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PAPER

Integrative Technology for Creating Electronic Educational Resources

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ABSTRACT

To increase the efficiency of using ontologies in the educational process, we have developed the Ontos.xyz resource, which consists of an ontograph editor and a viewer that allows displaying both individual EERs and their collections. The editor allows creating an ontograph that describes the structure of the EER as well as the ability to assign to each node a context of all types supported by the browser, including html pages, web 2.0 resources, etc. The EER built in this way allows the integration of data from different sources with the ability to adapt to the conditions of any subject area, regardless of its specifics. Thus, the digital competencies of the EER creators remain relevant since they do not need to learn new software resources to work with individual ontology concepts ("ontograph nodes"). As a result of our research, we have developed a technology for using the ontological approach to create an EER. For its implementation, the Ontos.xyz resource was developed, which is an ontological graph editor. The ontograph allows for the primary visualization of the EER structure, interpreting its structural elements as nodes (vertices) of the graph and displaying the logic of transitions between structural elements in the form of directed links. With such an approach, the ontology is a kind of aggregator that ensures the integration of the semantic and technological approaches. Building an EER using the ontological approach requires appropriate technological support in terms of description languages, models, software tools, and systems. The proposed software solution, in contrast to its functional counterparts, focuses on use in the educational process.

KEYWORDS

ontological approach in education, electronic educational resources, digital technologies, digital competence

1 PROBLEM STATEMENT

The requirements of technological progress determine the technologization of the educational process based on the integration of information, communication, and pedagogical technologies, which becomes a necessary condition for quality education.

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The material and constructive form of EER as a sociocultural phenomenon is determined by the development in society of methods of activity and technology of activity, i.e., a social order for a specific technology of activity. Modern digital technologies transform the traditional educational process into a cognitive activity based on digital competencies.

Such a transformation requires the creation of new teaching aids that meet modern needs. The development, implementation, and use of such tools implies that end users have a certain level of digital competencies. By *end users*, we mean, on the one hand, consumers (pupils, students) and, on the other hand, teachers (teachers, tutors).

Today, digital technologies have become an integral part of all spheres of human life, including the education system. The mass application of these technologies implies both the availability of special hardware and software that allow users to work with them and a certain level of development of digital competencies of end users. There is a large number of publications that consider the technologies for creating electronic educational resources (hereafter referred to as EER) both in theoretical and practical terms. One of these technologies is the ontological approach, which has already been described either by us or by many other authors. The key feature of this approach is the possibility of constructing an EER representation in the form of an ontology of a certain subject area, amenable to both mathematical interpretation (for example, using graph theory) and various visualization methods. EER is considered a structured set of concepts of a certain subject area with formalized rules of interaction and interpretation.

The theory and practice of using computer ontologies have attracted the attention of many authors. There are software products focused on working with different representations of ontologies, but, to date, the use of ontologies, which has great prospects in the educational process, has been studied only fragmentarily. In the article [1], we considered some features of the use in the educational process of such software products as OntoViz, GlowViz, OntoGraph, 3D Hyperbolyc Tree, Conceptino, Anychart, SciVi-CGraph, and TODOS (TODOOS). Each of these products successfully solves a certain class of tasks for working with computer ontologies but for one reason or another does not fully meet the needs of the educational process as a tool for developing and displaying EER. Most ontological editors, providing at a high level the possibility of creating complex structures typical for electronic textbooks and manuals, are not designed to visualize the data they describe in a form acceptable for the educational process [1]. On the other hand, the existing nonontological technologies for creating a UER with effectively implemented opportunities for displaying educational material experience difficulties in creating complex structures containing multilevel branching, reverse transitions, etc. In 2011–2015, a technology was developed [2] for creating cloud electronic educational resources, which allows integrating such elements of EER as video, audio, hypertext, testing, etc. into a single whole. This development, widely using the capabilities of web technologies, has made it possible to create dozens of electronic textbooks and manuals used in the educational process. The disadvantage of this technology, as practice has shown, was all the same difficulties with creating and, if necessary, changing the structure of the EER. Teachers trained in the development of the EER quite easily created the visualization of the resource pages but experienced difficulties when it was necessary to make changes to its structure. In subsequent years, the study of ontological editors and participation in the development of such resources as TODOS [3] and AGRON [4] made it possible to rethink approaches to the representation of complexly structured virtual objects.

