Structurization of educational expedition studies in the form of taxonomies

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Abstract. High volume and low level of data structuring cause problems with data processing nowadays. The scope of perspective to provide such structuring is scientific studies because, in most cases, they provide predicted measurement parameters, and it's easy to structure. As a result, the parameters that will be measured can be defined and forms prepared for completion during studies. As a result, the parameters that will be measured can be defined and forms prepared for completion during shipping. This study[3] corroborates how to handle this data in ontologies, providing structuring and interoperability of data. The case of the use of such an approach based on the expedition of real-life environmental study during Junior Academy of Sciences of Ukraine expedition is described. The approach uses Excel-based templates to be filled during the measurement of parameters. Each line in such an array represents the location or name of the search subject. An extra column is dedicated to geolocation insertion. After providing the research, such files are uploaded into the Polyhedron system, and ontology is generated. These ontologies are stored and integrated into ArcGis and can be used to present their own findings and provide basic searches by other researchers. The process of integrating a few ontologies that used a proposed template from different expeditions is described. Additional, as such studies are also used IMRAD, it is possible to use the approach of using IMRAD as the core of the expedition result's graph and use the expedition studies in the same structure as other.

Keywords: ontology · ontological journal · scientific method · science · geoinformation systems · GIS · student · cognitive IT Polyhedron

1 Introduction

Forming a student's personality adapted to modern life requires the use of new priorities in selecting methods and forms of education in the higher education

[3] This is an extended and revised version of the article [25]

sector [6, 17, 38]. Due to the need for students to process large amounts of information, the formation of their ability to think critically is a priority. Also, one of modern education's main tasks is forming the student's creative thinking [8, 36, 37]. For the educational environment, it is essential to build systematic training, which should be based on the active use of these methods in the work of specialized departments. It was provided that students more effectively studied while providing personalized studies. It is due to the interdependence of the object's parameters it studies [7].

Scientific and engineering methods are the basis of any research process [23], regardless of the specific field of knowledge. Both methods have been practiced for a long time and are now recognized by the international scientific community as the primary tools for scientific and educational – research activities.

1.1 Features and properties of the ontological systems

In this article, an "ontology" means a digital taxonomy graph consisting of nodes with specific data. All nodes are arranged in a particular hierarchical order, often referred to as a tree or graph. The node from which all branches go is called the parent. The other nodes are called subsidiaries. If there are no additional branches in the graph from the child nodes, this graph is called simple. The graph that describes concepts and their relations is called ontology. An ontology necessarily entails or embodies some sort of worldview concerning some domain. The helicopter view is often conceived as a set of concepts, entities, attributes, processes, definitions, and interrelationships; this is referred to as conceptualization [24]. Also, all ontologies consist of vocabulary and some specification of the meaning or semantics of the terminology within the vocabulary. The various ontologies are also distinguished by their degree of formality in the specification of meaning [24].

A range of open-source commercial and uncommercial tools are available for creating ontologies. They are called Ontology Editors. Today a variety of developing environments are used to create ontologies like Protégé 3.5 [4], Apollo [1], SWOOP [15], OilEd, IsaViz [2], and CIT Polyhedron. We propose to use cognitive IT Polyhedron. The core of the Polyhedron system contains advanced and improved functions of the TODOS IT platform, which were previously used to provide semantic web, systematization, transdisciplinary support, and GIS connectivity.

Cognitive IT Polyhedron can use the features of ontological interface tools [20, 31]. This system has a web-oriented interface and provides the creation of interactive knowledge systems, which provide adaptability to the thematic profile of each user subject area, activation of multiple binary taxonomy relationships, and allows visualizing the results of integration and aggregation of distributed information resources to organize user communication in an easily accessible visual form [34]. IT Polyhedron is based on a multi-agent approach. In the environment of the Polyhedron system, the construction of all chains of the process of transdisciplinary integrated interaction is ensured [34]. Due to active states being hyper-ratio plural partial ordering [18, 35]. The innovative component of

Cognitive IT Polyhedron has auditing and ranking functions. For example, previously, it has been scientifically justified to use this method to estimate water quality in reservoirs [32].

An important problem in conducting a literary review by a student: is the accumulation of “information garbage”. It is important to develop ways to solve this problem. The purpose of the article is to propose a method of visualization of scientific data, the use of which will be carried out during the application of the scientific method in previous research. The proposed approach provides the data in a structured view, and it can provide merging of similar ontology graphs with different research data.

