Methods of Using Geoinformation Technologies in Mining Engineers' Training

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TABLE OF CONTENTS

List of Illustrations

Figures

Tables

INTRODUCTION

Rationale. The modern engineer is a specialist who is able to find new solutions to technical problems by means of combining applied knowledge, mathematics, and inventive activity. The content of the engineer's activity provides the proof that engineers are some of the main creators of the noosphere in terms of material culture and applied science. They are responsible for scientific and technical advances and consequently for mankind's technological welfare. The nation training the largest number of highly qualified engineers will lead the way in the 21st century (1). The Ukraine is interested in increasing the amount of engineers in the country; this fact is reflected by the extra privileges afforded to school leavers who enter higher educational institutions (HEI) to get a degree in engineering.

Mining engineers, or engineers of mining operations, are engaged in mining iron, nonferrous, rare metals, manganese and uranium ores, coal and other nonmetallic minerals in the Ukraine. They are considered to be the subjects of Ukrainian Law. In order to increase the prestige associated with their job, the state "facilitates (development in) the coal and mining industry (…) and creates conditions for highly productive and safe work (by) introducing mechanization and new technologies into industrial processes" (2). The Ukrainian Mining Law provides legal and organizational principles that act as a framework for mining engineers' activities; it also defines the state policy with regard to mining enterprises' sustainability and advocates the type of training needed to create highly qualified staff for the mining industry.

The first principle is focused on increasing sustainability within mining enterprises. It requires mining operations to be, conducted according to accepted emission limit values, radiation, and environmental safety provision during mining operations; it also insists on reclaiming land for agricultural use after mining according to the Ukrainian Land Code. The major environmental requirements, harmful impact prevention, and environmental safety in mining are treated not only as separate articles in the Mining Law of Ukraine, but also as mandatory components of an environmentally conscious mining engineer's training program. The second principle concerns the training of highly qualified mining specialists to meet the recommendations of the methodological commission (branch 0503 "Mineral Mining" (4)) and should be realized through the development of new education standards based on the competence approach. This will ensure they meet the demands of the national qualification framework, ensuring lifelong self-development and self-improvement. It also deals with the introduction of research and/or innovation activities, making decisions under difficult or unpredictable circumstances that require new approaches, and forecasting etc. (5) based on the complex use of information and communication technology (ICT).

Various aspects of mining engineers' training have been covered in works by N. M. Bidiuk (6), N. P. Medvedovska (7), (comparative analysis of professional training), S. Ye. Blokhin (8), O. V. Derevianko (9), (professional competence formation), L. I. Zotova (10), O. F. Ivanov (11), O. O. Rusanova (12), L. M. Sadriieva (13), L. B. Shumelchyk (14), (ICT-assisted training), Yu. B. Baikovskyi (15), O. L. Herasymchuk (16), N. V. Zhuravska (17), S. O. Zelivska (18,19), O. M. Krivoshapkina (20), A. A.

Nasonova (21) (the pedagogical system of human safety support, environmental culture and competence formation).

A specialist's environmental competence formation has been the subject of research at different levels: general education in environmental culture and consciousness S. V. Alekseiev (22), A. O. Hlazachova (23), L. S. Hlushkova (24), N. V. Hruzdeva (25), S. V. Sovhira (26), Michael K. Stone (27); general professional levels in environmental awareness (Zenobia Barlow) (28), O. V. Hurenkova (29), David W. Orr (30), I. V. Petrukhova (31) as well as a specific focus in environmental competence (Carmel Bofinger) (32), B. E. Harvey (33). Thus, a complex solution is called for in order to solve the problem of environmental competence; this needs to involve a means to determine its content, structure, and position in the system of professional competences, levels, criteria, and formation indicators.

In the Ukraine, the use of IT in mining engineers' training is urgently needed in order to create economic, social, and cultural development. The Ukraine law, "On basic principles of creating the information society in Ukraine for 2007–2015", indicates how to create an ICT-oriented educational system in order to form a well-rounded personality; this law therefore, provides every person with an opportunity to receive the same education and skills (34). Therefore, the national educational strategy aims to update the training content, forms, techniques, and means by introducing up-to-date ICT and electronic content into teaching and learning activities by 2021. Educators have made it their priority to introduce modern ICT in order to improve training and increase education availability and efficiency, which will, therefore, enable the younger generation better able to live in an information-led society (35).