As practice has shown, the efficiency of creating an EER cannot always be ensured by a design engineer. In order for the electronic textbook to be of high quality, a team of engineers and a specialized teacher is needed. And ideally, the teacher should know the basics of developing a textbook, and upon completion of the creation of an electronic resource, its final revision can be carried out by a specialist with basic knowledge of engineering, design, and pedagogy. Obviously, a certain increase in the informative and communicative competence of teachers is necessary, without interrupting their main activity, i.e., requiring a minimum of their time and effort.

Based on the foregoing, the purpose of our work was to create a digital product designed for the development and visualization of EER: a product that would allow the effective use of the existing digital skills of participants in the educational process who are not programmers and that would not require special engineering education for the technical development of an EER—for example, a textbook—but would be intuitive and simple in use. At the same time, such a product must be high tech and provide a high level of usability for the end user.

2 ANALYSIS OF RECENT RESEARCH AND PUBLICATIONS

There is a huge amount of research related to the use of EER. Many teachers oppose electronic textbooks and manuals, preferring printed books; many are their ardent supporters. There are studies proving the benefits of both. In our work, we will not focus on theoretical disputes about the appropriateness of their use and the development of methods for their application. We are more interested in practical activities for their creation.

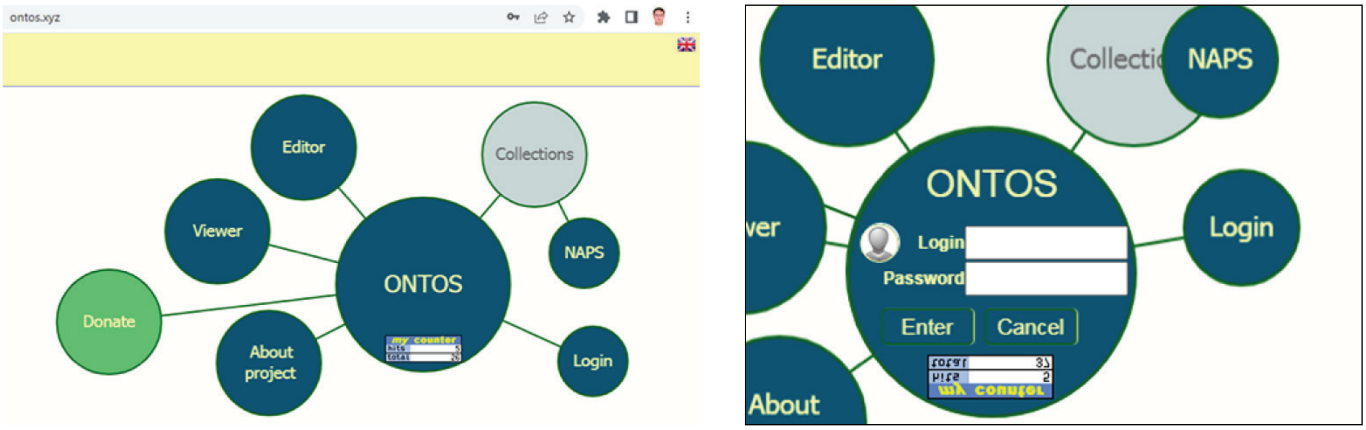
Electronic textbooks, technologies for their creation, development of specialized editors, requirements for their functionality to support cognitive processes, issues of increasing usability, matching the interface to the needs of the educational process, etc. have been developed by a large number of researchers. They include V. Bykov, V. Vember, O. Yesina, L. Lingur, V. Madzigon, O. Pinchuk, O. Spirin, M. A. Verkuyl, L. Atack, J. Lapum, A. R. Dennis, K, McNamara, S. Dowling, I. Arnedillo-Sánchez, and many others.

With the advent of the semantic network and semantic technologies, ontologies have emerged that have become one of the most modern paradigms for the representation of knowledge [10]. *Ontology* is a term borrowed from philosophy that refers to the science of describing the kinds of essences of various objects and the relationships between them. The use of computer ontologies has been considered by S. Greger, T. Gruber, T. Jeffrey, Y. Ding, A. Evseev, V. Lapshin, V. Litvin, V. Lyubchenko, L. Naykhanov, A. Narignani, S. Nirenburg, N. Noy, A. Palagin, M. Popova, A. Smirnova, E. Strizhak, S. Subbotin, Y. Sure, D. Faure, and many others.

We also note the scientists and educators who at various times participated with us in the development of the technology that we present in this article. They are T. Bondarenko, G. Cherevychnyi, O. Kuzmenko, T. Pavlysh, L. Petryshyn, M. Rostoka, and others.