However, not only using specific systems but also approaches and methods help provide an effective structurization. One of the helpful approaches is to provide structurization using the IMRAD approach, as noted before [27, 28, 33]. Also, one way to reach such an aim is to take a comprehensive approach to use geographic information systems (GIS) [5, 14, 22] and an ontological journal. After the structuration process and representation on GIS, the data is presented in an easy-to-handle form, easily read by standard GIS tools, and conveniently displayed to the end-user [31]. The ontological-based GIS must have complex means of synchronizing syntactic descriptions of the used objects and the statements themselves, representing specific states of the problem [21].

Therefore, the problem of structuring data exists, especially in science (where information, data, and knowledge are created). This paper aims to test the hypothesis that data obtained during educational expeditions may be structured in the form of ontology. Therefore, the tasks of the study are to develop the approach to creating templates to generate ontologies comfortably, to develop a standard template of ontologies (that in the future may be merged into a single ontology), and to develop an approach to the representation of expedition data in the form of ontology in GIS.

2 Material and method

Ontologies were created using tools of Cognitive IT Polyhedron using Ontology Editor. Two types of sheets, .xls to create structure (hierarchy of nodes; in further – structure file) and CSV to add internal information for numeric and semantic data (in further – data file), were uploaded to Ontology Editor to generate hierarchy. After generation, ontologies were uploaded to the store (if it was necessary to use specific functions, they were chosen at the download menu). Google sheets were used to store information and share it, with their further conversion into the .xls and .csv Excel sheets (figure 1).

The generated structure is displayed classically as a nodes tree, considering the relationships. An example of displaying information using a cognitive IT Polyhedron system is presented (figure 2). The structure of the information visualized in the ontological system corresponds to element 1 of figure 2. Element 2 of figure 2 is a visualization part of the ontology structure, which arises due to the presence of media files in the form of included information of the ontology.

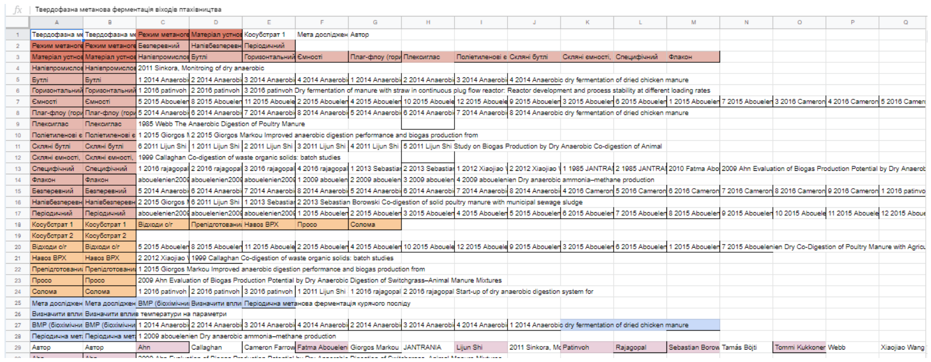

Fig. 1. Google sheet with data.

Included information on the system is opened by clicking on the graph's node. At the top of the display of embedded information is a visualization of the node's information, and below is additional textual or visualization information. For creating ranking, ontologies were used module "Alternative". An example of displaying information in the CIT Polyhedron is shown in figure 2.

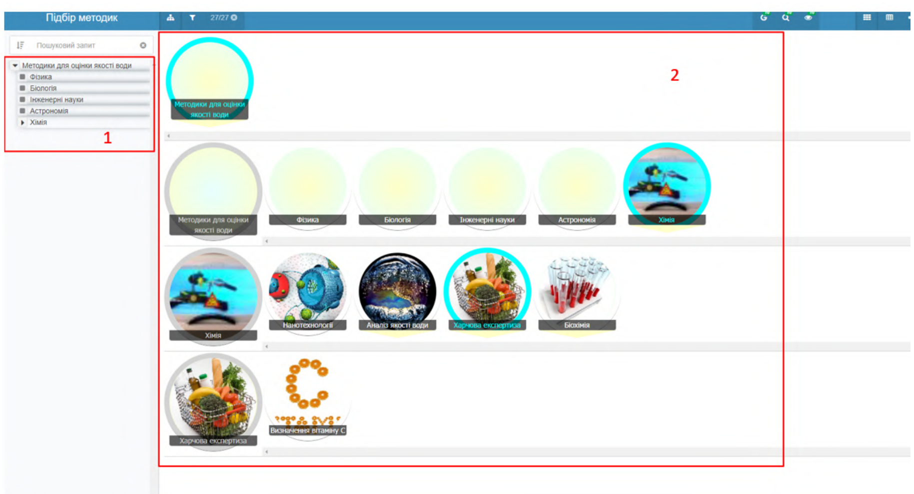

Fig. 2. An example of displaying information in the CIT Polyhedron.

