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Comparison of ontology with non-ontology tools for educational research

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Abstract. Providing complex digital support for scientific research is an urgent problem that requires the creation of useful tools. Cognitive IT-platform Polyhedron has used to collect both existing informational ontology-based tools, and specially designed to complement a full-stack of instruments for digital support for scientific research. Ontological tools have generated using the Polyhedron converter using data from Google sheets. Tools "Search systems", "Hypothesis test system", "Centre for collective use", "The selection of methods", "The selection of research equipment", "Sources recommended by Ministry of Education and Science of Ukraine", "Scopus sources", "The promising developments of The National Academy of Sciences of Ukraine" were created and structured in the centralized ontology. A comparison of each tool to existing classic web-based analogue provided and described.

Keywords: cognitive IT-platform Polyhedron, ontology, ontology tool, system, scientific method, scientific tool

1. Introduction

Nowadays, to increase the convenience and efficiency of data processing, the active digital transformation of all of the areas of human activity [11, 13, 16, 20, 21, 37] is underway.

The scientific method is a way that researchers used for many years. However, until now, there are no approaches that can support the research process in educational research. For example, in Crus, Campos and Mattoso [4] work, the research process considered as only three cyclical stages: Composition, Execution, and Analysis. But in this article, the term "scientific method" has used according to one of the most popular versions. The scientific method can be presented by the set of stages [3] that are shown as a simple algorithmic scheme in figure 1.

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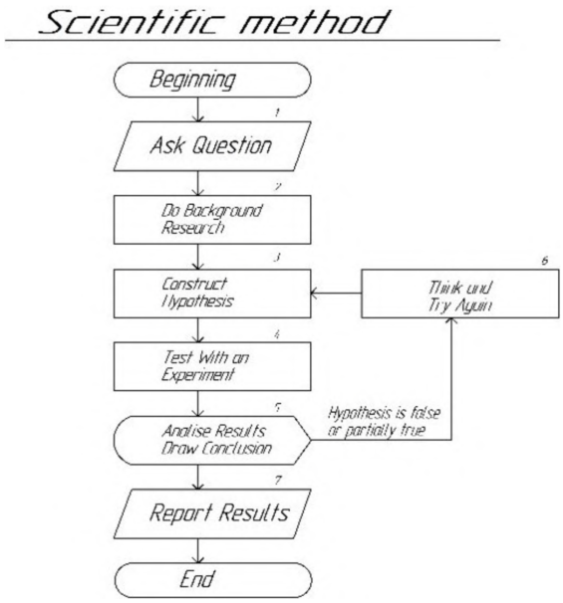


Figure 1: Algorithmic scheme stages of the scientific method.

The scientific method is often used in the educational process. Quite often, teachers require to research to complete an essay. There are various school competitions of scientific works such as the competition of scientific articles of the Junior Academy of Sciences of Ukraine, international competitions, those provided by international programs and other [36].

Often it is difficult for students and pupils to perform a scientific method and therefore, to simplify it, several authors suggested the use of ontological systems [1, 2, 4–6, 17, 22, 24, 33, 34, 38, 41, 42]. But they did not use on all stages of scientific methods used during educational researches.

It is possible to use a digital ontological-based approach to improve structuration, interactivity. Smith [33] believed in the effect that the authoring and maintenance and evaluation of scientific ontologies is an incremental, empirical, cumulative, and collaborative (i.e., precisely, scientific) activity that must be carried out by experts in the relevant scientific domains. Ontologies has used to sovling of practical oriented problems based on formalization of the contexts [26] and for creation of repositories [18].

In this article, an "ontological tool" is a term, that means some software or web system, that consists of nodes with specific data and provide solving of some problem during educational research. The node from which all branches go is called the parent or root. The top from which no ribs protrude is called a leaf. The other nodes are called child nodes. If there are no additional branches in the graph from the parent node, then this ontology is called simple. Also, a characteristic feature of ontologies systems is that multiple ontologies can be filled with concepts of various levels of complexity [34].

Ontologies have been using to visualize the results of the already performed experiment. In Crus, Campos and Mattoso [4] work, an ontological system named "Open proVenance" was developed. The root node in their ontology is the name of the experiment, from which withdraws names and surnames of specific performers and their role in the study, and the leaf node is a specific measured indicator, and its value (for example, pH 1). The system is based on the "Open proVenance" Model and the Unified Foundational Ontology. This ontological system can be useful only on the "Test with an Experiment" stage of the scientific method.

To create the structure of the all research process, an ontological system called "Elements of a common ontology of scientific experiments" (EXPO) [4] had developed. The root node in such application is the name of the research with its metadata (hypothesis, goal, conclusion etc.), from which depart factors (the child nodes) that may affect the experiment and its result. The leaf node is a specific scientific experiment, and its attributes indicate its name (a precision measurement of the mass of the top quark). EXPO based on the W3C standard ontology language OWL-DL. This ontological system can be useful only at the stage of "Test with an Experiment" and "Analyse results and Conclude" of the scientific method.

Ontology constructor MoKi [17, 41] developed for creating a structured ontology from Wikipedia articles and devoted to providing a literature review. The user can present the creation of their ontologies based on the Wiki articles he needs during the literature review. However, in any ontology created using Moki, there no root node, and all of them are looped. Nodes in Moki are a Wiki article connected to the other child node (other wiki articles). Moki is multiplatform and supports various ontological generators (Amine, Protégé, etc.).

It can be useful in the "Do Background Research" stage of educational researchers. At the same time, it is limiting by the Wikipedia database.

There are also more specific ontological systems designed for the scientific method. For example, an ontological database "Gene Ontology" [33] had developed and designed to obtain detailed information about genes. The root node in such application is called the gene classifier from which branch the filters (child nodes) used by geneticists (e.g. biological process, cellular component, molecular function, and others). The leaf node is a specific gene with its name (e.g. ABIN2-NFKB1-MAP3K8) and attributes which are keys semantic characteristics that describe the gene (e.g. Definition, Gene products, Synonyms, Ontology ID space, and others). The system based on the Open Biomedical Ontologies repository. It can be useful on the "Do Background Research" and "Analyse results and Draw conclusion" stages, but can be helpful only for the specialists in the genetic field.

All these ontological systems will be useful only at certain separate stages of scientific method such as "Do background research", "Construct Hypothesis" and "Report Results", and in most cases only for specialists in separate fields. So, none of the ontological systems previously proposed couldn't offer a universal and complex method to provide digital cloud-based support of educational researches. Also, all these systems haven't integrated. That means, all these systems cannot fully interact with each other's ontologies. Users must choose between them or feel discomfort memorizing and switching between them. The results of the comparison of ontological systems in the scientific methods have shown in table 1.

Besides, a common disadvantage of all considered systems [1, 2, 4–6, 17, 22, 24, 33, 34, 38, 41, 42] is unsuitability for use by pupils and novice researchers due to the complexity of using. For example, "Open proVenance" requires using both nodes and classes, which requires additional specific knowledge and additional time to create an ontology.