3 STATEMENT OF BASIC MATERIAL AND THE SUBSTANTIATION OF THE OBTAINED RESULTS

To implement the task, the online resource http://ontos.xyz (hereinafter referred to as ONTOS) was designed and implemented using a two-component data visualization based on an ontological approach to their description (see Figure 1a) [5].



(a) (b)

Fig. 1. Web resource ONTOS (http://ontos.xyz/)

The development technology presented on the ONTOS web resource was designed to create individual EERs and their collections (libraries). Such an EER is a file with the ".ovs" extension. The file is text organized by tags. For example, here is the structure of a file that describes an ontograph of two vertices and links between them:

<ovs>// *tag framing the ontograph.*
  <meta>
  Information about ontology name, software product version, creation date, ontology type, short description, keywords, etc.
  </**meta**>
  <**addition**>
  Terms that require clarification or alternative translation, links to dictionaries and thesauri
  </**addition**>
  <**head**>
    Settings - colors, sizes, etc.
  </**head**>
  <**body**> // *tag framing the ontology body*
  <**Nodes**> // *tag framing the list of ontology nodes*
      <**Node** *parameters of node 1*> </**Node**>
      <**Node** *parameters of node 2*> </**Node**>
  </**Nodes**>
  <**Edges**>// *tag framing the description of links in the ontology*
    <**Edge** *links parameters 1*> </**Edge**>
  </**Edges**>
  </**body**>
</**ovs**>
The node tag has the following structure:
<Node
  id=" *Node code 1*" // *unique node code*
  name=" *Node name 1*" // *display the name of the node on the screen*

```
        class="" shape=" " radius="" fill="" x="" y="" geoX="" geoY="" fontFamily="
        " fontsize="" color="" // screen design and position settings
> // opening node tag with parameters
        <data
            id=" Block code 1" // unique block code
            name=" Block name 1" // block name
            type="image" // block type
            link="" // link to an object on the Internet
            properties="{ }" // parameters depending on the block type
        > // opening tag of information block 1
            Description of the picture
        </data> // closing tag of information block 1
</Node> // end tag of node 1
```

The link tag is described as
<**Edge id**=" *code* " **nodeID**=" *node 1 id* " **parentNodeID**=" *parent node id* " </**Edge**>.

Depending on the version, the tag parameters can be supplemented.

To automate the processing of the contents of ontology files, a number of applications were created, the main of which are the “Editor” and “Viewer”, which have several access levels (see Figure 1b), differing in functionality. It is conditionally possible to distinguish three main ones:

- public – does not require authorization;
- anonymous – login and password "anonym" are entered automatically when you click on the avatar to the left of the "Login" field (see Figure 1b);
- individual – requires entering a login and password issued by the administrator.

The public level of access to the "Editor" component allows performing all the basic actions to build an ontograph that describes the EER. By an ontograph, we mean a certain structure consisting of nodes (vertices) interconnected by directed links (edges). By a directed link, we mean a given parent-child subordination relationship. In Figure 2. an editor is displayed with an ontograph placed in the edit field, whose “New node” vertex is the parent (see Figure 2e.3).

The main elements of the editor form are:

- the top menu (see Figure 2e.1) contains buttons to go to the main page; transition to the viewer; creating a new one, adding a saved one, downloading and uploading an ontology; settings, display in tabular and text modes. In the upper right corner, there is a language switcher, and below it is a button for selecting the ontology display style (EER or collection).
- editor field (see Figure 2e.2).

The creation of the ontograph structure is controlled by calling the context menu by pressing the right button (see Figure 2e.4). Depending on the object on which this menu was called, the available actions are activated. This is the creation of a new node, setting the beginning/end of the connection, selecting nodes for group operations, creating a copy of the node, deleting, changing the color, etc.