2.1 Creation ontologies with module "Alternative"

Module "Alternative" can be used to provide filtering of information [30]. It was necessary to create nodes of a graph filled with semantic data grouped in semantic classes to achieve this. This function was used to create a general ontology of the wastewater treatment system and concrete ontologies of technologies devoted to finding concrete parameters of technologies. To provide this, the sheets were prepared as was shown before.

To create both ontologies, three sheets were created. As was noted before, they were the structure in datasheets, and they were provided with an additional sheet with pictures links for each node. Inputted information in the node was structured by semantic classes located in table rows. Describing node of ontology was determined by cells located in a column. At their intersection was located semantic data related to concrete semantic class and concrete node of the ontology. One node can contain one or more pictures, for example, real-life installation, principles of working, and technological scheme. For building ranking systems, only numerical values are used. To activate this function, specific ranking tool was activated during graph's storing.

2.2 Using GIS

GIS was used as a tool to systemize geo-based data. The ArcGIS software was used as such a tool [16]. The links for ontologies containing results to geodata are located as links in objects (points) in ArcGIS. However, the proposed approach may be provided using of any GIS. To provide integration with GIS graphs' links were used and inserted to object with coordinates in GIS. The method of using ArcGIS to provide it is described and discussed.

2.3 Template creation

The proposed template was developed taking into account the specifics of the graphs' generation using CIT Polyhedron and simplifying the data input process by the researcher. Therefore, the template is an excel-based table where the main parameters expected to be measured during the expedition are columns of the table, and rows of the table are used to put in the names of sampling points (that correspond to graph nodes' names). If the researcher makes a few measurements in different places, he should use a single template because one can be used to measure at multiple points during expeditions. The ontologies generated in this way may be merged into a single ontology using CIT Polyhedron tools (see discussion section).

3 Results and discussion

3.1 Principles of systematization of knowledge and development of the templates for ontology generation based on expedition data

Nowadays, a large amount of information is in an unsorted condition. This phenomenon was associated with the strong growth of humanity's scientific and technological progress.

The information created by a human is a potential "information garbage" in the case of its placement on the Internet without its structurization. Any helpful information placed in a chaotic mode does not bring any use to the user.

To reduce the amount of "information garbage", it is advisable to sort and classify information [29]. Any information contains several classified features, called "Direction", "Class", "Type", "Subtype", etc. Defining such characteristics allows us to find the information that we need quickly. Such characteristics in the ontological approach indicate semantic characteristics. For example, ecological research of river Dnieper properties the following semantic characteristics:

– Type of information: Research
– Direction: Ecology
– Class: Hydro ecology
– Subclass: Study of the river.

The information sorted on such characteristics allows the researcher to quickly and efficiently find the necessary information in this field of ecology.

One approach to information retrieval is to search for specific information elements. For example, for writing a scientific paper on the diffusion of chloride ions in the river, objects first need to find information about the concentration of chlorine ions in different places of the river and the necessary patterns of their deposition. In this case, we are interested in specific data related to a specific characteristic of this substance. Therefore it is advisable to allocate an additional subclass for any of the specific indicators.

It seems relevant to provide classification using GIS and ontology systems [12, 13, 19]. The principle of the complex approach is to embed ontologies in a point on the GIS with the author and the analysis date to consider the reliability of the result. Using geographical coordinates in a structured ontological form allows receiving the most effective access to information.

Implementing a complex approach will permit creating databases for research in various areas performed by different researchers and research institutions that store material in a structured form.

Figure 3 shows an ontological journal template for water analysis. The main information classes are pH, Cond, Min., Hardness, Cl, SO4, Pb, Fe total, Fe (II), Fe (III), and Cu, corresponding to the indicators: acidity, conductivity, mineralization, chloride content, sulfates, lead, total iron, ferrous iron, ferric iron, and copper. The names of the information classes are abbreviated according to the comparison ontology file. Templates of ontological journals for different types of ecological research have been developed and proposed for use. A general view overview of the template for creating a logbook is shown in figure 3. The template for the created ontological log is an spreadsheet file stored in CSV format.

Therefore, the results of the proposed studies are templates to be filled during expedition studies (including educational expedition studies). As graphs were built using the same or similar template, it will be possible to provide integration of graphs of the same type using a specific tool called "scenario editor" of knowledge base script editor (that is part of Polyhedron).