Therefore, creating a mining engineer's environmental competence, based on the competence approach, calls for the substantiated choice and development of methods to use ICT in training in order to facilitate environmental competence. One of the possible ways of solving this problem is by exploring what the application of geoinformation technologies actually means. Geoinformation technologies consider the location of a mining enterprise's production facilities, mineral stock, and waste dumps at all levels. This includes the tracking run-off and return air filtration when introducing advanced technologies into mining; simulating a sanitary and hygienic zone between a mining enterprise and a residential area, as required by law; taking steps to prevent subsidence, inundation, swamping, salting, drying, and surface littering from industrial waste; preventing negative impacts of water discharge from mine workings onto ground water levels and surface water objects; monitoring waste levels and pollutants discharged into the environment during mining operations; preventing accidents associated with burst and accidental emissions as well as releases and so on..

Methods of applying geoinformation technologies were dealt with on the following levels: specialized secondary education for upper-form students (N. Z. Khasanshyna (36)); professional training of specialists in geography, geodesy, cartography, and a land use-system (R. D. Kulibekova (37)); professional training of specialists of other training fields (L. Ye. Hutorova (38), I. V. Lytkin (39), A. M. Shylman (40)). However, the problem of geoinformation technologies application as a means of forming a future mining engineer's environmental competence has not yet been considered.

Therefore, there is a requirement to solve contradictions between:

- The need to reconstruct standards of higher education professionals' training based on the competence approach and to develop a system of competences for future mining engineers.
- A state order for training highly qualified professionals, who are able to ensure the sustainable development of the mining industry and rectify the lack of a developed integral system to create environmental competence in future mining engineers.
- The potential to use geoinformation technologies in training and to amend the lack of developed methods in their application with regard to environmental competence.

The authors of the monograph find it reasonable to focus on the following issues:

1. To analyze sources concerning environmental competence formation and the application of geoinformation technologies in professional training for mining engineers.
2. To prove the need to develop a model for the use of geoinformation technologies in environmental competence.
3. To define the content, components, criteria, and levels that should underpin environmental competence.
4. To develop and describe the basic components of the methods used in the application of geoinformation technologies to form environmental competence and to check its efficiency by experiment.

The monograph also touches upon the issues surrounding the training of mining engineers with regard to the formation of environmental competence on the basis of geoinformation technologies.

The solution to the problem of creating environmental competence in future mining engineers is complex as it involves many elements such as determining its content, structure, and place in the system of professional competences; formation levels and measuring criteria; the substantiation and development of methods to facilitate environmental competence through the use of information and communication training technologies. One of the most promising solutions to this problem is the application of geoinformation technologies.

This book targets scholars, university lecturers, students, doctoral candidates, postgraduates, and everyone interested in the application of information and communication technologies in the teaching process.

The research provided here does not examine all angles with regard this particular problem and the scientific inquiry on these issues needs to be extended in the following directions: the development of theoretical and methodological foundations of competence-oriented training; working out methods of teaching geoinformation technologies to future geography teachers; improving mining engineers' environmental competence in industrial training.

CHAPTER ONE

THE STRUCTURE OF METHODS OF APPLYING GEOINFORMATION TECHNOLOGIES WHEN CREATING ENVIRONMENTAL COMPETENCE IN FUTURE MINING ENGINEERS

Relying on Yu. V. Tryus's research (41, p.234), we regard the application of geoinformation technologies as a means to create environmental competence in future mining engineers. This implies a system of interrelated organizational forms, methods, and means of training used by the teacher to realize these technologies at every stage of competence formation in order to achieve the expected result.

The application of geoinformation technologies as a means to create environmental competence needs a detailed training content that is not specified in the model at every stage of its formation. Taking into account the fact that at the first and the third stages the creation of environmental competence occurs in the course of teaching standard subjects, it is, therefore, necessary to work out the content of the special course of study, Environmental Geoinformatics in the second stage.

The development of methods to teach Environmental Geoinformatics plays a key role in the application of geoinformation technologies, as the second (formation) stage is considered the main one in the special course training. This is why it is of great importance to analyze its constituents, weak points, and problems that affect its efficiency, as any further development is impossible without first overcoming these difficulties.