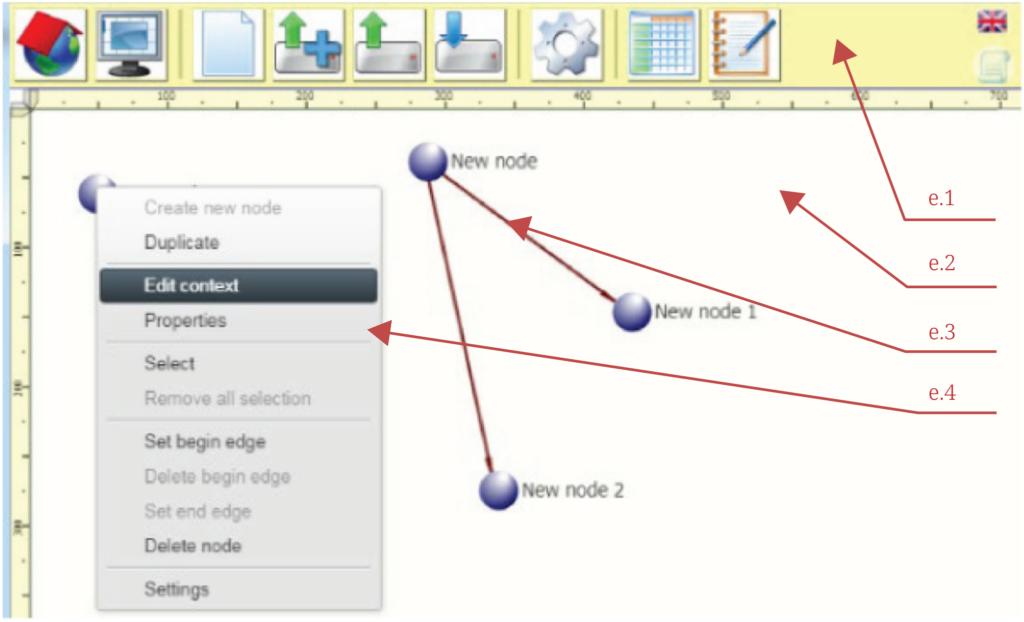
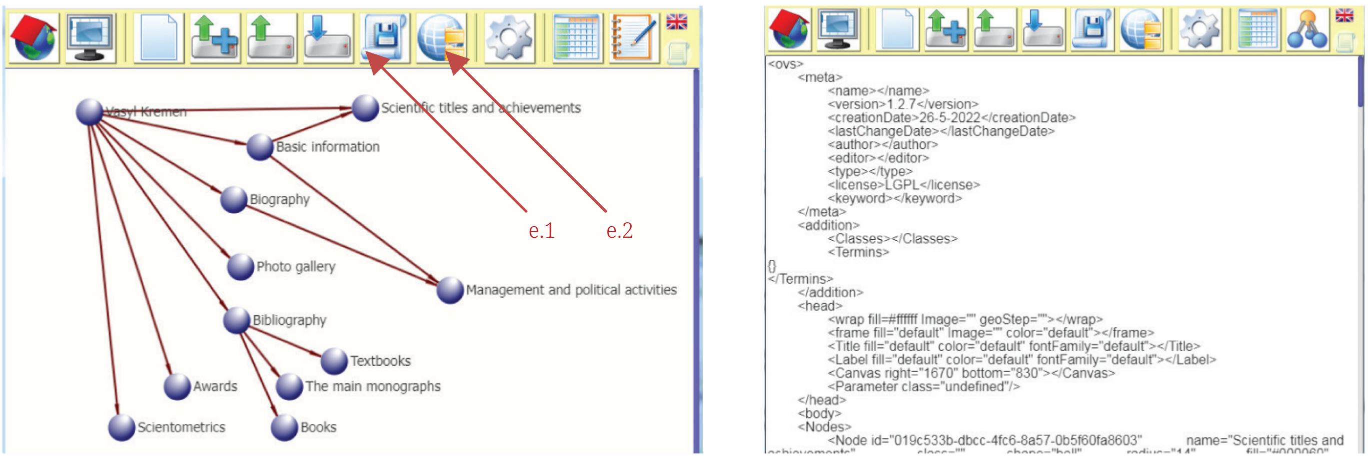


Fig. 2. ONTOS web resource (http://ontos.xyz/)

The ontograph structure can be quite complex (see Figure 3). The number of nodes can exceed several thousand. In Figure 3a the ontology is presented as a visualization using an ontograph, and in Figure 3b we see the description of the same ontology using text with tags.



(a) **(b)**

Fig. 3. ONTOS editor window (http://ontos.xyz/)

As already noted, certain actions can be performed on each node. One of the most important functions available when selecting a node is to create and populate its context (associated with the information pack node). In fact, we define a certain concept (information element with an arbitrary level of detail) as a graph node that allows us to provide information to the end user. The editor provides the ability to assign to each node the context of all types supported by the browser, including images, videos, hypertext, html pages, web 2.0 resources, pdf files, and others (see Figure 4).