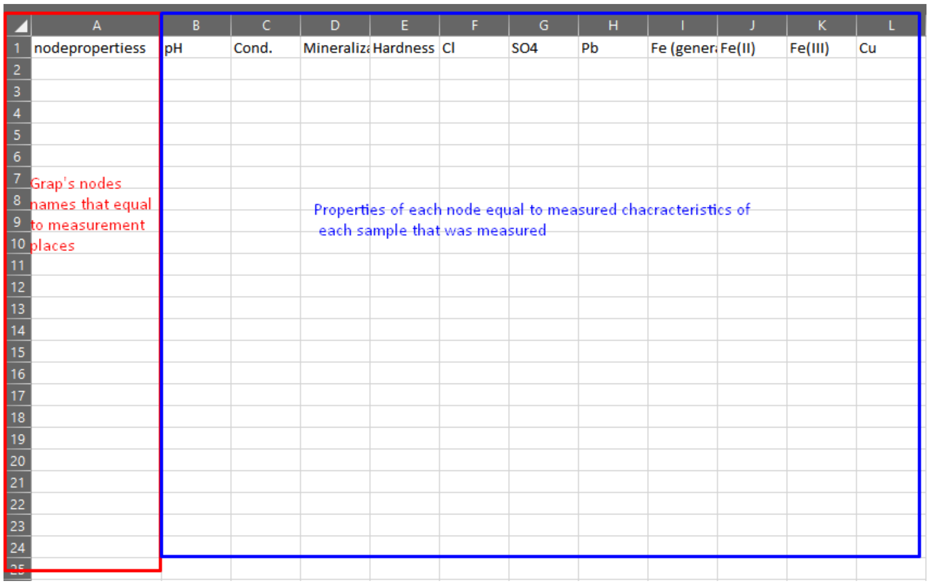

Fig. 3. General view of the template for creating an ontological journal.

The expedition studies also have their own structure based on locations where samples were taken. Ontology and GIS can provide geolocation structuring and semantic structuring (figure 4).

3.2 Creation of ontology journals

It is proposed to use ontological journals to systematize research knowledge. Ontological journals are an ontology designed for multifunctional analysis and systematization of information. A feature of the ontological journal is the separation of semantic characteristics in the study (for further structuring). The general view of the ontological journal is presented in figure 5.

The peculiarity of the ontological journal is the high level of structuring and visualization of data, the possibility of transition between related nodes, and the search for semantic connections between vertices and their elements.

Visualization of scientific data in the form of an ontological journal is presented in figure 4. The figure 4 shows that large arrays of information obtained during the study are grouped and structured, and the transition to scientific data is quick and clear. The initial data for the CIT Polyhedron are descriptions of objects, represented by many of their features. The initial data can be presented as a text file.

For preparing the ontology, it is proposed to use the Excel format tables to construct the ontological tree and nest in the ontological node's information in the ontological journal form. In figure 6, the visualization of expedition data in the ontological journal.

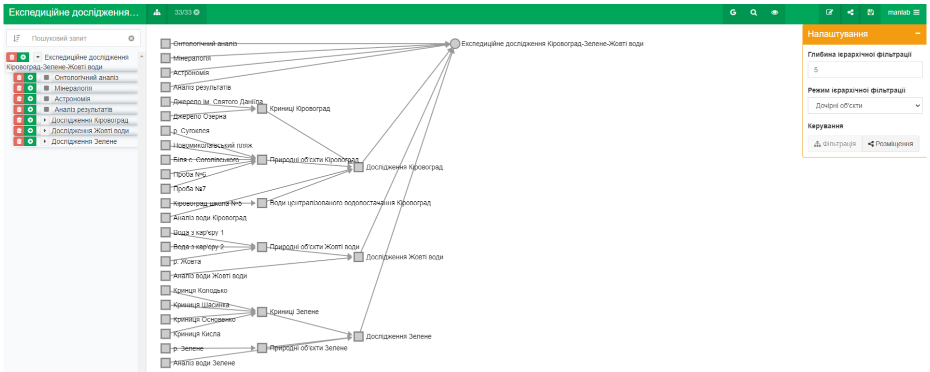

Fig. 4. Ontological structure of expedition studies.

Fig. 5. General view of the ontological journal.

The proposed graph was built using the proposed template; it allows the collection of data taken from a few sample points or a few groups in a single point (or both). In this study, four groups measured water quality data at a single measurement point. Therefore, the graph's structure allows transferring from data measured by any of the groups. Using the structure of the graph to investigate the data taken by different groups of the expedition is shown in figure 7.

