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TRANSDISCIPLINARY INTEGRATION OF KNOWLEDGE IN THE ENVIRONMENT OF A VIRTUAL STEM CENTER

The **subject** of the article is the role of ontological systems in improving the processes of structuring and analyzing scientific content, especially in the context of STEM education. The **goal** of the work is to research and analyze the application of ontological systems in the context of managing educational materials in STEM education. The use of such approaches is focused on developing effective methods for structuring and presenting educational knowledge in the STEM education system, emphasizing the importance of integrating different scientific disciplines to optimize the educational process. In accordance with the purpose, the following tasks were set: to develop a methodology for creating and implementing ontological systems in STEM education and to develop the architecture of a virtual STEM center that would provide the implementation of the proposed principles. The research is based on the following **methods**: For the development of the architecture of the virtual STEM center, we used UML diagrams. We developed UML diagrams of roles and activities that illustrate the interaction of different users and systems, as well as demonstrate work processes and interactions in multi-agent systems. Special attention is paid to activity diagrams, which reflect the processing of user requests and the interaction of the stemua.science agent with other components of the STEM center. The following **results** were obtained: A modular system architecture of the virtual STEM center was developed and described using UML diagrams, which includes roles such as the STEM center administrator, editor, author, and user, as well as the administrator of the CIT "Polyhedron". The interaction of these roles with the virtual STEM center is described in detail, revealing the mechanisms of their interaction and joint work aimed at creating, filling, and editing content in the transdisciplinary STEM center. The process of optimizing work processes in the modular system of the virtual STEM center is also considered. Ways to fill and use the T-STEM center in an ontological form have been identified. The interaction of software entities of the T-STEM center in an ontological form has been analyzed. **Conclusions**: Based on the conducted research, it is concluded that the use of ontological systems in the context of managing educational materials in STEM education is an effective method for structuring and presenting scientific content, promoting the integration of various scientific disciplines, and optimizing the learning process. It is determined that ontological systems are an effective method for structuring and presenting scientific content, facilitating the integration of various scientific disciplines, and optimizing the learning process. The modular architecture of the system is found to facilitate efficient interaction among different roles and automate workflow processes. Integration with a multi-agent system allows for the use of external data sources and ensures interoperability with other systems. For the further development of the system, research is needed to enhance the efficiency of role interactions and workflow automation. Additionally, research on integrating the system with other STEM education systems is necessary.

Keywords: ontological systems; STEM-education; content structuring; data analysis; scientific materials; knowledge; educational process.

Introduction

Ontological systems are critical for structuring and analyzing scientific and educational content, in particular in STEM education (an approach to education based on the application of science 3, technology, engineering, and mathematics). They allow us to identify and systematize key concepts and their interrelationships, which contributes to a deeper understanding of subject areas.

Generally speaking, an ontology can be defined as a certain form of comprehensive and detailed formalization of descriptions of a certain area of knowledge that reflect images of the world picture using a conceptual scheme. Typically, such a scheme consists of a hierarchical structure of concepts (taxonomy) containing all relevant classes of objects, their relationships and rules accepted in this area of knowledge. A conceptual scheme means a set of concepts and information about concepts (properties, relations, constraints, axioms and rules for using concepts that are necessary to describe problem-solving processes). The relationships between these concepts and the axioms that define the basic rules and principles are fundamental to creating a coherent ontological structure [1, 2]. In fact, an ontology is a conceptual and conceptual framework of all scientific theories without exception.

Ontologies, as a formal description of concepts and their relationships, are crucial for the exchange and reuse of knowledge, especially in education [3]. The creation of an ontological structure involves the use of axioms, which are basic rules and principles, to define these relationships [4].

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This process can be facilitated by the systematic method, which involves the creation of ontologies in conceptual and logical-linguistic formats, where the former is intended for human understanding and the latter for machine processing [5].

Analysis of the problem and existing methods

Narratives and their ontological mapping STEM narratives, which include descriptions of various processes, facts, and their properties, can be represented through ontological models. This allows for greater semantic clarity and structural organization of scientific and educational texts [2]. Ontological models have been proposed as a means of structuring and representing scientific and educational information, which provides greater semantic clarity and organization [6]. These models can be used to develop deeply structured educational tasks, methods, textbooks, laboratory works, etc. They structurally reflect the semantics of academic disciplines, which is integrated in a transdisciplinary manner into interconnected content knowledge bases [7]. The problem of annotating scientific and educational texts with semantic information has been solved by using a modular ontology that allows building a reduced structure useful for automated annotation [8]. In addition, the development of ontological models for representing information accumulated by scientific and educational institutions has been investigated in order to facilitate the evaluation of their effectiveness [9].

In this context of scientific and educational activities, ontology can be considered as a certain explicit conceptualization of a logical theory, a certain calculus with certain rules. This theory allows to systematize the categories of reality as those expressed in the language of meanings of certain statements and utterances [10, 11], and which are in the content of narrative descriptions. Particular attention is paid to the presentation of their display formats. In the process of presenting a narrative in an ontological format, the contexts of all its concepts (ontology concepts) are hierarchically interconnected and distinguished by a strict order relationship. This determines the conditions for using the concepts of STEM disciplines in the formulation of educational and research tasks.