The context editing window can be conditionally divided into five zones:

- panel for displaying information blocks (see Figure 4e.1);
- control menu (see Figure 4e.2);
- showcase panel (see Figure 4e.3);
- node properties (see Figure 4e.4);
- block properties (see Figure 4e.5);

Using the control menu, one can create new information blocks on the panel (Figure 4e.6; e.7). Each of these blocks can be set to a specific type of data display (see Figure 4e.8). This division of information into blocks is implemented for several reasons. Firstly, each of the blocks has a preset design, which is convenient for the author of the EER. That design can be adjusted by changing the properties for each of the blocks (see Figure 4e.5). Secondly, the block structure of information simplifies its automatic analysis. (The consideration of its tools is beyond the scope of this article.)

The showcase panel allows the viewer to organize the ontograph node displays in two ways. If there is a splash screen, the site is displayed as a splash bar. The node content is displayed as a pop-up window with information blocks located on it [5].

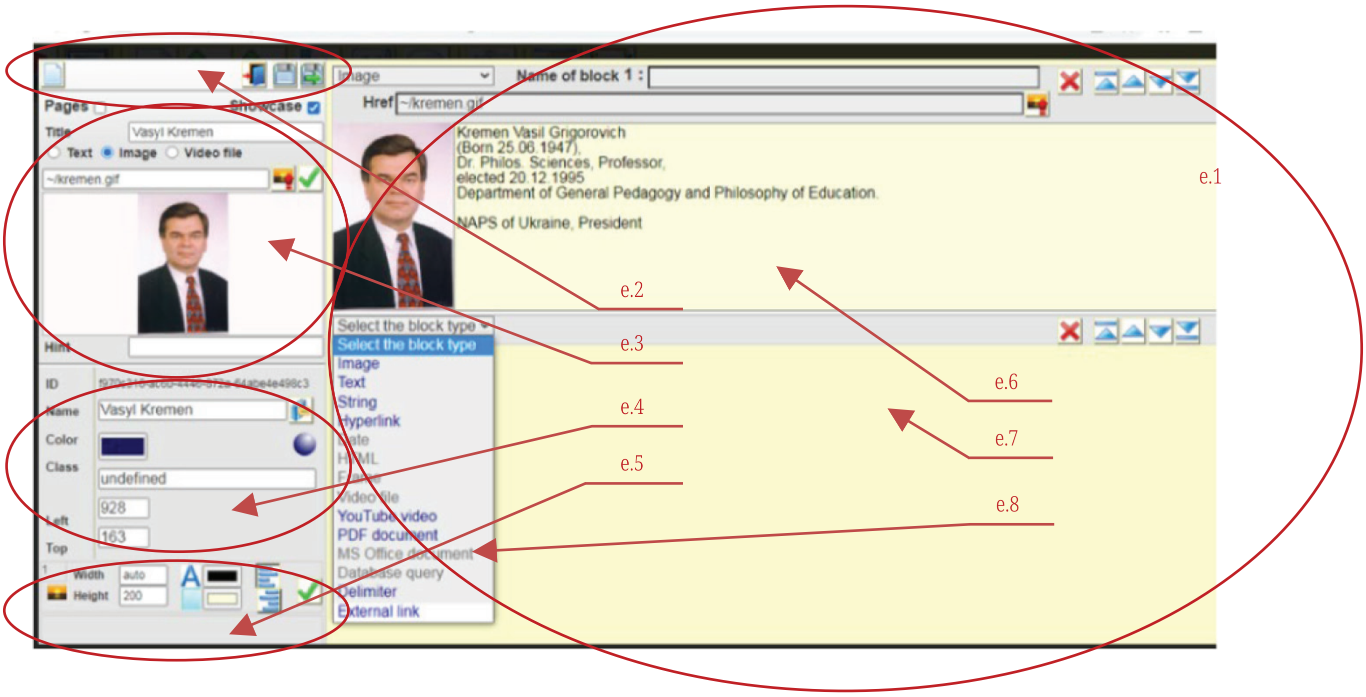


Fig. 4. The context editing window

In Figure 3a the authorized access level to the editor is displayed. These levels are both anonymous and individual. The key difference from the public level of access is the ability to save created EERs on the server, and not just locally. The user is allocated a certain space on the server (for an anonymous user, a limit of 100 MB is set, and anyone who logs in under the name "anonim" gets access to manage the saved resource).

In the main menu, with authorized access, buttons "Save" the ontology to the server (see Figure 3a, e.1). and "Cabinet" (see Figure 3a, e.2) are added. When one selects the "Cabinet" button, a pop-up window appears, consisting of two parts. In the left part, there is a list of ontologies available to the user, above which there are controls. In the right part of the menu for managing the list of ontologies, there is a button for displaying a list of ontologies that are in the public domain.