So, it seems relevant to provide digital support of educational researchers provided by the scientific method using uncomplicated and understandable tools. Unlike observed systems,

Table 1
The results of the comparison of scientific ontological systems

Name of ontology instrument	Root node	Leaf node	Was built on	Using on scientific method stages	Authors
Open proVenance Ontologyt	Name of the experiment	Measured indicator its value	Open Provenance Model and the Unified Foundational Ontology	Report the results of experiment and test the experiment	Sergio Manuel Serra Crus, Maria Luiza Machado Campos and Marta Mattoso
MoKi	There no initial node and all of them are looped	Wiki article in ontological form	Multiplatform and supports various ontological generators	Report the results and test the experiment	Alessio Bosca, Matteo Casu, Mauro Dragoni and Andi Rexha
EXPO	The name of the experiment with its metadata	A specific scientific experiment	Based on the W3C standard ontology language OWL-DL	Test with on Experiment and Analise results of experiment	Larisa N. Soldatova, Ross D. King
Gene Ontology	The gene classifier	Gene with their name	Based on the Open Biomedical Ontologies repositorys	Report the results and test the experiment	Barry Smith

tools developed using IT-platform Polyhedron are simple to use, and it is possible to create all primary instruments in one environment.

This paper aims to develop the system of the most common ontology-based tools used by pupils during educational researches using the scientific method characterized by advantages compare to non-ontological-based tools. To provide it, IT-platform Polyhedron has used due to its simplicity. These functions can provide semantic web, systematization, internal and external searches [28] and transdisciplinary support.

This system is multi-agent, and internal sources can be used as agents. In such a way, IT-platform Polyhedron allows to provide of transdisciplinary and interactivity of educational research[28, 30]. In the environment of the Polyhedron platform, the construction of all chains of the process transdisciplinary integrated interaction is ensured [39].

Besides, cognitive IT-platform Polyhedron has all advantages of the ontological information representation [9, 23, 25]. The ontological interface has provided by the procedure of activation of multiple binary taxonomy relationships. It is an intelligent means of user interaction with an ontology-based information system [39].

The cognitive IT platform Polyhedron platform can provide the digitalization of the scientific method in the learning process. Also, this system can be useful for the education process in general by creating a centralized Information web-oriented educational environment [28, 31].

All proposed instruments can be used together with different modern educational and scientific methods like an augmented reality [14, 15, 32, 40], and distance learning [19, 43].

2. Materials and methods

For creating digital instruments, the sheets with data have loaded to editor4, the part of the cognitive IT platform Polyhedron. After that, the generation of the graph nodes with its characteristics have carried out. To provide information storage and exchange Google sheets were used to store data, with their further conversion into the .xls and .csv Excel sheets (see figure 2).

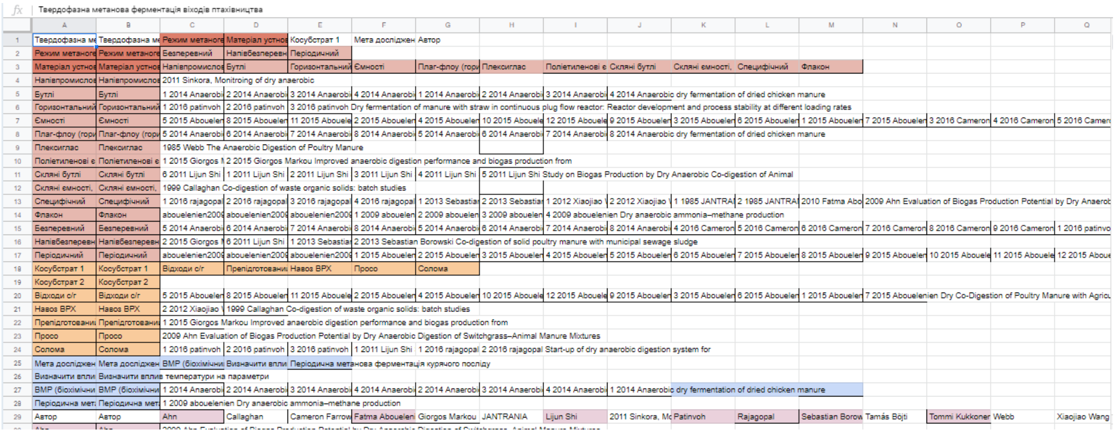


Figure 2: Google sheet with data.

The obtained documents have used to create the ontological structure .xml and to fill the ontology graphs with semantic and numeric information for ranking or filtering. Some of the instruments to the web-oriented educational environment is using artificial intellectual features of the cognitive IT platform Polyhedron to provide additional semantic characteristics.

The received documents have used to create an ontology structure (.xls) and to fill the ontology graphs of ranking and filtering. To provide it, they were downloaded in editor4, the part of the cognitive IT platform Polyhedron. After that, the graph generation and the inputting of semantic characteristics to each vertex have carried out. Ontological edges have formed using predicate equations which described in previous work [39].

For the development of some ontological tools, specific “audit” and “ranking” [7, 12, 35] instruments have used. Both of them based on “Alternative” module, which has described in previous works [8]. To use “Alternative” a module has been created nodes of the graph with semantic data grouped in semantic classes that will be ranking criteria. IT platform Polyhedron is an innovative complex of programmatic information and methodological knowledge management tools, which is using ontological management approaches to corporate information resources. Users are considered as the source for new knowledge, for transferring it in the form of their knowledge through the tool IT platform Polyhedron, which is the only integrated point of access – “the single window” – to the information and applications of the system to provide interactive interaction with users. A key benefit of this system is the context-based method of data processing and structuring based on semantic relations.

IT Platform Polyhedron allows users creating a system or graph, read, update a system or graph, delete a system or graph and update the system configurations or graph configurations. All these sections we can split into several different subsections that are named: customization, data creation, information searching, data processing, data structuration, data validation, data isolation, data visualization and data deletion. Every different user has a different role in IT Platform Polyhedron. The Expert can create graphs, delete graphs, add metadata, edit metadata. Thus, the Expert is responsible for creating term fields and filling them with data for further processing in the Polyhedron IT platform. The IT Platform Polyhedron administrator performs specialized functions – the formation of a public library of ontologies and the system administration of transdisciplinary representation. The Young researcher can only read the necessary data, for individual purpose. UML different types of users functions diagram is shown in figure 3.

2.1. Criterion of the searching systems comprising

Search systems and scientometrics bases have compared with each other and the cognitive IT platform Polyhedron search system according to the following criteria: "Content integration", "Lack of advertising", "Interoperability with scientific and a patent search", "Data security" and "Data Availability", "Indexing of educational programs".

Search systems which in response to the user's query, provides all types of data (links, graphical results, semantic characteristics) meet the criterion of "Content integration", and those of them. Search systems which characterized by the lack of advertising met the criterion of "Lack of advertising". Search systems that provide results in the form of articles and patents have considered to meet the criterion "Interoperability with scientific and a patent search". Search systems which do not find any malicious programs and viruses, meet the criterion of "Data security". Search systems which don't have no one restrictions on access to information (for example, the fee for access or a mandatory registration) meet the criterion of "Data Availability". Search systems that can use data directly from educational programs and integrated with them has been evaluated as meet the criterion "Indexing of educational programs".

