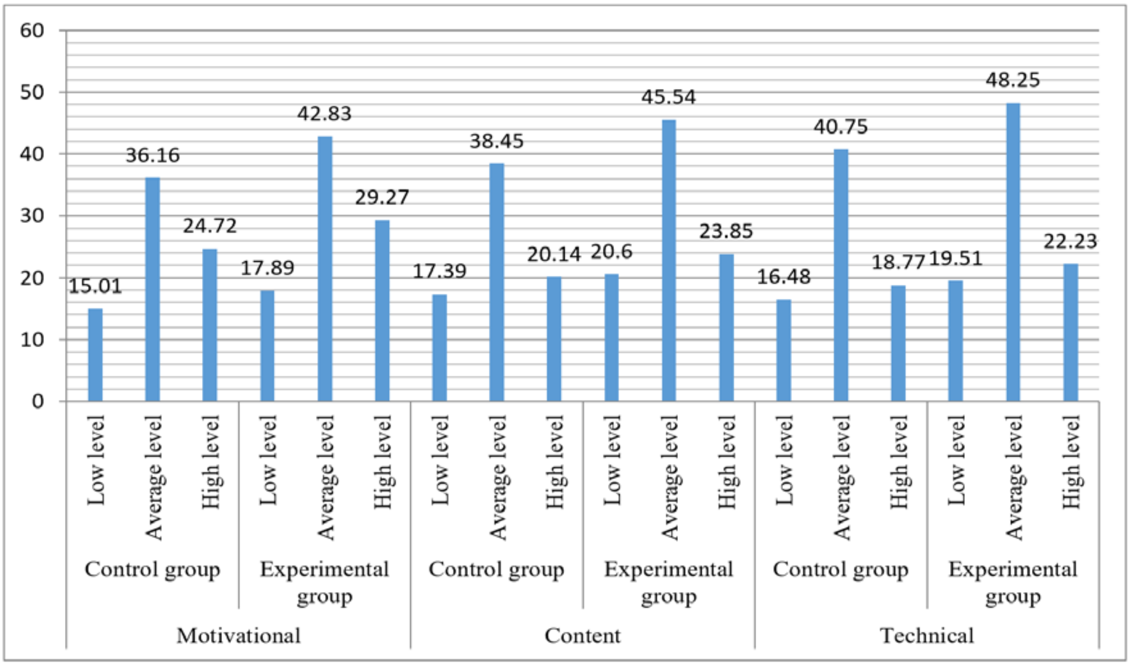

Figure 2: Results by motivational level.

CONCLUSIONS

In order to determine the results of training geoinformation systems in higher educations institutions, the following tasks were performed:

Based on the experience of the world's leading universities, the educational programme of higher educational institutions of the Republic of Kazakhstan includes 15 theoretical and 15 practical sections in the GIS course content.

A training manual for students of natural sciences *Using the Python programming language in creating geoinformation systems* has been developed and released. Digital educational resources *Geoinformation system* have also been prepared for students, and a copyright-protected certificate has been obtained. As a result, the training of professionals proficient in geography and information technology, who are able to use the Python programming language in creating GIS, have the knowledge, general skills and skills to work with databases, create tables, queries, and display results on a map in a geographic information system was justified.

The course on geoinformation systems has been successfully implemented as an elective discipline *digital technologies by industries*. As a result, it allows students to choose educational modules in accordance with their professional interests and the needs in the subject, and it contributes to the flexibility of the formation of an individual curriculum. Within the framework of this course, students will be able to deepen their knowledge in the field of geoinformation systems and acquire skills related to spatial analysis, programming and the use of modern geoinformation technologies.

The study involved 166 students from three universities of the Republic of Kazakhstan. The experiment was conducted with 90 students. Google Drive was used to compare the results of the student survey undertaken as part of the study. The questionnaire included questions related to the level of motivation, technical-technological level and content level. The result of the Pearson chi-square criterion was determined by the levels of students using the system. During the experiment, theoretical, empirical and statistical research methods and tools were used. Lecture, practical work, independent work, narrative, discussion, project-based learning, distance learning forms and teaching methods were used.

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