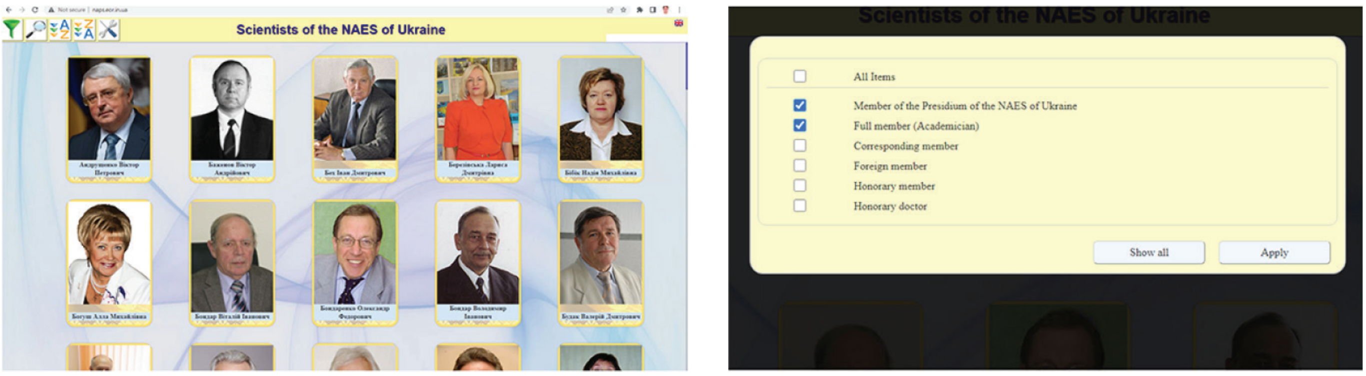
Each ontology on the server can be automatically assigned a folder in which materials displayed in the content can be stored. This folder and its management menu are located on the right side of the cabinet pop-up window (see Figure 5).

Fig. 5. Virtual office

Using an office greatly simplifies the creation of an ontological structure.

Let's limit ourselves to the summary outlined above, which is far from a complete list of ONTOS editor features, and move on to visualizing the results.

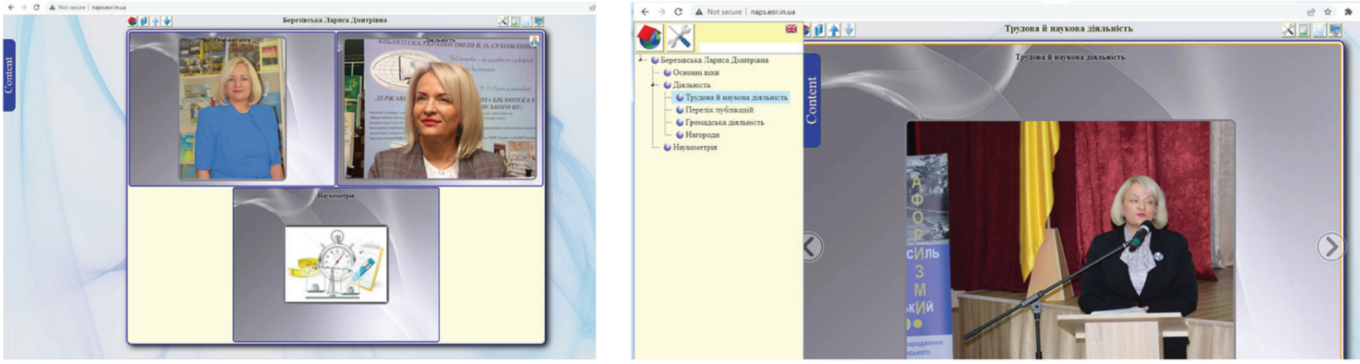
The developed viewer (which can be called either from the editor's menu or from the main page) allows viewing of both individual EERs and their collections. Also, the viewer can be hosted on an independent web resource. So at http://naps.eor.in.ua/ there is a collection of EER "Scientists of NAPS of Ukraine", which contains data about full members (academicians) and corresponding members of the National Academy of Pedagogical Sciences of Ukraine (see Figure 6). The collection is a set of interactive objects (image + caption); clicking on each of them brings up a viewer with extended information about the object.



(a) (b)

Fig. 6. Scientists of the NAPS web resource (http://naps.eor.in.ua/)

The EER collection itself is an ontology. A number of settings are provided, allowing one to apply a filter by object classes (see Figure 6b), search by a combination of letters in a surname, sort, select various design settings, etc.