2.2. Criterion of the research tool systems comprising

Proposed ontology-information solutions have compared with their web-oriented analogue criteria (except search systems) according to the following criteria: "Customization potential", "Multifunctionality of information processing", "Data structuration", "Availability of adaptive interface", "Data validation", "Multi-user support", "Data isolation".

"Customization potential" criterion has used to evaluate possibility of the simply interaction with the system to provide adaptive analysis. Criterion "Multifunctionality of information processing" to evaluate possibility of the systems to provide data processing using few algorithms in same time. If all information is structured, easy to read, and perceived by the user the systems has been evaluated as meet criterion "Data structuration". The criterion "Availability of adaptive interface" means that the system will be convenient in use for any circle of users, regardless of

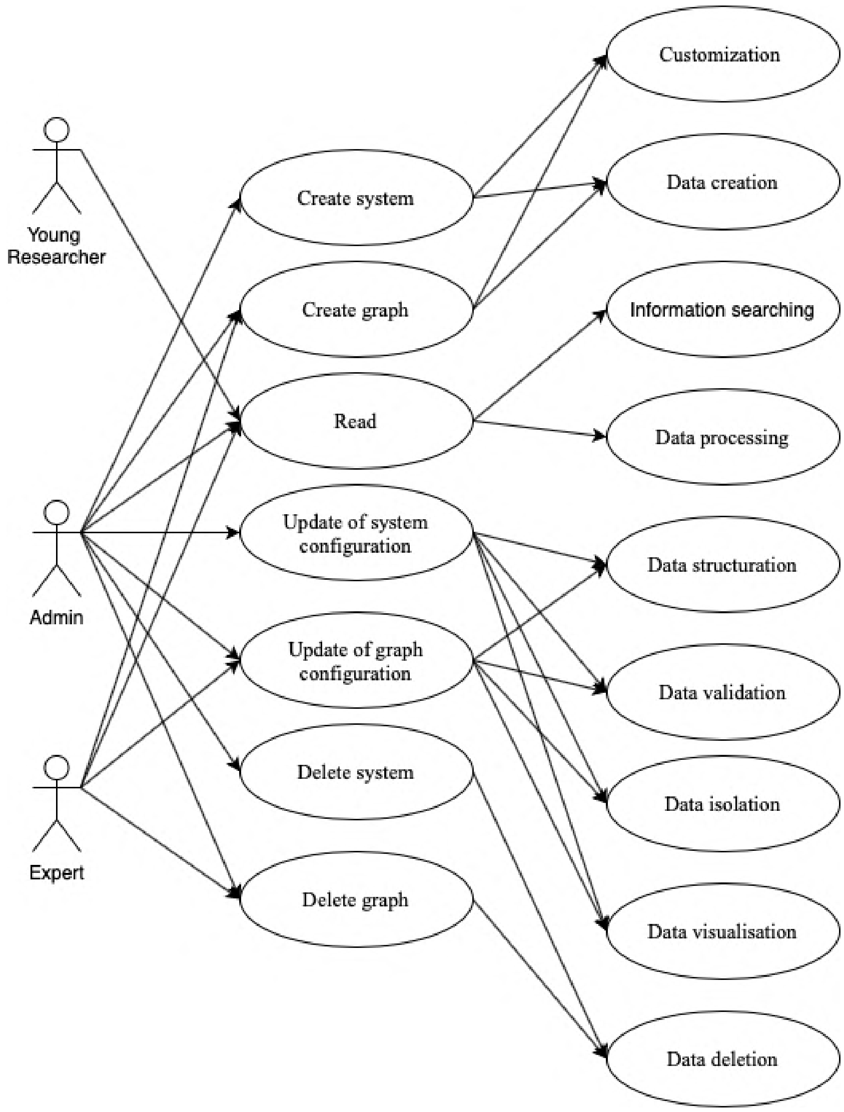


Figure 3: UML different types of user's functions diagram.

their computer literacy level. "Data validation" criterion has used to evaluate functionality of data validation by experts (on the absence of inaccurate or incorrect information on the resource and its coresponding to the actucal stadarts; for example, educational programs and national standard such as on the names of chemical compounds used during educational process (DSTU 2439:2018). The criterion "Multi-user support" indicates that the document in the system can be changed at one time by multiple users. "Data isolation" criterion means that system can provide access rights to information according to user roles and publish in the search only those results that relate to the user and his interests. "Multi-user support" criterion has used to evaluate the possibility of the systems to provide access management to information changing according to user roles and publish in the search only those results that relate to the user and his interests.

3. Scientific method with using ontological tools

3.1. The general concept of ontological-based model based on Polyhedron

An ontology-based solution has developed to simplify the process of educational researches using the scientific method. Such ontological solutions were: “Search systems ranking”, “Search systems”, “Hypothesis test system”, “Centre for collective use”, “The selection of methods”, “The selection of research equipment”, “Sources recommended by the Ministry of Education and Science of Ukraine”, “Scopus sources”, “The promising developments of National Academy of Sciences of Ukraine”.

For systematization, simplification, and providing of a single ecosystem, these tools have compiled into the single simple ontology named “Scientific method”. It is structured according to the stages of the scientific method as “Do Background Research”, “Construct Hypothesis”, “Test with an Experiment”, “Analise results and Draw conclusion”, “Report Results” (see figure 4). The “Ask questions” stage skipped because no software required at this stage. Each of the nodes contains links to ontological tools, that can be used at an appropriate stage. The next part of the article will devote to the analysis of these tools.

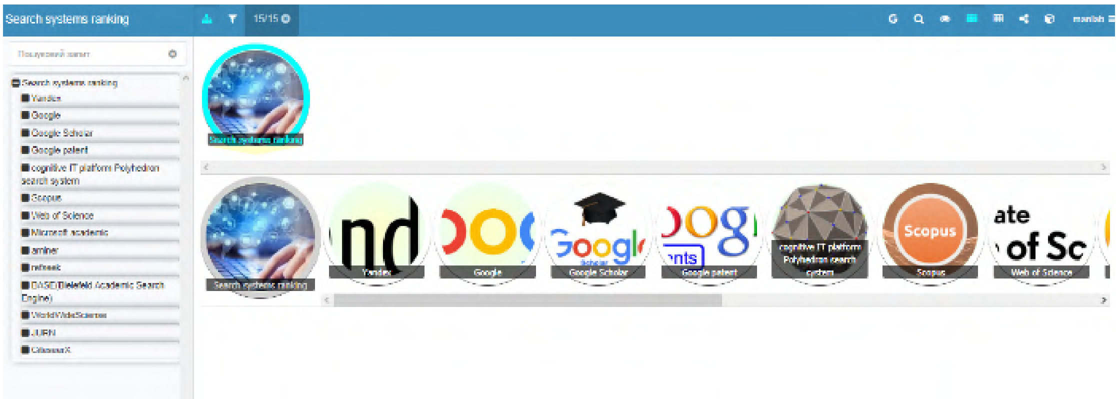


Figure 4: The general view of the ontology-based model.