Hierarchically interconnected concepts of educational narratives form the basis of its taxonomic representation. Taxonomy in scientific and educational ontologies plays a key role, allowing to classify and systematize concepts according to their properties and interrelationships of their contexts. This contributes to a better understanding of the hierarchical relationships between different elements of knowledge [2]. Taxonomy as a structural platform for the ontology of scientific and educational narratives is crucial for the classification and systematization of concepts in STEM disciplines, as it helps to understand the hierarchical relationships between different elements of knowledge [16]. This is especially important in the semantic analysis of narratives of scientific and technical subject areas that make up the subject of STEM education, where the taxonomy of relations can be used to identify semantic relationships and automatically build ontologies [16]. The use of formal ontology tools such as identity, entity, unity, and dependency can further enhance the properties of the taxonomy and improve human understanding [17]. In the context of web documents, the structure of narratives can be used to highlight relevant concepts and establish hierarchical relationships between them, contributing to the creation of a taxonomy [18].

The axiomatic principle of forming STEM narrative ontologies provides a scientific foundation for teaching STEM disciplines, based on the basic rules and conditions on which their scientific concepts and their interconnectedness are defined [2]. Axioms and the basic principles of their use are crucial in the development of ontological systems in STEM education, as they provide the basis for scientific concepts and their interaction [19]. These principles guide the development of ontologies, ensuring that they are reusable, application-independent, and easy to maintain [19]. They also play a role in the selection of concepts and hypotheses, the reconstruction of scientific theories, and the evaluation of scientific and educational outcomes of STEM users [20]. Top-level ontologies that describe domain-independent categories of reality are particularly important in this regard [21]. The development of ontological theories based on established work in various fields further contributes to the creation of fundamental ontologies [20].

As a tool for displaying taxonomies, oriented graphs without cycles are most often used, which is formed by the concepts of educational narratives that are hierarchically interconnected. This allows us to consider the contexts of taxonomy nodes as components of certain knowledge, and to display their entirety as a fragment of the world picture. However, when considering the whole variety of taxonomies, the researcher encounters the phenomenon of the hyper-property of reflection, which is expressed in the fact

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that all taxonomies can be reflected on themselves. This reflexive reflection of a taxonomy on itself is verbal in nature. This can be deduced from the fact that the nodes of any taxonomy form specific statements that may have truth values [22].

Interactivity and consolidation in ontological systems. Ontological systems themselves are characterized by a high level of interactivity and the ability to consolidate with other information resources. This makes it possible to create more flexible and adaptive models for analyzing and studying scientific data. To do this, some researchers use logical-linguistic models and their components – concepts of a certain sequence of finite-length symbols (SFLS concepts), which form a certain set of names for marking the nodes of a taxonomic graph. The taxonomic graph itself is represented in the format of growing pyramidal networks (GPNs) [15].

This allows us to consider taxonomies as type-free constructions in the format of lambda expressions [23]. To prove the truth of taxonomies as a technological platform for ontologies of arbitrary narratives, the uniqueness of the SPNs to Bem trees is usually considered [23–25]. A constructive characteristic of the type-lessness of Bem trees and their uniqueness of the GPN is the formation on their basis of technological conditions for the implementation of taxonomies in order to ensure the implementation of scientific and educational narratives of different topics in the STEM environment and to identify the intercontextual coherence of the concepts that determine their content [1, 2, 15, 23–25].

The purpose of this article is to study and analyze the use of ontological systems in the context of learning materials management in STEM education. The use of such approaches is focused on the development of effective methods for structuring and presenting educational knowledge in the STEM educational system, emphasizing the importance of integrating various scientific disciplines to optimize the learning process. In accordance with the goal, the following **tasks** have been set: to develop a methodology for creating and implementing ontological systems in STEM education and to develop the architecture of a virtual STEM center that would ensure the implementation of the proposed principles.

Solving the problem. Materials and methods

In the course of the study, we developed the architecture of a virtual STEM center, which was used later to develop a virtual STEM center template (stemua.science) and its other components. In this study, we developed an architecture and described it using UML (Unified Modeling Language) diagrams to describe the architectural and software components of a virtual STEM center for transdisciplinary knowledge integration in a STEM learning management system. The described UML diagrams perform different functions in the context of the article. UML role diagrams are used to illustrate and analyze the different roles or actors that interact with a system. They help to understand how different users or systems interact with the components being developed. A UML diagram of the agent interaction activity of a multiagent system shows the interaction between different agents in a multiagent system. It details the processes and relationships that occur between different agents and their impact on the overall functionality of the system. A UML process activity diagram is used to describe the flow of workflows or operations that occur in a system. It visualizes the steps of an algorithm or the interaction between system components.