(a) (b)

Fig. 7. ONTOS viewer (http://naps.eor.in.ua/)

When you click on the corresponding photo, the data is visualized using a viewer similar to an electronic textbook. This type of information display is organized as closely as possible to a traditional electronic textbook—in the center of the screen, there is a field where the main information is located (video, image, text, etc.). Depending on the settings, the field displays either brief information (splash screen) (see Figure 7a) and the main information appears when you click on it in a pop-up window (see Figure 8), or the main information appears immediately—as in a traditional textbook. On the left side of the screen (this can be changed) there is a drop-down panel with the content of the EER—a drop-down list of navigations (see Figure 7). Navigation buttons may also be present above and below the information panel (two-component control system).

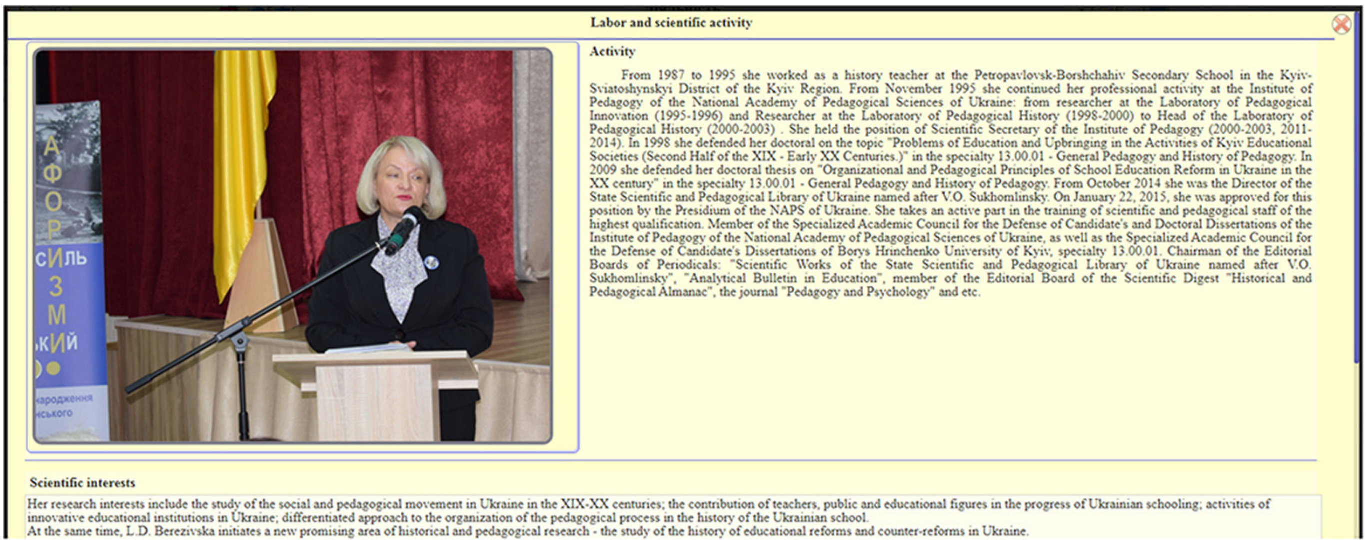


Fig. 8. The content window

Another example of using EER integrated into ONTOS is discussed in detail in the article "The Development of Constructive Interaction Skill as a Component of Social Success of Junior Pupil". The interactive textbook (for the purpose of testing, a fragment of such a textbook was developed), which was created using the ONTOS system, included a game application created using the LearningApps.org service (see Figure 9). In a fourth grade math class, when studying the topic "Area of a Rectangle and a Square", students were offered a task, the image of which is shown in Figure 9. The task is a drawing that reflects the size of rectangular sections and text, which directly indicates which areas each student has to find. At the bottom of the page is an interactive game where students have to connect images of a crop growing on a plot with a number equal to the area of the plot (numbers on the screen are 3 more than plots) [6].