3.2. Stage “Do background research” of educational researches

Tools like search sites (Google, Bing, Yahoo, etc.) and scientometric databases (Scopus, Web of Science, CiteseerX, Microsoft academic, a miner, refseek, BASE (Bielefeld Academic Search Engine), WorldWideSciense, JURN, Google scholar, and Google patent and others) have represented in the “Do Background Research” ontological node. Each child node were a specific search system or a scientometrics database with a link to it. The general view of “Search systems” ontology has presented in figure 5.

The advantage of the cognitive IT platform Polyhedron internal search function is using an algorithm, which conducted between the ontological graph with nodes. Additionally, this algorithm can provide isolation and validation of information based on experts’ decisions called internal search. That led to extended security and an increase in searching for material quality.

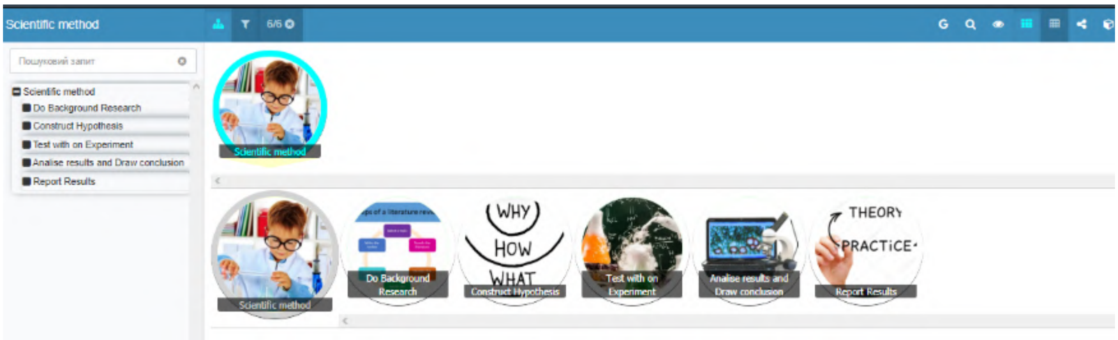


Figure 5: General view of the "Search systems" ontology.

This is significantly important in conditions of developing science society, that led to dynamic changes of the standards, as was with names of chemical substances of substance in Ukraine last year. The proposed in this article system also has its search engine (internal and external) described in previous works [28].

Scopus, Web of Science, CiteseerX, Microsoft academic, aminer, refseek, BASE (Bielefeld Academic Search Engine), WorldWideSciense, JURN, Google Scholar, Google patent have evaluated as particularly meet the criterion "The content integration". Scopus, Web of Science, CiteseerX have assessed partly, because they provide only necessary information about article and their metadata.

Scopus, Web of Science, CiteseerX, Microsoft academic, aminer, refseek, BASE (Bielefeld Academic Search Engine), WorldWideSciense, JURN, Google Scholar, Google patent have evaluated as partly meet the criterion "Interoperability with scientific and a patent search", because they provide search only among between scientific publications or patents in the one time. Google has evaluated as partly meet the criterion "Interoperability with scientific and a patent search" partly because it publishes results of search not only in the form of scientific publications and patents.

Scopus, Web of Science, CiteseerX, Microsoft academic, aminer, refseek, BASE (Bielefeld Academic Search Engine), WorldWideSciense, JURN, Google Scholar, Google patent have evaluated as partly meet the criterion "Data security" and "Data Availability", because some search results require a fee for full access to information or mandatory registration on the website.

Google has evaluated as partly meet the criterion "Indexing of educational programs", because it publishes search results primarily in the form of links on normative documents containing educational programs. The search systems have compared to each other. The results of the comparison are shown in table 2.

Thus, the comparison has found that the Polyhedron search system is more appropriate to use because it fully meets all the criteria. Also, has been found and confirmed that the Google search is more suitable for daily search and external literature review, as it meets such criterion: "Content integration", but do not meet criteria: "Lack of advertising", "Data security" and " Data availability", and only partly meet criteria: "Interoperability with scientific and a patent search", "Indexing of educational programs". The rest of the considered systems are suitable only for in-depth scientific research because they meet the criterion "Lack of advertising" and partly

Table 2
The result of the comparison search system

Search system and scientometrics bases name	Content integration	Lack of advertising	Interoperability with scientific and a patent search	Data security	Data availability	Indexing of educational programs
Polyhedron search system	Yes	Yes	Yes	Yes	Yes	Yes
Scopus	Partly	Yes	Partly	Partly	Partly	No
Web of Science	Partly	Yes	Partly	Partly	Partly	No
CiteseerX	Partly	Yes	Partly	Partly	Partly	No
Microsoft academic	Partly	Yes	Partly	Partly	Partly	No
aminer	Partly	Yes	Partly	Partly	Partly	No
refseek	Partly	Yes	Partly	Partly	Partly	No
BASE (Bielefeld Academic Search Engine)	Partly	Yes	Partly	Partly	Partly	No
WorldWideSciense	Partly	Yes	Partly	Partly	Partly	No
JURN	Partly	Yes	Partly	Partly	Partly	No
Google Scholar	Partly	Yes	Partly	Partly	Partly	No
Google patent	Partly	Yes	Partly	Partly	Partly	No
Google	Yes	No	Partly	No	No	Partly

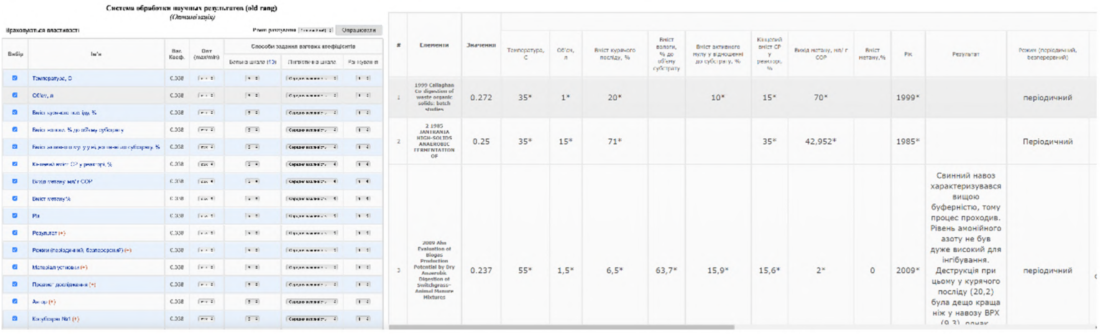
meet by the following criteria "Content integration", "Interoperability with scientific and a patent search", "Data security" and "Data availability".