The UML process activity diagram of the process of issuing user request results demonstrates how the virtual STEM center system processes user requests and returns results. It is useful for explaining the mechanisms of user interaction with the system and receiving answers. Interaction diagram of the stemua.science agent: shows how the stemua.science agent interacts with other components or agents of the virtual STEM center. It is important to reflect the role of this agent in the overall architecture and its impact on workflows.

Results

Transdisciplinary integration of management roles in the modular architecture of a virtual STEM center

Moving on from the conceptual description of ontological systems and their importance for structuring scientific content, especially in the context of STEM education. We will consider the architecture of a virtual STEM center, which provides for specific roles, such as STEM center administrator, editor, author and user, as well as the administrator of the CIT (Cognitive Information Technology) "Polyhedron". The discussion focuses on the interaction of these roles with the system, revealing the mechanisms of their interaction and collaboration aimed at creating, filling and editing content in a virtual STEM center, which is fundamental to ensuring an effective information flow and development of the educational process.

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The architecture of the virtual STEM center includes roles such as STEM center administrator, editor, author, user, and administrator of the Polyhedron CIT. The architecture provides for the interaction of these roles in order to create a single field for them to fill and edit the educational resources of the virtual STEM center. It is advisable to consider the capabilities of each user and model their behavior in its environment.

The STEM center administrator determines its basic settings and provides access to users, determining their additional capabilities. The virtual STEM center settings include upgrading resources and ensuring data structuring in the system. The STEM center is based on the API (Application Programming Interface) client server architecture, which is operated by the STEM center administrator.

The main material is prepared by dispersed authors who have access to the virtual STEM center using their own automated workstations (offices), which provide the appropriate functionality that imitates the traditional functionality of text editors familiar to authors. It is assumed that teachers of schools and institutes, as well as methodologists, will play the role of authors. The author has the functionality to create and edit materials.

In order to ensure that the STEM Center template (stemua.science) provides high quality content, the role of a publication editor is envisaged. The editor checks the quality and style of writing, completeness of sentences, and grammar of the texts uploaded to the STEM Center. Accordingly, the role of the administrator includes the functionality of validating and publishing materials previously submitted by authors for publication.

After the data is entered into the virtual STEM center, it is structured in accordance with the standard provided by the ARI exchange protocol and transferred to the STEM center based on the Polyhedron CIT, which provides for the automated generation of structured data sets in the form of ontological graphs that can provide transdisciplinary educational materials. The administrator of the Polyhedron CIT ensures that data is received according to a certain standard and that ontologies are generated automatically.

After completing the entire cycle, STEM Center users can use the content of the STEM Center. Users have the functionality of working with a search engine, using the functions of selecting and filtering materials, and further viewing educational information.

The described process is a complete cycle of creating and using information based on a virtual STEM center. Detailed scheme of roles of a virtual STEM center (Fig. 1).

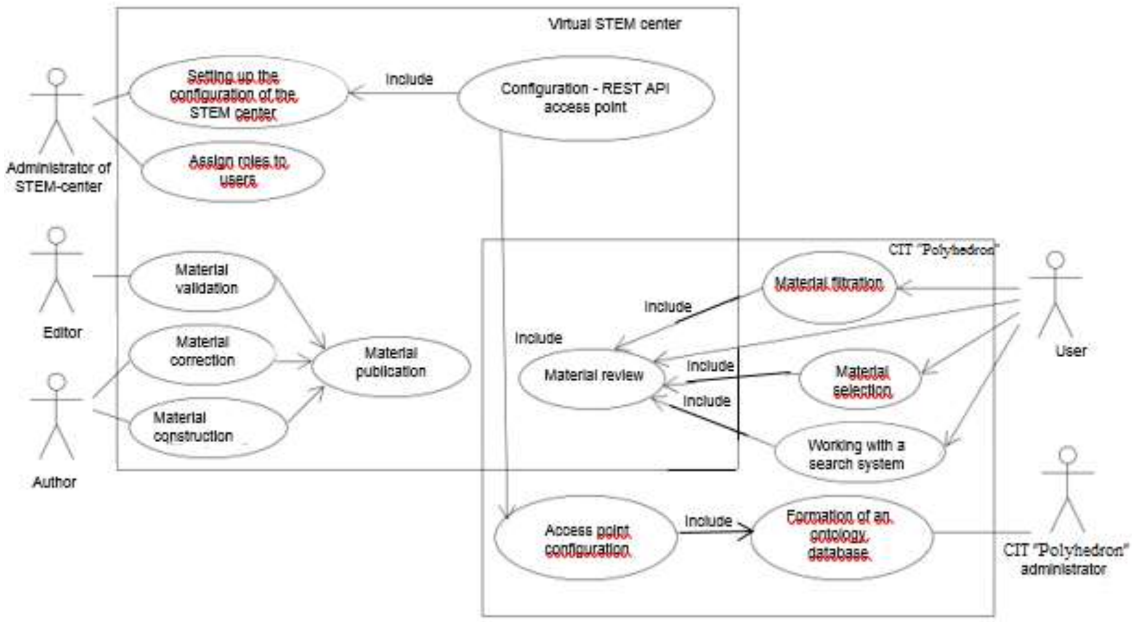

Fig. 1. Ways to use the virtual STEM center

Modeling user functional processes in a virtual STEM center using UML diagrams

To display behavioral models for different users performing different functional tasks in the virtual STEM center, the processes are described using UML diagrams of the interaction activity of the agent of the multiagent system of the virtual STEM center and its subsequent automated transformation into a structured information

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resource of the virtual STEM center (Fig. 2), the process of issuing the results of the request of users of the virtual STEM center (Fig. 2), the process of working with the resource of the virtual STEM center (Fig. 4).