3.3 Creation of a system of visualized scientific databases and further potential of its use

The principle of the complex approach consists of embedding ontologies in a point on the GIS map with the indication of the author and time of carrying out the analysis for the account of reliability and result. Placing information con-

Fig. 6. Visualization of expedition data in the ontological journal.

cerning geographical coordinates in a structured ontological form allows getting the highest quality access to information.

The development of an integrated approach will allow the creation of research databases in various fields performed by researchers and research institutions that store material in a structured form.

Structuring based on GIS provides the potential to view related information and search for patterns associated with the coordinates of the location of specific properties of objects. Further development will allow us to accumulate structured information that does not turn into “information garbage”.

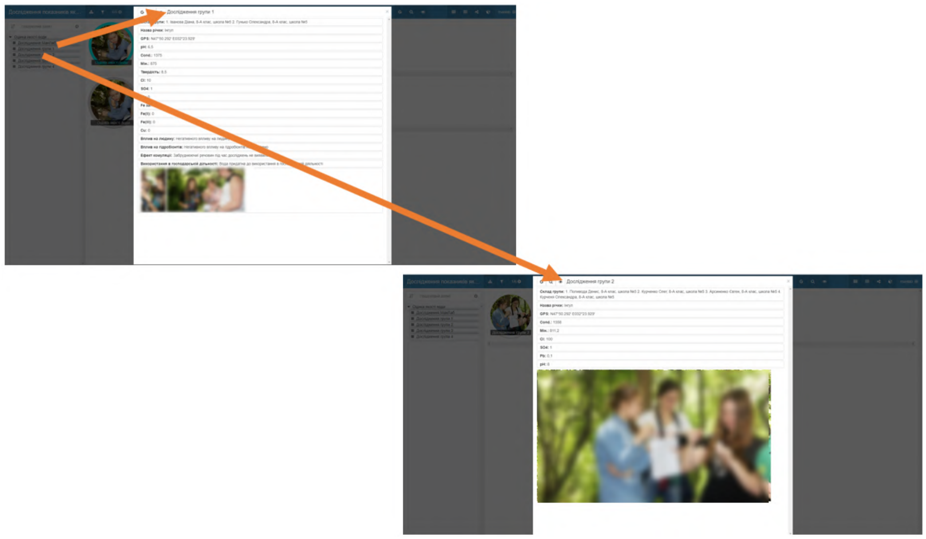

Fig. 7. Using the structure of the graph to investigate the data taken by different groups of the expedition.

Such systems are essential for developing environmental expertise and creating an environmental safety system. In the future, such systems can be fully used as the primary tool for the functioning of the eco monitoring system with the system of data analysis and forecasting.

4 Discussion

4.1 The usage of the proposed approach in terms of the scientific method

The researcher conducting a study is interested in a particular issue (formulation of the question) and conducts theoretical and literary research in this area (previous research). Despite the received information, the researcher can create a hypothesis (constructing a hypothesis) about the object under study [7]. The next step is to develop an installation for research and experimental test of the hypothesis (experiment "works"?). At this step, a student may use the proposed templated to fill up during the experimental procedure.

Quite often, the investigated installation cannot provide confirmation or refutation of the hypothesis; then, the researcher must return to the stage of preparation of the laboratory installation and make changes to it. In the case of obtaining results based on which it is possible to draw certain conclusions about the hypothesis, the results are analyzed. The results that confirm or refute the hypothesis, draw up (presentation of results). If the hypothesis was refuted, the researcher builds a new hypothesis based on the obtained data (returns to the step of constructing the hypothesis).

The formation of students' research skills following the scientific method in the educational process should begin with formulating a scientific problem or question. Formulating a scientific problem or question is determined in the context of a more significant scientific problem and meets specific criteria.

At the stage of background research, the researcher searches for information according to various criteria, one of which is the geographical relevance of the results. To find information about a particular object, the student must familiarize himself with similar research conducted previously. However, the most relevant for a young researcher is to get acquainted with scientific works that have been performed geographically close to the object of interest of the researcher.

4.2 Features and properties of the ontological systems and using ontologies to provide interoperability

CIT Polyhedron is based on a multi-agent approach. Usually, the resources on which the information is located narrowly. Combining such resources as agents of Cognitive IT Polyhedron is the ontology-oriented system that provides transdisciplinary and interactivity of any educational and scientific research. In the environment of the Polyhedron system, the construction of all chains of the process of transdisciplinary integrated interaction is ensured: a semantic content analysis of text documents; taxonomy; highlighting the properties of taxonomy concepts; formation of the ontology of the choice problem; transdisciplinary integration of contexts, based on properties-criteria concepts that determine the ontology of choice; the inclusion of documents found in the global environment through the recursive procedures of the system and the linguistic corpus [34]. Usually, the resources on which the necessary information is located have a narrow subject orientation. Combining such resources as agents in the ontology-oriented, the Cognitive IT Polyhedron system allows providing a transdisciplinary and interactive component in educational research.