Therefore, the usage of ranking system can be more relevant, comparing to existing approaches (searching systems). The ranking system expect preparation of numeric data from scientific papers(reports). It is possible due to the experimental papers includes the same information, for example, different works in the field of anaerobic digestion. All research papers about anaerobic digestion include data processing parameters such as temperature, type of substrate, reactor volume, moisture content, initial pH, parameters, characterises of the efficiency of the process, biogas yield, methane content, average pH during the process, destruction process etc [10]. An example of the ranking system on numeric data analysis of educational researches is shown in figure 6.

The proposed approach involves the use of an ontology for the management of specialized literature using other functions of the Polyhedron platform such as filtering (according to the parameters created by the user), ranking, and audit (if the user needs it).

3.3. Stage of "Constructing Hypotheses" with using ontological tools

There is only one ontological tool "Hypothesis test system" for testing of hypotheses status only this tool has represented in the "Construct Hypothesis" node. The Polyhedron platform has an instrument to compare the hypotheses of several works. The instrument is a simple ontology, where already have tested predictions from the scientific researches are semantic characteristics of each node. Next, the audit function of the Polyhedron platform described in previous works



a) b)

Figure 6: An example of input (a) and result interfaces of the ranking system on numeric data analysis of educational researches

[7, 12, 35] find the affinity of the semantics and highlight by red colour those of hypothesis which already tested. An example of the results of such an audit is presented in figure 7.

3.4. Stage of "Planning and test with an experiment" with using ontological tools

At the stage of "Test with an Experiment" specific ontological tools have developed and represented in the general ontology as: "Centre for collective use", "The selection of methods", "The selection of research equipment". In Ukraine, it is possible to provide an experiment using tools located in centres of collective use of the National Academy of Science. To simplify the process of selecting the equipment, the web-based tool "Centre for collective use" has been created. However, to simplify the interface and make it more useful, ontology with the same data but with extended functionality have created. The leaf nodes of this ontology are analysis devices. Visual comparison of ontological and non-ontological tools "Centre for collective use" is presented in figure 8.

Non-ontology system "Centre for collective use" has several shortcomings, both visual and functional which are obsolescence and inconvenience of the interface, inconvenient navigation in the system, and the complete absence of a filtering system. These factors make the application unsuitable for the selection of equipment during the process of planning of the experiment.

The proposed ontological-based tool "Centre for collective use" is having not only an up-to-date interface but also several advantages. One of the key features is a stable semantic link and the ability of the system to combine all of the innovative applications of digitalization of the educational and research process. Also, have created an ontological-based system "Centres of collective use" is conveniently classifying scientific equipment by departments of science it belongs to. This feature was realized as non-user-friendly in traditional web-based tool.

Besides, the "Centre for collective use" use in the cognitive IT platform Polyhedron platform has several useful filters, unlike web-based tool. These filters are "the sphere of science", "section of National Academy of Science of Ukraine institution belongs to", "Location", "object of study", and "measured parameter". All these filters will be especially useful for novice researchers.

Hypothesis testing system
(Аудит)

Враховуються властивості

#	Показники	Одиниця виміру	ДСТУ	Зразки		
				supposition 1	supposition 2	supposition 3
Abstract						
1	Object of study	Object of study	Chlorella vulgaris		Chlorella vulgaris	
2	Subject of study	Subject of study	Cultivation of Chlorella vulgaris microalgae on effluents obtained after methane fermentation.		Cultivation of Chlorella vulgaris microalgae on effluents obtained after methane fermentation.	
3	The aim of the study	The aim of the study	Developing a method of growing Chlorella Vulgaris in effluents after methane fermentation.		Developing a method of growing Chlorella Vulgaris in effluents after methane fermentation.	
4	Practical value	Practical value	The results of this work will contribute to the spread of biogas technologies. This approach makes it possible to increase the economic benefits from the utilization of bird droppings by converting the anaerobic digestion effluents into microalgae that have a wide range of applications.		The results of this work will contribute to the spread of biogas technologies. This approach makes it possible to increase the economic benefits from the utilization of bird droppings by converting the anaerobic digestion effluents into microalgae that have a wide range of applications.	
5	Scientific novelty	Scientific novelty	A method of utilization of methane tank effluent using microalgae is proposed. Cultures of Chlorella Vulgaris were adapted to the methane tank effluent.		A method of utilization of methane tank effluent using microalgae is proposed. Cultures of Chlorella Vulgaris were adapted to the methane tank effluent.	
6	Keywords	Keywords	microalgae		Chlorella Vulgaris	
7	Hypothesis	Hypothesis	The effluent obtained after anaerobic digestion can be used as a nutrient medium for microalgae Chlorella Vulgaris.	The effluent obtained after anaerobic digestion can be used as a nutrient medium for microalgae Spirulina Platensis.	The effluent obtained after anaerobic digestion can be used as a nutrient medium for microalgae Chlorella Vulgaris.	The effluent obtained after anaerobic digestion can not used it as a nutrient medium for microalgae Chlorella Vulgaris.

Figure 7: General view of the audit results in the “Hypothesis test system” ontology.

a) b)

Figure 8: General view systems for the selection of equipment in centre of collective usage during planning the experiment in the non-ontology-based (a) and (b) ontological-based system.

These two systems have compared each other. The result of the comparison is shown in table 3.

As a result of the comparison, it has found that the “Centre for collective use” in the cognitive IT platform Polyhedron is more appropriate to use, because it fully meets all the criteria. It has established that the non-ontology-based version of the “Centre for collective use” is undesirable for use because it doesn’t meet the following criteria: “Customization potential”, “Multifunctionality of information processing”, “Data structuration”, “Availability of adaptive

Table 3
The result of the comparison of two ontological-based with non-ontology-based systems for the selection of equipment in “Centre of collective usage”.

Criterion name	Non-ontology “Centre for collective use”	Ontological-based system “Centre for collective use”
Customization potential	No	Yes
Multifunctionality of information processing	No	Yes
Data structuration	No	Yes
Availability of adaptive interface	No	Yes
Data validation	Yes	Yes
Multi-user support	No	Yes
Data isolation	No	Yes

interface”.

There are many potential cases of using “Centre for collective use” in the cognitive IT platform Polyhedron. For example, the user needs to find a device that is located in Kyiv, and which investigates atomic particles. As a result of the user request, the device is the Isochronous cyclotron U-240 of the Institute of Nuclear Physics, which is located on Nauki Avenue. This and some other examples of applications are shown in table 4.