The traditional model of the training system is a five-component model by A. M. Pyshkalo (42), which implies that training system components create an integral whole with definite inner connections according to the system approach. The methodological system of training is made up of hierarchically connected components: content, training goals, methods, means, and organization forms (Figure 1–1). The system functions are subject to the laws of the internal structure of the system itself, when a change to one or several of its components will cause the whole system to change.

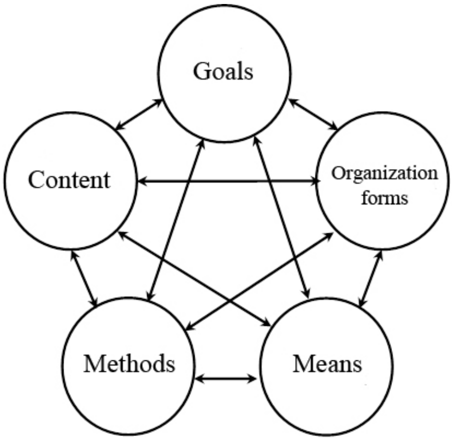

Figure 1–1. The structure of the training method system (according to A. M. Pyshkalo)

In our consideration of the components from the traditional method system of training as methods, organization forms, and means of training, we agree with L. O. Chernykh that they compose a subsystem of the integrated system, which is called *a training technology* (43). The scheme of the method system structure is shown in Figure 1–2 and the technological subsystem is dotted.

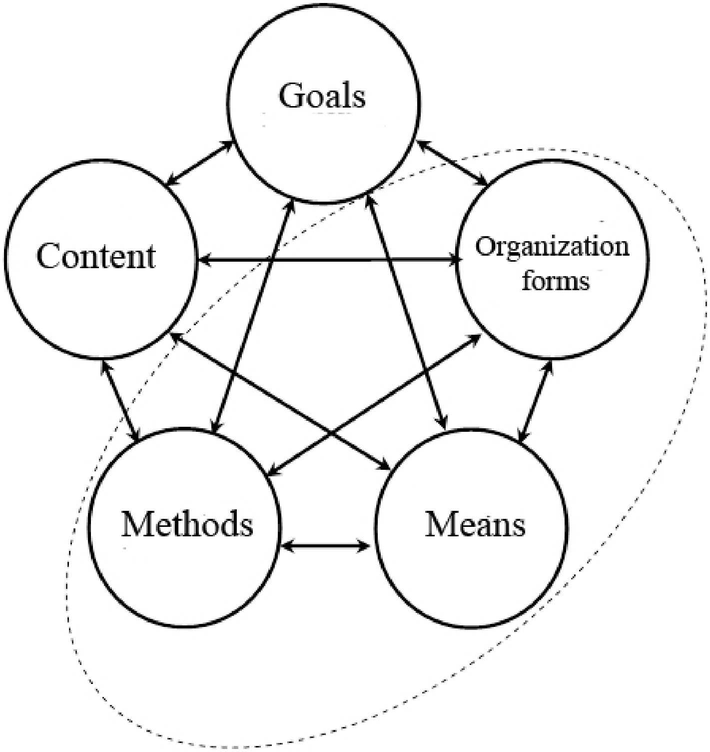

Figure 1–2. The structure of the training method system with the "training technology" subsystem dotted

Making the training technology a separate component of the method system of training is determined by the close interrelations between its components as "the conclusion of the theoretical generalization of pedagogic and method materials" (42, p. 42) forms the method system structure, in which the training goals and content influence the technology components (44, p. 25).

"It is possible to admit that radically new means of training changing the ways of information transfer and expanding the training potential lead to reconsideration of the content, forms and methods of training and can indirectly influence the training goals" (45, p. 7). This remark was made almost ten years before the mass introduction of computers at school. Yet, from a present-day perspective, we can assume that it implies all basic ideas of creating and substantiating the method system of training for Environmental Geoinformatics as computers now determine the content, training goals, methods, and organizational forms in modern higher education institutions.

The use of computers require the creation of a training technology and determine the choice of corresponding computer-oriented organization forms and methods of training. Additionally, the theory, methods, and means of geoinformation technologies make up the basic content of training and determine its goals. Thus, these modern means of applying geoinformation technologies form the foundation of the method system of teaching Environmental Geoinformatics as shown in Figure 1–3.