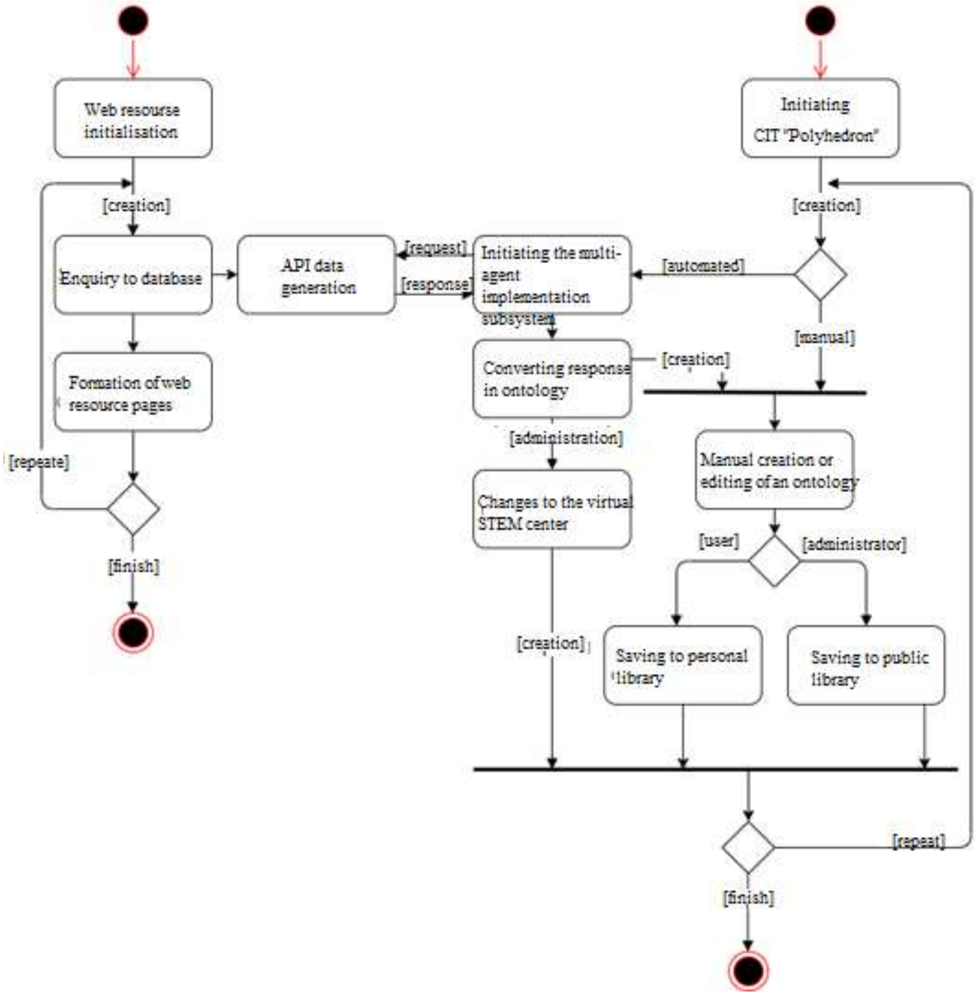

Fig. 2. UML diagram of the activity of interaction of the agent of the multi-agent system virtual STEM center and its further automated transformation into a structured information resource of the virtual STEM center

As can be seen from Fig. 2, to ensure the interaction of the agent of the multi-agent system of the virtual STEM center with the STEM center itself, a process is provided on the software side of the stemua. science agent, which consists of initializing a web resource, querying the database, depending on the type of query (determined by the user) to the database, the process can take place in two milestone flows – the formation of the page and the subsequent process of completing the work or creating a new resource (step querying the database); or the process of interaction between the stemua.science agent and the virtual one is initiated.

To simplify, systematize, and structure the STEM center data, the virtual STEM center uses an algorithmic mechanism for issuing the results of the virtual STEM center users' queries (Fig. 3), which involves the stage of initialization of the web resource and further milestone variability, which involves the display of all materials in a list, filtering by subject or filtering by type of material at the choice of the virtual STEM center user; based on the user's request, a list of virtual STEM center objects is generated that matches the user's request. After that, the process can be repeated or completed.