Table 4
The list of examples of using the proposed filtering system

	Filters	Results
Case 1	*Location: Kyiv* The object of study: Atomic particles	cyclotron U-240
Case 1	*Location: Kyiv* Purpose: Analysis of X-ray spectra	Module for CEM INCAPenteFETx3
Case 3	*Location: Lviv* Purpose: Microscopic examinations	Scanning electron microscope EVO 40XVP

In the laboratory MANLab of the National Center of Junior Academy of Science centre of collective usage of the research equipment devoted to the research education has been created. The same approach to simplify (using the ontology) the selection of the equipment called “Selection of equipment in MANLab” has been developed. Leaf node in this ontology is separate equipment located in MANLab. The filters such as the parameter which needs definition, “Measurement accuracy”, “Measuring range” “The parameter which needs definition” will be useful for selection. The General view of filtering input system for “The selection of research equipment in MANLab” ontology is shown in figure 9

Novice researchers can easily find the equipment in both, Centers of collective usage in National Academy of Science and Junior Academy of Science. For example, the researcher needs to provide the information about the content of heavy metals in the water, and it is already known that the content is high. The system can provide both ranking and filtering for solving the tasks. Any of these instruments will propose to use for this task the Universal polarograph EKOTEST-VA. By Choosing of this instrument, novice researchers will be able to use the links

Hypothesis testing system
(Аудит)

Враховуються властивості

#	Показники	Одиниця виміру	ДСТУ	Зразки		
				supposition 1	supposition 2	supposition 3
Abstract						
1	Object of study	Object of study	Chlorella vulgaris		Chlorella vulgaris	
2	Subject of study	Subject of study	Cultivation of Chlorella vulgaris microalgae on effluents obtained after methane fermentation.		Cultivation of Chlorella vulgaris microalgae on effluents obtained after methane fermentation.	
3	The aim of the study	The aim of the study	Developing a method of growing Chlorella Vulgaris in effluents after methane fermentation.		Developing a method of growing Chlorella Vulgaris in effluents after methane fermentation.	
4	Practical value	Practical value	The results of this work will contribute to the spread of biogas technologies. This approach makes it possible to increase the economic benefits from the utilization of bird droppings by converting the anaerobic digestion effluents into microalgae that have a wide range of applications.		The results of this work will contribute to the spread of biogas technologies. This approach makes it possible to increase the economic benefits from the utilization of bird droppings by converting the anaerobic digestion effluents into microalgae that have a wide range of applications.	
5	Scientific novelty	Scientific novelty	A method of utilization of methane tank effluent using microalgae is proposed. Cultures of Chlorella Vulgaris were adapted to the methane tank effluent.		A method of utilization of methane tank effluent using microalgae is proposed. Cultures of Chlorella Vulgaris were adapted to the methane tank effluent.	
6	Keywords	Keywords	microalgae		Chlorella Vulgaris	
7	Hypothesis	Hypothesis	The effluent obtained after anaerobic digestion can be used as a nutrient medium for microalgae Chlorella Vulgaris.	The effluent obtained after anaerobic digestion can be used as a nutrient medium for microalgae Spirulina Platensis.	The effluent obtained after anaerobic digestion can be used as a nutrient medium for microalgae Chlorella Vulgaris.	The effluent obtained after anaerobic digestion can not used it as a nutrient medium for microalgae Chlorella Vulgaris.

Figure 9: General view of filtering input system for "The selection of research equipment in MANLab" ontology.

on manlab.inohst.com.ua web-page with detailed information on the equipment. The list of cases of application the proposed filtering system is presented in table 5. The General view of filtering input system for "The selection of methods" ontology is shown in figure 10.

Table 5
The list of cases of application the proposed filtering system

	Filters	Results
Case 1	*The parameter which needs definition:* concentration of heavy metals in the liquid Measuring range: 0.1 μg / dm3-1g / dm3	Universal polarograph EKOTEST-VA
Case 1	*The parameter which needs definition:* CO2 concentration Measurement accuracy: 20% Measuring range: 350-5000%	Carbon dioxide sensor DT040
Case 3	*The parameter which needs definition:* O2 concentration Measuring range: 0-12,5 mg / dm3 Oxygen sensor DT222A	

The other routine tasks that need to be solved during the planing of the experiment ("Test with an experiment stage) is choosing the methods of research. The main problems in that field that a wide variety of methods are presented in the form of printed text (books or methodical

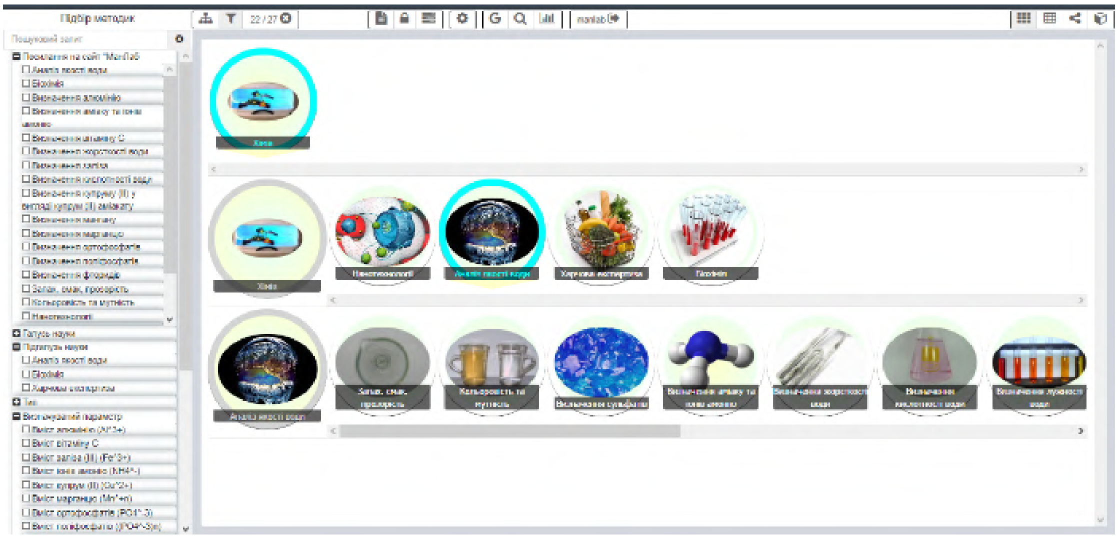


Figure 10: General view of filtering input system for “The selection of methods” ontology.

instructions) which is hard to process. However, using filtering systems of IT-platform Polyhedron, it is possible to provide management and simplify this task. The ontology used to solve this task called “The selection of methods”, and the leaf node of it is method itself with the metadata. For example, the youth researcher “is required to select to determine the content of Al (III) in water. As a result of a user request, the system will propose the photometric analysis methodology, and display all necessary information, including chemical utensils, reagents, needed equipment. Finally, the result will contain a link to the web-methodology at Junior Academy of Science web-environments (manlab.science or stemua.science [27, 29]) where it will be detaily described and visualized by video demonstrations. The list of examples of using the proposed filtering system is presented in table 6.

Table 6
The list of examples of using the proposed filtering system

	Filters	Results
Case 1	*Purpose: Water quality analysis* The parameter which needs definition: Al (III)	Investigation of water samples for aluminum content by photometric method
Case 1	*Type of analysis: qualitative* The parameter which needs definition: The presence of proteins	Deposition of proteins by mineral acids
Case 3	*Type of analysis: Titrimetric determination* The parameter which needs definition: vitamin C	Determination of vitamin C content in food by iodometric method

3.5. Stage of "Analise results and draw a conclusion" with using ontological tools

An example of the application of the proposed ontological system has given at "Analise results and Conclude" node. At the stage of result analysis, both offline tools like MS Office, PTS Mathcad Origin Pro, and cloud-based like G Suite and Office 365. The Polyhedron IT-platform can allow to process and present the results of researches. Semantic and numerical characteristics from Excel or Google Sheets have used to construct graphs and diagrams. Also, the necessary data can be taken from the existing ontological graph. This is followed by the standard method of creating for ontological graphs and further use the module to build graphs and charts. For demonstration results of statistical researches on mortality from various diseases in Ukraine from 2016 to 2020 (include from COVID-19) were taken. The graph with these results of statistical surveys in the Polyhedron system is presented in figure 11.