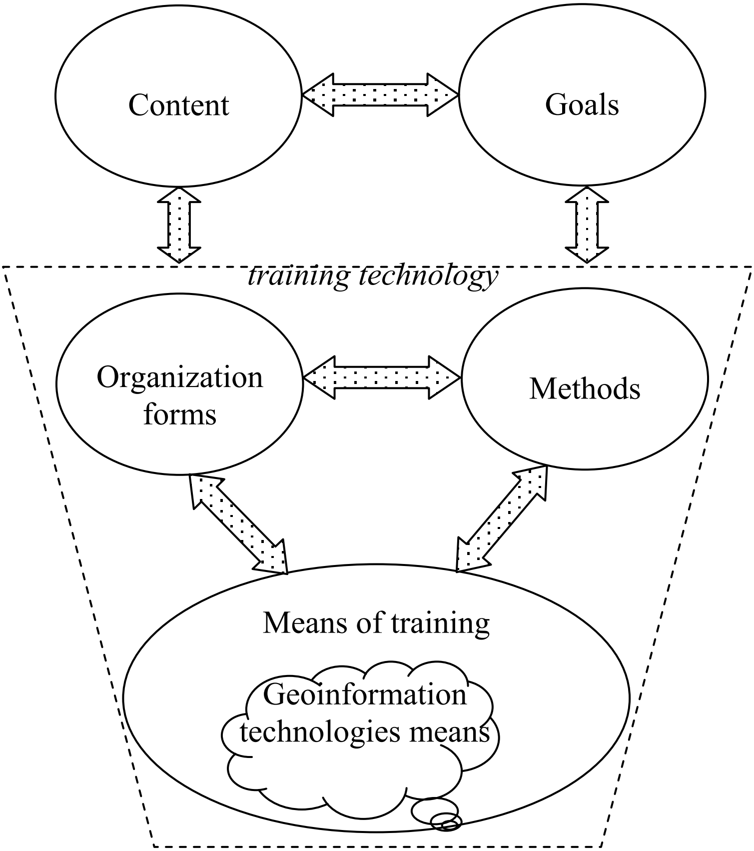

Figure 1–3. The structure of the method system of teaching Environmental Geoinformatics

By making the technological subsystem a component of the method system of the special course teaching, it means it is possible to indicate the interrelation of its components: content, goals, and technology. During the creation of the method system to teach the special course, Environmental Geoinformatics it was necessary to:

- Consider the professional orientation of future mining engineers by choosing the training content and means of geoinformation technologies aimed at creating sustainable development within the mining industry.
- Ensure the applied environmental orientation of training through the use of system-defined considerations of techniques and methods when applying geoinformation technologies to an environment-oriented activity.
- Forecast the results of the pedagogic impact of the environmental competence components contained within the Environmental Geoinformatics module and provide suggestions to develop the use of geoinformation technologies in further professional training.

So, on the assumption of this structure, we have distinguished the components of the method system of training as the content, goals, and technology.

A goal of training is an idealized prediction of training results or, in other words, the results that both students and educators want to achieve. The competence approach implies training through gaining knowledge and skills, as well as attitudes and behaviors. This creates three basic groups of interrelated goals:

1) Educational (forming students' scientific knowledge, as well as general and specific training skills)
2) Developmental (developing students' language skills, thinking, memory, motion, sensory systems and so on)
3) Morale building (forming students' worldview, moral principles, aesthetic culture, and so on)

The principle goal of the developed method system, which should be be projected onto the special course goal, is to create environmental competence through the facilitation of specific knowledge and skills relating to the application of geoinformation technologies. Students should learn how to embed this in both their educational and, later, in their professional activities.

The goals of the special course, Environmental Geoinformatics are determined by the following tasks:

- Introducing basic models and methods of geoinformatics
- Mastering modern geoinformation technologies in their professional activities
- Forming environmental research skills using geoinformation technologies.