Due to active states being hyper-ratio plural partial ordering [18, 35], cognitive IT Polyhedron is an innovative IT technology for ontological management of knowledge and information resources, regardless of the standards of their creation. The proposed ontology system functionality is based on information processing methods – Big Data, Data Mining, and Semantic Web [28]. We propose using this system for quick and accurate environmental management decisions such as selecting waste treatment equipment.

The innovative component of Cognitive IT Polyhedron has the availability of unique features. For example, there is a function comparison with some standards called auditing. One of the applications in ecology is the use of environmental standards to compare and determine the status of specific objects. For example, previously, it has been scientifically justified to use this methodology to estimate water quality in reservoirs. [32]. Also, it provides processing of the data related to data analysis in practical valuable fields such as environmental management [26].

In addition, it allows providing merging of graphs that are built by a similar structure. It means that using expedition templates of ontologies will provide the same type of data structurization and specific tool "scenario editor" of knowledge base script editor (an element of CIT Polyhedron). It provides the function of reading some graph and the possibility of adding to it additional data from another graph. If the structure is similar and has the same nodes and subnodes, the structure of the first graph will be used as basic and to add new subnodes from the graph being added. The process of integrating ontologies that used a proposed template from different expeditions is shown in the figure 8.

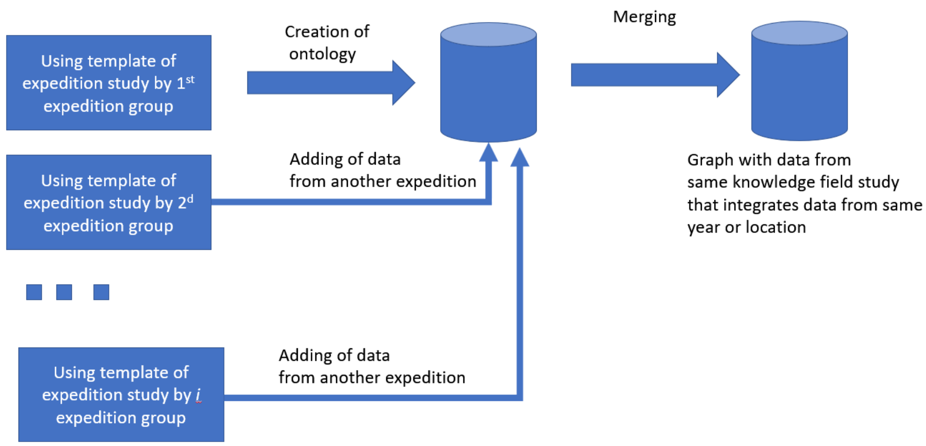

Fig. 8. The process of integration of ontologies that used a proposed template from different expeditions.

4.3 Using IMRAD to structure the expedition data

The scientific method provides expedition studies (as it was proven before in the discussion sections) [27]. The scientific studies often are described in the form of publications using the IMRAD structurization approach.

For this purpose, the set of data related to structurization of details of providing of study will be corresponded to level L5 in the concept structurization of studies using IMRAD, and details of the study will correspond to L3-L4 level. The general concept of using IMRAD to provide structurization of the studies is shown in the figure 9.

4.4 The concept of ontology journals

One way to do this is to take a comprehensive approach to using geographic information systems (GIS) [5, 14, 22] and an ontological journal. Recently, many

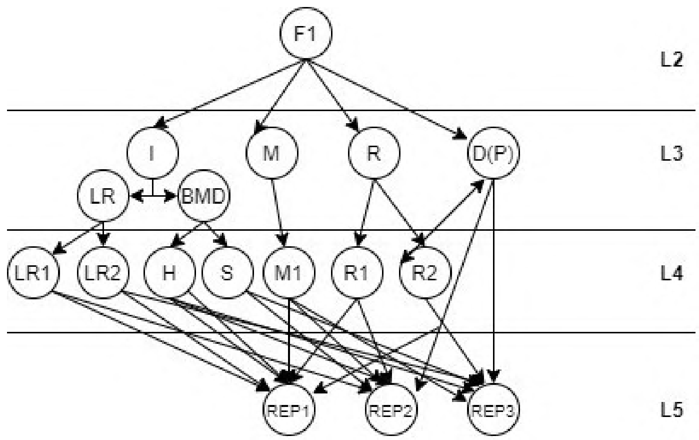

Fig. 9. The general concept of the of using IMRAD to provide structurization of the studies.

methods have been developed to visualize scientific information, considering the geographical relevance of scientific data. New in data analysis and visualization is the method of using GIS to present expedition results. The student and teacher's use of such information, which is presented in the form of the proposed approach, allows for improving the quality at the stage of previous research.