Optimizing workflows in the modular system of a virtual STEM center

The process of working in a virtual STEM center is initiated by activating the Polyhedron information technology complex (ITC), where users review existing ontologies created in advance. Automated data processing is realized with the help of integrated modules of the Polyhedron ITC, which include Synopsis, Confor, Editor, Alternative, Search Engine, Linguistic Corpus, and Crypto.

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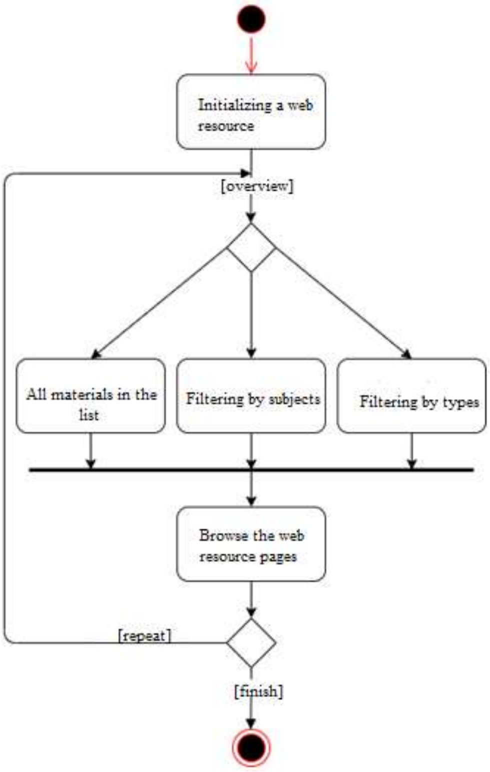

Fig. 3. UML diagram of the activity of the process of issuing the results of the request of users of the virtual STEM center

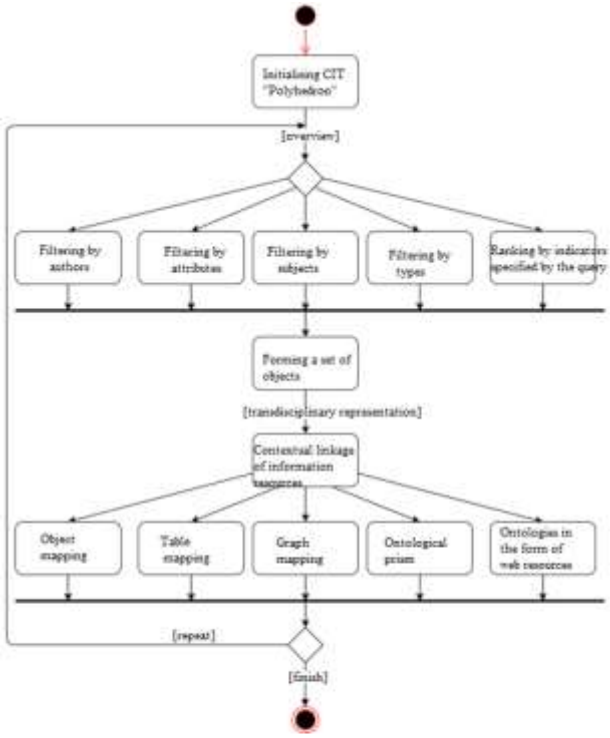

Fig. 4. UML diagram of the activity of the process of issuing the results of the request of users of the virtual STEM center

The data in the vertices of taxonomic graphs are processed in the Alternative module, which allows processing large data sets and selecting vertices with relevant semantic data and ranking ontological vertices by integral characteristics according to the user's request.

STEM-oriented systems are transdisciplinary and contain ordered disparate data sets that can be processed (filtered) according to the user's request to select information by the requested authors, attributes, subjects, and types, or to rank according to the user's request.

After processing by the Alternative module, sets of objects are formed and the user is given the opportunity to view them in a transdisciplinary view. Such processed data is subject to contextual linking of information resources and can be presented in an object representation, tabular representation, graphical representation, in the form of an ontological prism or in an ontology in the form of web resources. The user of the virtual STEM center can complete the work with the virtual STEM center or go through the algorithmic actions starting from the milestone of choosing options for forming sets of objects again. The UML diagram of the activity of the process of issuing the results of the request of users of the virtual STEM center is shown in Fig. 4.

As can be seen from Fig. 5, there are several ways to fill and use the T-STEM center in ontological form. An expert using the program module "Outline" can generate basic information to fill the T-STEM center. With the help of a recursive reducer, such basic information is processed and arrays of methods and research papers are formed. The methods and research works formed are read by queries using the Polyhedron and Alternative APIs, which in turn form a data array for the ontological configuration analysis module. The ontological configuration analysis module generates content that can be displayed and processed in the ontological workbench and further processed in the testing module. The user of the testing module can use the material data to select them according to the query criteria.

In addition, the ontological configuration analysis module can receive information from the editor through ontological configurations. The information processed by the ontological configuration analysis module can be used for viewing in the viewer and, in particular, in the form of an ontological prism. The ontological data through the viewer can be processed in the Alternative software, which can also be accessed directly through the Alternative API.