The training content implies a pedagogically grounded, logically structured, and textually fixed approach focused on presenting scientific data in a shortened form; it also requires the training activity of both educators and students to be centered on mastering all the components of the professional training content of the required level or field (46, p. 155). The degree of mastery of these training components can be assessed by the results of the education process. This process, according to the Ukrainian Law "On higher education", is "a total of knowledge, skills and other competences acquired by a person in the course of training following some educational and professional, educational and scientific programs, which can be identified, evaluated and measured" (47, Article 1). The training content of Environmental Geoinformatics can be determined considering these common principles, as well as more specific information-related principles (48, p. 70):

1. The principle of unity with regard to the educational, developmental, and morale building functions of training indicates that it is aimed at a person’s overall development because knowledge and skills, as well as moral and aesthetic qualities form the foundations of life and social behavior (49, p. 713). The realization of this principle is determined by the goals contained within the delivery of Environmental Geoinformatics which indicate the acquisition of environmental competence components.
2. The principle of the scientific character of the training content and methods reveals the interrelation of the geographic ICT theory, a mining engineer’s environment-oriented professional activity, and the research approach applied to the organization of training. The special course content should include sections and themes essential for a mining engineer’s professional activity irrespective of the technology used to teach Environmental Geoinformatics.
3. The principle of the systematic character and consistency provides for a reliance on the training content, models, and methods of those subjects taught prior to the special course (Informatics and Ecology). In addition, the further application of geoinformation technologies requires being taught professional training, as well as course and diploma papers.
4. The principle of knowledge solidity implies a well-grounded acquisition of knowledge and skills, a consistent and permanent memory of the acquired knowledge, as well as its free reproduction and usage in practice. This is realized through a variety of complex didactic training methods (explanatory-illustrative, reproductive-research), as well as corresponding ICT training and organization forms (a project, a simulation game, etc.).

5. The principle of visualization is realized through the application of geoinformation technologies for geomodelling when teaching Environmental Geoinformatics.
6. The principle of connection of training and practice is realized by the applied and professional orientation within geoinformation technologies training.
7. The principle of correspondence to training goals indicates that the goals of teaching Environmental Geoinformatics are determined by the method system goal and the general education goal of creating environmentally competent mining engineers
8. The principle of fundamentality provides an opportunity to master essential methodological and invariant knowledge that is both durable and necessary for a future mining engineers' professional activity, as well as creating a close connection between mining education and professional practical activity; development of students' creative cognitive activity and independence. It also provides professional training that considers methods to develop the "knowledge-based economy" and create a sustainable society; it also allows for the systematic mastering of information-oriented subjects based on a profound understanding of the current state and problems of informatics (50, p. 86).
9. The principle of openness provides a chance to correct the special course content according to the training specification without disturbing the complete character of the subject's fundamental core.
10. The principle of modernity indicates that the rapid development of geoinformation technologies demands regular reconsideration of the subject curriculum in order to update its components.

11. The principle of prospects improves students' attitudes towards lifelong learning ensuring their ability to solve future professional problems.

In addition to all of this, we need to consider the principles of availability, consciousness, activity, individualization, systematicity, and so on when choosing training content..

While forming the content, it is important to determine exactly what geoinformation technologies means. They should be included in the training content and realize the principle of differentiated fundamentality developed by G. O. Mykhalin (51, p. 12) who indicates that fundamental training should be differentiated not only by the training goal but also by its means.

The special course content contains two interconnected constituents: theoretical and practical. The theoretical constituent forms students' ideas with regard to the place of geoinformatics in the system of sciences; basic tasks of geoinformation technologies in mining and ecology; methods of studying the interaction of the geological environment and technosphere; sources, models and methods of working with spatial data; methods of mathematical and cartographical simulation and visualization; environmental geoinformation systems (GIS); means and methods of environmental geomodelling in the context of rational resource use; information support with regard to the environmental safety of rational resource use and the stages of developing a system project of environmental GIS.

The practical aspect is connected with the acquisition of the following skills: registering, inputting, digitizing, and saving spatial and coordinate data; scanning and vectorizing raster pictures; using the Internet to access geodata bases; performing geocoding and attribute layer stacking;

performing general analytical operations of space-time simulation; image digital processing, digital simulation of technogenic landscapes; constructing buffer zones; making virtual models of technogenic landscapes; visualizing geomodels; applying Internet-oriented GIS; predicting the environment state and mineral material quality; classifying minerals as to their exploration extent; calculating mineral reserves; estimating mineral reserve costs; keeping records of mineral reserves as to their mining availability; designing environmental databases and regional environmental GIS.