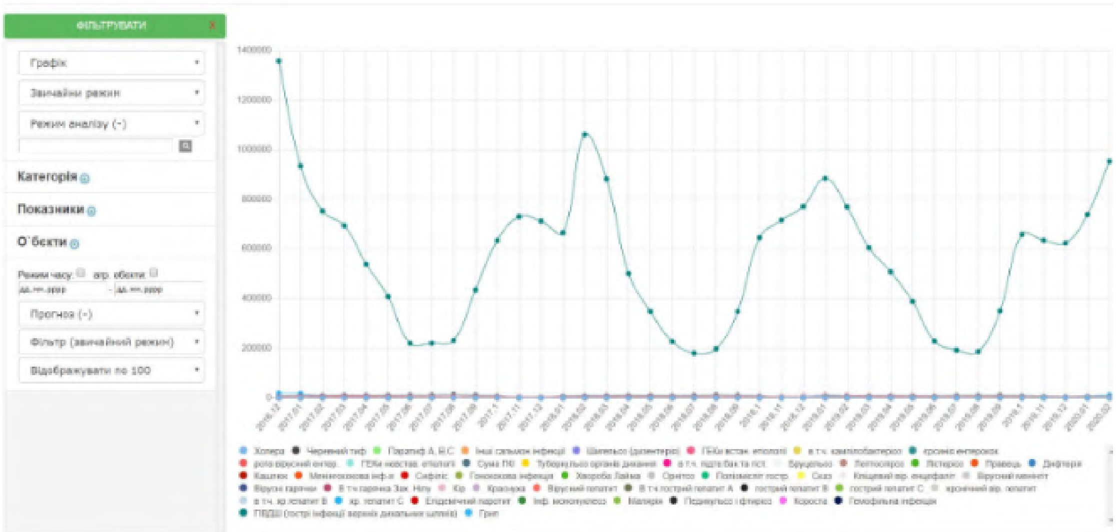
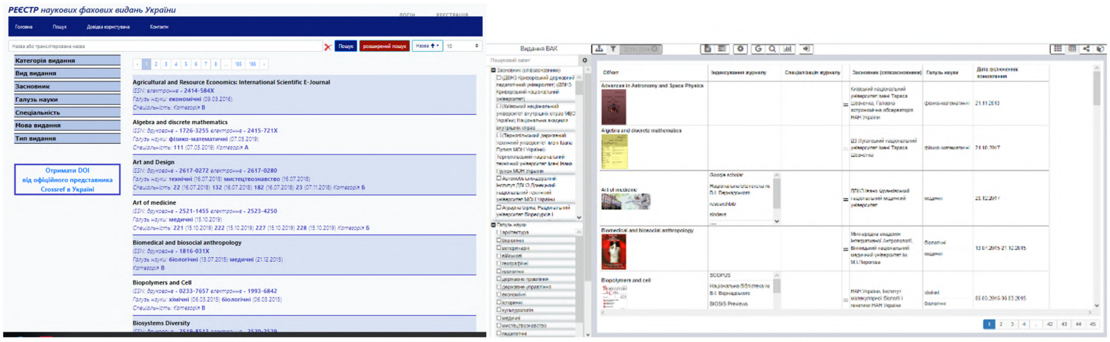


Figure 11: The graph with results of statistical surveys of on mortality from various diseases in Ukraine from 2016 to 2020 by cognitive IT platform Polyhedron.

3.6. Stage of "Report results" with using ontological tools

The "Sources recommended by the Ministry of Education and Science of Ukraine", "Scopus sources" "The promising developments of National Academy of Sciences of Ukraine" ontological systems have represented in "Report Results" node. Those instruments have compared with their non-ontological web-analogues.

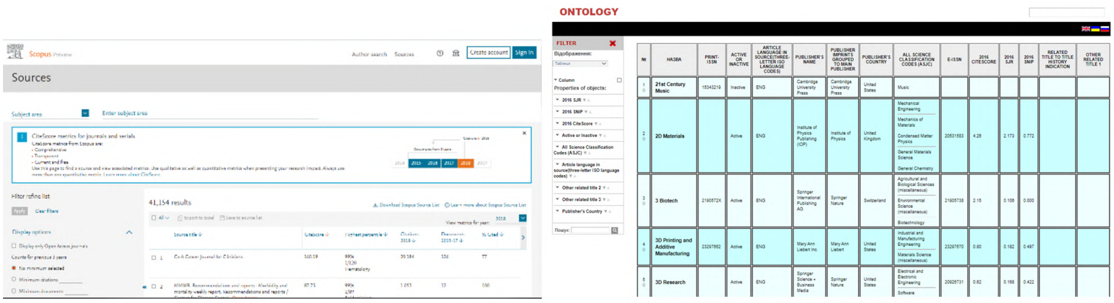
After providing the research and analysing of the results, it may seem relevant to publish the data. Now in Ukraine, it is possible to can be divided into between the journals recommended by the Ministry of Education and Science of Ukraine, and the journals indexed by scientometric bases. However, choosing of the journals, is always the challenge, especially for novice researchers and to simplify the tasks both ontological and non-ontological tools is existing nowadays. The ontological tool developed using IT-platform Polyhedron consist from the leaf nodes (separate journals) with semantic data. To simplify the tasks, the filters like “Field of Science”, “Free of Charge Journals”, “Publication Languages” have developed. There are web-oriented and ontological systems for the selection of sources recommended by the Ministry of Education and Science of Ukraine. A general view of references recommended by the Ministry of Education and Science of Ukraine in bought forms are shown in figure 12.



a) b)

Figure 12: General view of sources recommended by view of sources recommended by Ministry of Education and Science of Ukraine in (a) non-ontology-based (b) ontological-based form.

“Sources recommended by the Ministry of Education and Science of Ukraine” and “Scopus sources” ontologies have created. Both of ontologies are complex and contains branching by branches, of science, type, indexes, and other parameters of journals for publication. The final child nodes are each journal for publication. Such necessary filters as language of the journal, cost of publication (including frees) is absent in web-based application, which may limit it using. For example, today researchers are increasingly paying attention to the citation style of the journal. General view of Scopus sources in standard web-oriented and ontological form are shown in figure 13. All these systems have compared to each other. The result of the comparison is shown in table 7.



a) b)

Figure 13: General view of Scopus sources in (a) non-ontology-based (b) ontological-based form.