GIS is the most natural and convenient way of presenting geospatial information [31]. Structuration is important because it may provide an opportunity to find hidden information in the input data [31].

Any ontological GIS is formed based on a structured representation of the subject area of its application. Structuring is usually based on classes of objects, the properties of which determine the semantics of the subject area. The properties of objects directly allow us to determine the set of relationships between them. Multiple order binary relations are a type of hyperlink with the properties we have already mentioned: acyclicity, partial ordering, and linear ordering, and provide the formation of different classes of GIS objects of taxonomic structures. It should be noted that taxonomic categories are formed based on allocating a specific subset of objects with a common property that characterizes them all. This property may be unique to each object. However, by defining a specified class as a complex category, such a property allows us to define many binary relations "to be an element of a class" of general concepts of a class. It should be noted that single property, common to many subject area concepts, can be interpreted as a feature of these concepts or as a criterion for selecting concepts of this class [21].

4.5 Future perspectives for using the developed integrated ontological GIS

A developed ecological map envisages structuring the material according to the criteria of ecological direction – analysis of air, water bodies, soils, elements of the biosphere, etc. Criteria for environmental structuring are presented in the form of layers in ArcGIS. This approach allows the analysis of materials to group the material by the maximum number of study aspects.

The use of obtained data through this method is very relevant in forecasting results. For example, the developed map on ecological studies of the quality of soils will allow the scientist to continue researching directions of migration or vice versa – the accumulation of chemicals in biological systems. Furthermore, the proposed GIS aims to visualize environmental research by students of extracurricular educational institutions throughout Ukraine. In this case, the data of own research and other researchers conducted in the specified territory are used to carry out preliminary research.

The use of geographic information systems is one of the modern areas of visualization of scientific data, particularly in environmental research. However, the widespread use of GIS leads to the accumulation of large amounts of data on a single map. Therefore, it is essential to develop thematic GIS maps, where information is displayed concerning a specific topic.

To enter the data on the map, it is proposed to use the geo-information system ArcGIS based on the ecological map of the students of the National Center "Junior Academy of Sciences of Ukraine" (JASU). Creating GIS ontology also needs additional inputting geographical coordinates separately in the data file. Obtained graph from XML format is needed to download on a particular GIS server of Cognitive IT Polyhedron, this tecnology based on ArcGIS solutions. To place the ontology on the map, it is necessary to provide the following actions: enter data on the attributes we do need, which we previously set in the data file (figure 10, field which occurs after selecting the location of the analysis on the GIS), Enter a reference for ontology in the "ontology" cell, click the "OK" button.

ArcGIS system is a way of presenting information with graphical visualization of data linked to geographical coordinates. Visualization is based on geographical maps with the ability to create "points" of the objects of analysis. A general view of the GIS is presented in figure 11.

Zooming and control of the map viewing area are performed using "element 1". To control the scale, the following is used: a scale that shows the scale by the ratio of the virtual size to the real one (for example, 1:100,000). Also, the scale can be changed using the tools of increase and decrease (11 and I and respectively).

Control is performed using the "move" tool (EC) on the control panel of the viewing area. In addition, for automatic control, there are orientation arrows on the control panel to move the map work area in different directions.

Fig. 10. GIS data input table.

"Element 2" visualizes the scale of the map; it is a ruler that reflects a constant segment in space (regardless of the change in scale), but the numerical value of the segment changes when the scale changes (for example, 50 km, 100 km).

Map tools are presented in "element 3". The tools include "drawing" (E2), "printing" (9), and "change" (II). Finally, "element 4" is responsible for displaying the layers on the map. The layers on the map correspond to the types of objects propose to create in filling the map.

Search for a point on the map using "element 5" is carried out. The search can be performed by the names of geographical objects and coordinates. To perform a search, left-click on the address entry area and enter the coordinates or name of the geographical object.

"Element 6" is responsible for the type of map display. This element, in particular, changes the map type from political to physical.

"Element 7" is designed to display information about the program.