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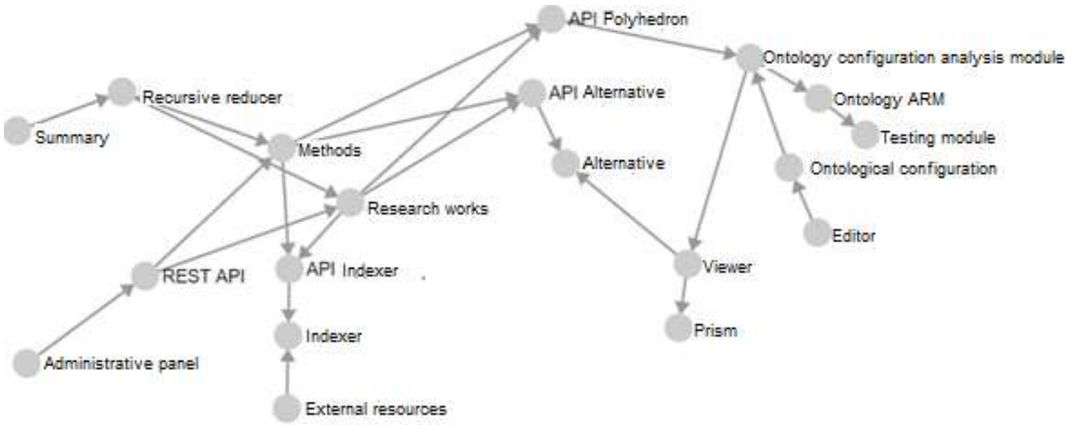

Fig. 5. General representation of the interaction of program entities of the T-STEM center in ontological form

Another way of filling is to use the administrative panel of the STEMUA templating tool and further use the REST API. The ontological entities of the T-STEM center are generated by analyzing natural language texts with the "Synopsis" module, processed by the "Indexer" module and using the REST API by converting data from the MySQL database into the XML format of ontologies.

In addition, the ontological T-STEM center can use data from external sources. To do this, the material from external resources is indexed by an indexer and an array of data on methods and research works is formed using the Indexer API.

The formation of data arrays is based on previous studies and provides for additional automation of a number of processes and simplification of data entry and formation of taxonomic arrays with data in the nodes. To process the input data and create relevant information output, the ITC "Polyhedron" software modules are used. For this purpose, an architectural solution has been developed, which consists in using the data of agents of a multiagent system. Let us consider the architectural solution on a practical example of using the external agent stemua.science and other external agents as sources of ontological data.

The formation of a display for the end user is created using the Polyhedron API or, if necessary, the Alternative API. The Polyhedron API transmits data to the ontological configuration analysis module, which, based on the analysis of the received data, loads the Ontology Viewer or the Ontology ARM.

The author of the publication creates content and enters it into the virtual STEM center, where the publication editor automatically generates, formats and processes the content. If the virtual STEM center has successfully processed the entered data, it generates a report on the content's compliance and notifies the author. In response, the author generates a confirmation request for the content to be published. The publication editor transfers the processed data to the database, where the exchange process is initialized using data exchange protocols. The exchange process includes saving and structuring and receiving a response about the successful completion of the process. The database generates a request for data exchange from the multi-agent system to the controller for initializing the resource interoperability point. A data tracer passes between the database and the resource interoperability point initialization controller.

Using the data obtained from the stemua.science agent database, the resource interoperability point initialization controller provides the generation of a data array in the standard defined by the protocol, where the data is actually transferred, which involves the formation of a request from the ontological database creation controller and a response from the angent. After that, an exchange XML file is generated and the data is transferred to the multi-agent system of the CIT "Polyhedron".

The XML file is automatically transferred to the CIT "Polyhedron" administrator's office, where the administrator can perform a number of actions, including making a decision on saving. Further, the architecture of the virtual STEM center provides for the process that was previously proposed, which consists in recording in an ontological database. From the ontological database, it becomes possible to process the data with the tools of the CIT "Polyhedron", in particular, to receive a request from the user for interoperable interaction and calculation using semantic and integral characteristics. The processing takes place in the "Alternative" module.

In accordance with the proposed architecture, the user has the option of using the resource in the agent's database, using a taxonomized resource located in

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the CIT "Polyhedron", or using data processed by the Alternative module. The diagram of interaction between the stemua.science agent and the CIT "Polyhedron" is shown in Fig. 6.