In the general structure of the special course, Environmental Geoinformatics, practical knowledge correlates with theory in the ratio of one to two.

The special course content is composed of two conceptual modules. The first conceptual module, “Basics of Geoinformatics”, uses applied (ecology) and professional (future mining engineers’ training) orientation in order to deal with the basic notions and ideas of geoinformatics (the concepts of GIS, their functions, subsystems and classification, basic tasks to do with environmental activity in mining operations and GIS); sources and methods of inputting, processing, and storing the data (data sources, vector and raster models of spatial data, analogue and digital transformation of data, spatial data bases and their control systems); data analysis and geomodelling (general analytical operations and methods of space-time simulation, geodata classifications, landscape digital simulation, mathematical and cartographical simulation); data visualization (cartographical visualization, non-Euclidean matrix pictures, virtual reality technologies, cartographical animation); GIS as the basis of integrating spatial data and technologies (GIS and distance probing, GIS and global systems of satellite positioning, GIS and the Internet).

The second conceptual module, “Environmental Geoinformation Technologies in Mining”, aims to create environmental competence and deals with the theoretical fundamentals with regard to environmental GIS (geoinformation technologies in mining and ecology, environmental data sources, environmental geosimulation and prediction); mineral deposit geosimulation (specific features of environmental geosimulation, mineral commodity quality prediction, interpolation of geofactors, mineral deposit visualization); GIS for sustainable development of mining (methods of calculating mineral reserves, evaluation of reserves costs, calculation of reserves movement, informational support of environmental safety of mineral rational use); environmental GIS designing (working out a system project of an environmental GIS, substantiation of spatial data infrastructure, choice of geoinformation technologies means, realization of environment-oriented geoinformation projects).

The final aspect that focuses on student knowledge is a credit that is dependent on the results of current and module controls, as well as the defense of individual training and research projects in regional environmental GIS. The choice of the latter is determined by the fact that regional-specific issues have an impact on the activity content, in order to reflect the environmental peculiarities of mining in a given area.

Chapter Two

The Application of Geoinformation Technologies to Different Organizational Forms of Training

Content, and training content in particular, is always in a close relationship with a form. In philosophy, the category of content refers to the unity of all an object's components, properties, inner processes, connections, contradictions, and trends. The category of a form is a means of content existence and presentation. A form comprises the system of an object's stable connections; this means that in the method training system, forms are less dynamic than the training content. The contradiction between content and form, in the course of the method system, means that development is solved either in a revolutionary way (by rejecting the old forms and creating new ones) or in an evolutionary way (by changing a form gradually to adapt it to new conditions) (52, p. 622). In the most general sense, different training forms are a means of organization and they determine its external characteristics, namely, its time and organization modes, place, the character of interaction, and interrelations of its participants, and so on. (53, p. 965).

The Ukrainian Law, "On higher education", distinguishes such terms as "forms of training", and "forms of organizing an educational process and types of studies". Article 49 of the Law defines such training forms at higher educational institutions as intramural (full-time/part-time) and correspondence (distant). The training programme, of the special course Environmental Geoinformatics, is developed in the light of these basic forms of training—full-time and correspondence—and can be also completed part-time.

Article 50 determines the organization of forms of training at higher educational institutions (HEIs), such as classes, independent work, practical training, and tests. Basic types of training classes at HEIs are lectures, laboratory and practical classes, seminars, individual classes, and consultations. A HEI can also establish other forms of training and class types (47).

In the model that applies geoinformation technologies as a means of creating a future mining engineer's environmental competence, organization forms of training and class types are defined as organizational forms of training, that is, a purposeful, distinctly organized, information packed, and theoretically substantiated system of perceptional and instructional communication, interaction, and cooperation between lecturers and students (54, p. 316).

The choice of a training form is determined by the prevailing activity, as well as the time and place of its performance. It determines the possibility and necessity of their combination based on the methodologically grounded application of ICT in order to achieve the stated training goals. A. M. Striuk interprets combined training as a purposeful process of acquiring knowledge and skills under conditions of integrating both the classroom and extracurricular activities of teaching subjects based on applied and complementary technologies of traditional, electronic, distance, and mobile training. Following this interpretation, one should underline the intermediate role that combined training (traditional (mostly classroom) and distance (mostly extracurricular) training) has in