A system has been developed to analyse the data depending on the geographical relevance of information by integrating scientific knowledge with the geographic information system. Furthermore, it is possible to structure the material by systematizing information in ontological graphs and making a transition between GIS and ontological graphs.

Transdisciplinary research has a unique potential to apply an integrated approach to GIS and ontologies. There is a relationship between the natural sciences, which is often essential, but insufficiently studied. Sometimes it is necessary to conduct research that explains the chemistry of physical processes or when physical laws explain the migration rate of chemicals. The use of GIS tech-

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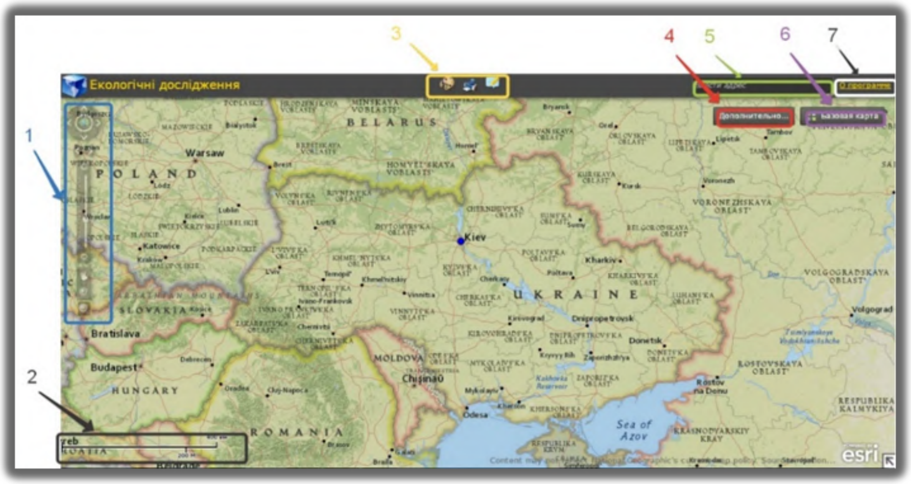

Fig. 11. General view of the GIS.

nologies allows us to conduct a transdisciplinary preliminary study on the chosen topic by the student of JASU.

Searching for relationships between the states of geospheres on the ecological map is one of the elements of ecological analysis, which is possible with the accumulation of information about the quality of different geospheres. It is necessary to separate semantic categories of the received information presented in the form of ontological journals for further systematization and the possibility of searching for the information and reducing the quantity of "information garbage" in science. The application of the proposed technology will improve the quality of the preliminary research and allow us to choose the highest quality material for its processing in the scientific activity of the student.

4.6 The role in educational programs

Currently, in Ukraine, the Concept of natural and math (STEM) education development is in force [3]. The goal of STEM education is the formation of competencies, natural science picture of the world, worldviews, and life values using a transdisciplinary approach to learning to provide the development of personality. Transdisciplinary involves a deep integration of disciplines in content and methods and anticipates a new quality of research or problem-solving. Transdisciplinary ensures close integration of knowledge areas and – hence – disciplines such as nanotechnology are emerging. In our opinion, applying a transdisciplinary approach during the actual learning process at school is hard. However, ontologies, in general and specifically, the proposed approach may provide such transdisciplinary effect (maybe not in full scale, but a significant one). For example, few fields of expedition studies may require measuring the same parameter (pH – in water and soils; conductivity in environment expeditions and physics)

In addition, the concept of the New Ukrainian school is also in force [10, 11], and it declares the development of 21st century skills and research skills. The research process is necessary for most professions today. Also, research plays a vital role in the list of 21st century skills, which are also closely related to research and analysis processes. These skills include deep learning, thinking, questioning and inquiry, citizenship, creativity, critical thinking and problem solving, leadership and personal development, communication and collaboration, digital literacy, reflection, and self-assessment [9].

5 Conclusions

The proposed approaches show how to integrate different studies into single ontology graph. New pattern for generating ontological journals has been developed. This pattern convenient for filling in expeditions in excel format. The approach of using IMRAD for structuring expeditionary research on a level with others was described. And all this creates a comprehensive solution for researchers and the ability to work in one ecosystem of solutions CIT Polyhedron. It is proposed to use a complex approach using ontologies for data structuring and GIS for displaying geospatial information and visualizing scientific data, which will improve the quality of previous student research. The medodology of linking GIS and ontologies is described in detail.

The proposed approach corresponds to the aims declared in both, Ukrainian and international pedagogical documents. It is because providing educational expeditions and further systematization of obtaining data led to the development of 21st century skills, developing research skills of students, and providing such transdisciplinary effect (even not in full scale).

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