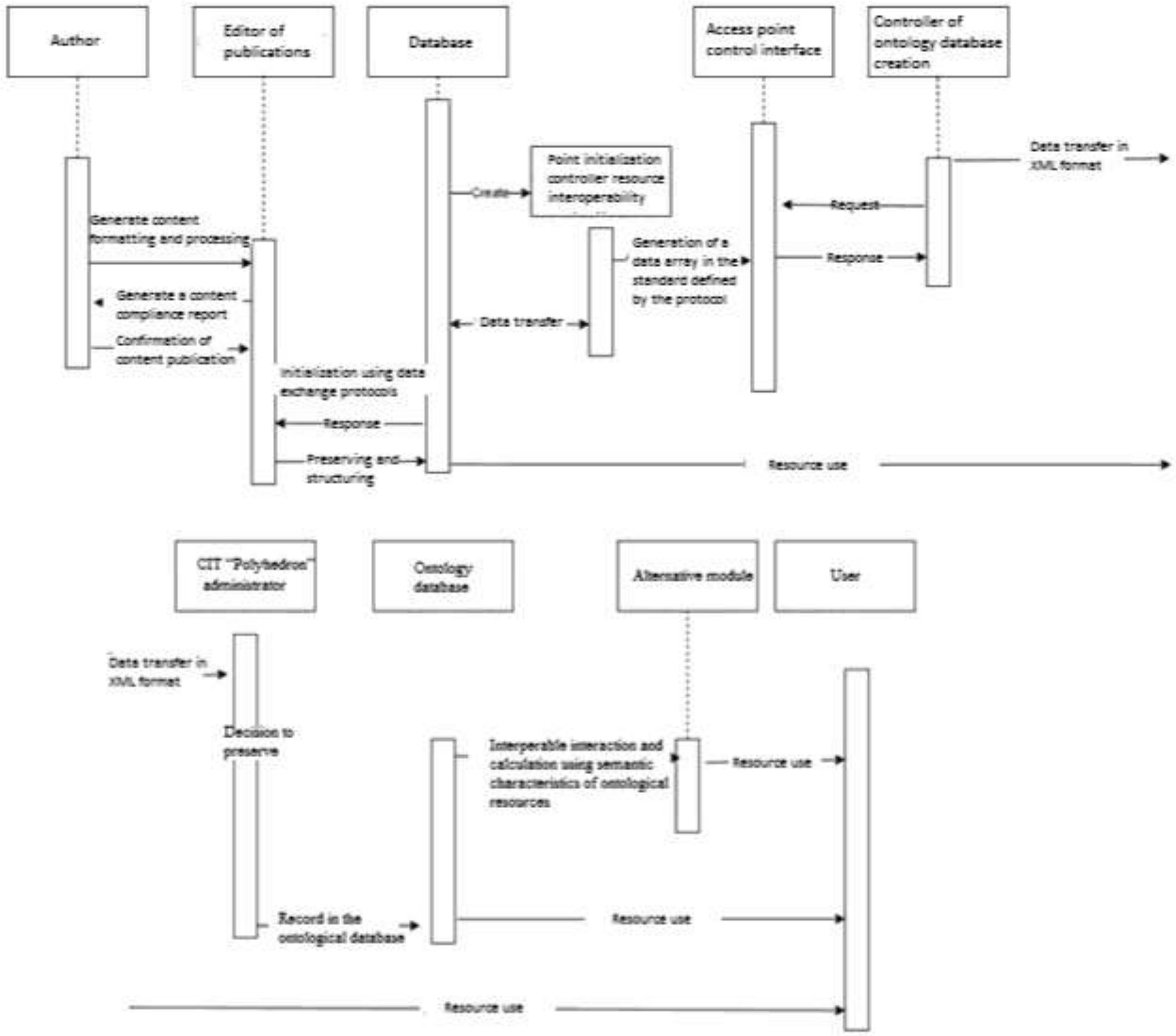

Fig. 6. Diagram of interaction between the stemua.science agent and the CIT "Polyhedron"

Structure and Functionality of Classes in the Modular System of the Virtual STEM Center

To ensure the integral functioning of the virtual STEM center, the architecture provides for the use of classes that can be divided into controller classes, data classes, and processing classes (Fig. 7).

The STEM center controller provides the use of agents of a multi-agent environment by generating request-responses from disparate web environments (for example, those using wordpress).

To generate structured information, the models of ontograph, node, property, alternative, criterion, and dessiontask were developed earlier.

The Ontograph class is responsible for displaying an ontological graph consisting of a set of graph nodes and allows you to access the parent and child nodes and elements of the selected node. Ontograph provides quick access to each node by its name or unique identifier. It uses xml/json to load and save the ontological taxonomy.

The Node class is used to generate information about the point itself and its attachments. This class ensures the correct storage and use of information about the name, properties, related nodes and vertices.

The Property class is used to store and display the properties of each vertex. It also contains tools for managing the properties of a node, including defining the property class, adding, editing, and deleting.