As a result of the comparison, it has found that “Sources recommended by the Ministry of Education and Science of Ukraine” in cognitive IT platform Polyhedron and “Scopus sources”

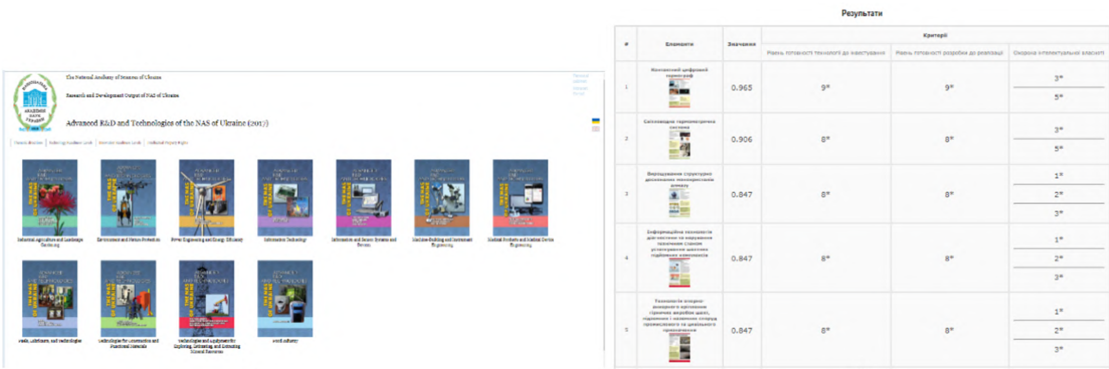
Table 7
The result of the comparison of edition structuration systems

Criterion name	"Sources recommended by the Ministry of Education and Science of Ukraine"	"Scopus sources"	"Sources recommended by the Ministry of Education and Science of Ukraine" in cognitive IT platform Polyhedron	"Scopus sources" by cognitive IT platform Polyhedron
Customization potential	No	No	Yes	Yes
Multifunctionality of information processing	No	No	Yes	Yes
Data structuration	No	No	Yes	Yes
Availability of adaptive interface	No	Yes	Yes	Yes
Data validation	Yes	Yes	Yes	Yes
Multi-user support	No	No	Yes	Yes
Data isolation	Yes	Yes	Yes	Yes

by cognitive IT platform Polyhedron are more appropriate to use because it fully meets all the criteria. "Sources recommended by the Ministry of Education and Science of Ukraine" is undesirable for use because it doesn't meet the following criterion "Customization potential", "Multifunctionality of information processing", "Data structuration", "Availability of adaptive interface", "Multi-user support". As a result of the comparison, it has established that the "Scopus sources" is undesirable for use because it doesn't meet the following criterion "Customization potential", "Multifunctionality of information processing", "Data structuration", "Multi-user support". So, ontology-based tools "Sources recommended by the Ministry of Education and Science of Ukraine" and "Scopus sources" is more appropriate to use.

For presentation of research results was created "The promising developments in The National Academy of Sciences of Ukraine" in web-oriented non-ontology form containing all the promising scientific projects of Ukraine. Ontology-based tool" The promising developments of National Academy of Sciences of Ukraine" ranking ontology has created with functions of ranking and provides better information management. The ontology is simple with scientific developments, as leaf nodes. General view all the promising projects of National Academy of Sciences of Ukraine and result of the ranking ontology tool presented in figure 14.

This tool will be useful for potential investors who are looking for investments. For example, investor requesting to find the most finalized developments "The promising developments in The National Academy Sciences of Ukraine" by the cognitive IT platform Polyhedron, the system will display the projects "contact digital thermography", "fibre-optic thermometric system", "growing of structurally perfect diamond single crystals", "Technology of support, and anchor fastening of earthworks appointment" are the most finalized developments. The non-ontology tool "The promising developments in The National Academy of Sciences of Ukraine" has been compared with ontological-based form "The promising developments in The National Academy Sciences of Ukraine" by cognitive IT platform Polyhedron. The result of the comparison is shown in table 8.



a) б)

Figure 14: General view of "The promising developments in The National Academy of Sciences of Ukraine" (a) and result of the ranking ontology tool (b).

Table 8
The result of the comparison of "The promising developments of The National Academy of Sciences of Ukraine" systems

Criterion name	Non-ontology "The promising developments in The National Academy of Sciences of Ukraine"	"The promising developments in The National Academy Sciences of Ukraine" by cognitive IT platform Polyhedron
Customization potential	No	No
Multifunctionality of information processing	No	Yes
Data structuration	No	Yes
Availability of adaptive interface	No	Yes
Data validation	Yes	Yes
Multi-user support	No	Yes
Data isolation	Yes	Yes

4. Discussion

As a result of the comparison, it has been found that Ontological tools for the support of the scientific method created by cognitive IT-platform Polyhedron are more appropriate to use because they fully meet all of the comparison criteria. And all of the non-ontological tools for the support of the scientific method only meet the criteria: "Availability of adaptive interface", "Data validation", "Data isolation". The overall result of the comparison is shown in table 9.

We can use the "search system" ontology in the background research stage, "Hypothesis test system" can be used in the construct of hypothesis stage. Depending on the presence or absence of the experiment, we can use two different ontological solutions "The selection of research equipment" and "The selection of methods". In the report results stage it is possible to use three different ontologies "Scopus edition", "The edition recommended by Ministry of education and

Table 9
The overall result of the comparison of ontological and non-ontological tools

Criterion name	Ontological tools	Non-ontological tools
Customization potential	Yes	No
Multifunctionality of information processing	Yes	No
Data structuration	Yes	No
Availability of adaptive interface	Yes	Yes
Data validation	Yes	Yes
Multi-user support	Yes	No
Data isolation	Yes	Yes

science of Ukraine" and "The promising developments of NASU". All proposed ontological tools are extensions and support the method as illustrated in the workflow diagram (see figure 15).

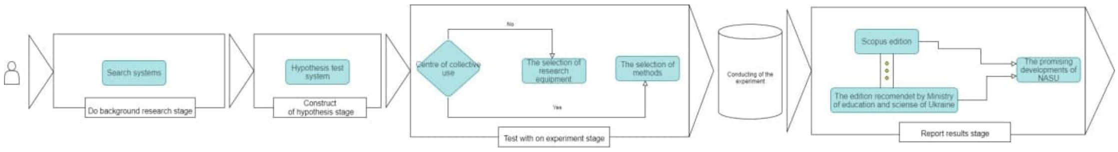


Figure 15: Workflow diagram of proposed ontological tools

5. Conclusions

A centralized ontological tool based on the IT platform Polyhedron consisting of "Search systems ranking", "Search systems", "Hypothesis test system", "Centre for collective use", "The selection of methods", "The selection of research equipment", "Sources recommended by the Ministry of Education and Science of Ukraine", "Scopus sources", "The promising developments of The National Academy of Sciences of Ukraine" has been created. These ontological tools can be used during almost all stages of the scientific method used in educational research. As a result of the comparison, it was found that all systems created by the cognitive IT-platform Polyhedron are more appropriate to use because they fully meet all the comparison criteria.

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