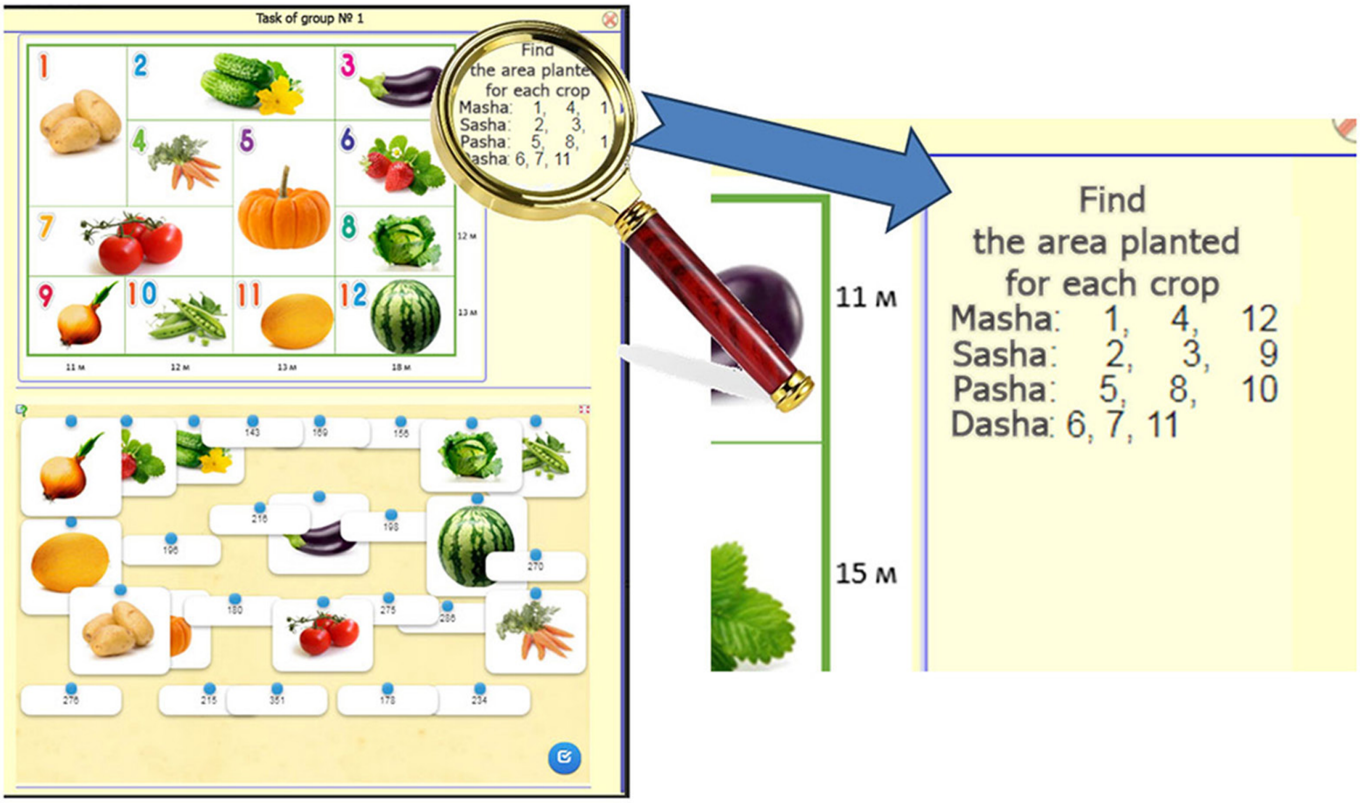


Fig. 9. Example of using the LearningApps.org service application as the ontograph node content (electronic textbook page content)

The use of the proposed EER showed high efficiency of its application. The children easily understood the task and completed it with enthusiasm.

Thus, the proposed integrative technology can be used during training sessions. The teachers highly appreciated its ability to develop electronic textbooks and manuals. Thus, we come to the conclusion that the EER proposed in our study makes possible the integration of data from different sources with the ability to adapt to the conditions of any subject area, regardless of its specifics.

4 CONCLUSIONS

As a result of our research, we have developed a technology for using the ontological approach to create an EER. It was concluded that from the point of view of the semantic approach, there are no fundamental differences between, in fact, the EER itself and the electronic catalog (library of resources), and it is possible to use an ontological graph (ontograph) to describe both the library and a certain EER.

Such an ontograph allows for the primary visualization of the EER structure, interpreting its structural elements as nodes (vertices) of the graph, and displaying the logic of transitions between structural elements in the form of directed links. With such an approach, the ontology is a kind of aggregator that ensures the integration of the semantic and technological approaches.

To increase the efficiency of using ontologies in the educational process, we have developed the Ontos.xyz resource, which consists of an ontograph editor and a viewer that allows one to display both individual EERs and their collections.

Thus, the digital competencies of the EER creators remain relevant, since they do not need to learn new software resources to work with individual ontology concepts (ontograph nodes), and the creation of the ontograph itself is carried out using an intuitive interface.

The software solution proposed by us, in contrast to its functional counterparts, is focused on use in the educational process.

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