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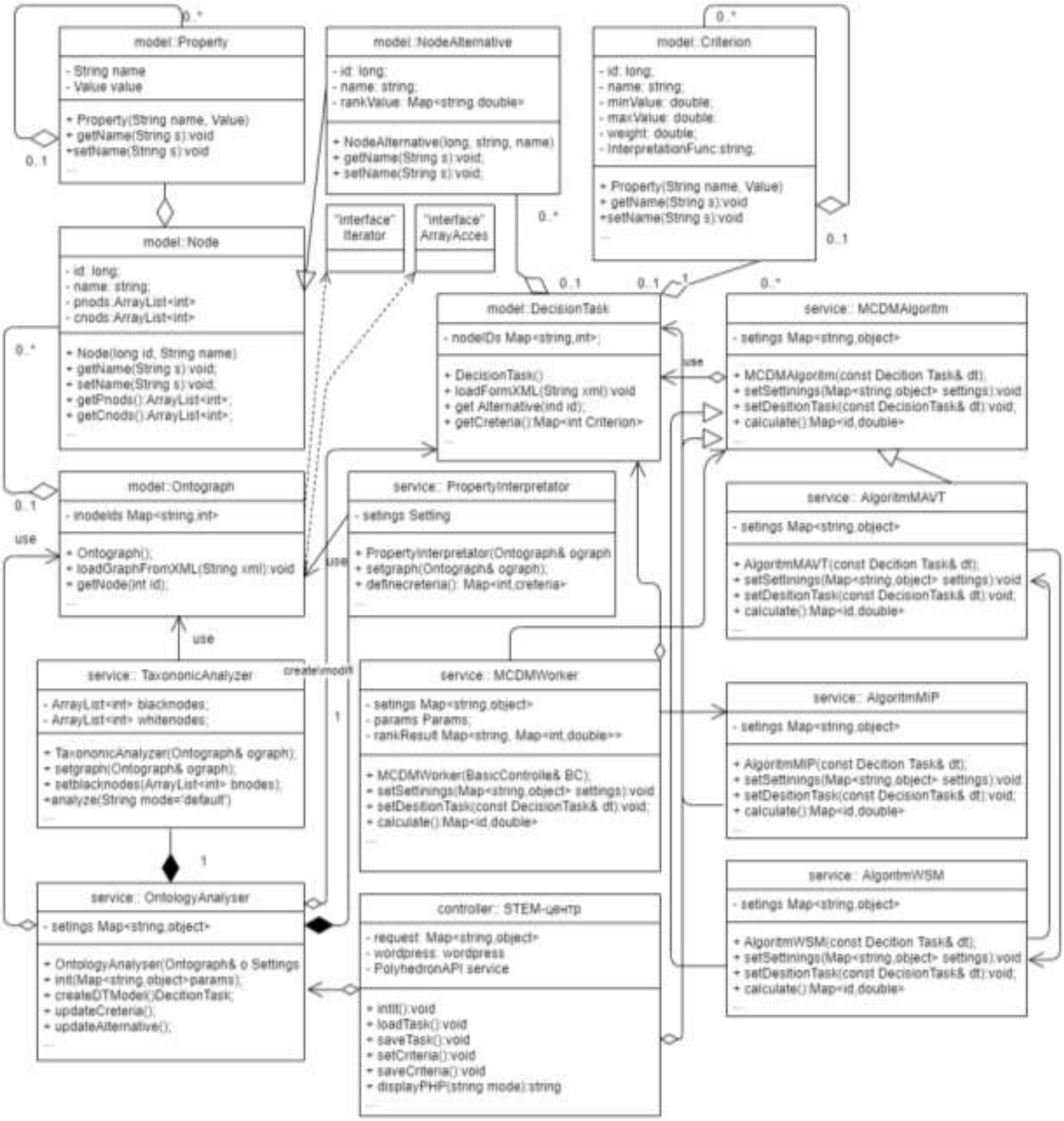

Fig. 7. Diagram of T-STEM center classes

The DecisionTask contains information about the ranking model, alternatives, and criteria, and allows you to use nodes for ranking tasks. It allows you to create weighting factors.

The NodeAlternative class is used to solve problems of alternatives. It is derived from the Node class and is compatible with Ontograph. It contains algorithms for processing properties and attributes.

The Criterion class is used to solve optimization problems and uses information about the properties of a point and forms criteria from them, including the name, range of possible values, and optimization vector.

Services are an important component of a virtual STEM center that use models to generate structured data sets from unstructured ones, in particular, agents of a multi-agent STEM center. These services include Ontology Analyzer, Ontology Analyzer, Taxonomic Analyzer, and Property Interpreter.

OntologyAnalyser generates ontologies according to the models. This class allows you to use ontological nodes and taxonomic structure to form a task of ranking alternatives based on an ontological model. The OntologyAnalyser analyzes the ontology and extracts information from it and generates data sets that are

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further processed. It works in a complex and includes the TaxonomicAnalyzer and PropertyInterpreter classes.

The TaxonomicAnalyzer class analyzes the taxonomy and separates the nodes that contain relevant data and can be used as alternatives from those that do not contain relevant data and cannot be used as alternatives. It provides labeling of such vertices and passes the task formation for filtering vertices and alternatives.

The PropertyInterpreter class provides the formation of an array of input data of all vertices that can be used to process alternatives. It also provides the definition of common properties of alternative objects that form arrays of criteria for ranking and filtering.

Since the data in the virtual STEM center are formed by significant arrays of heterogeneous data, it is important to process them using the alternative tool for ease of use. Therefore, additional ranking classes are used, such as the solution of the formed problem of ranking alternatives (MCDMWorker), the class of the algorithm for solving the problem of ranking alternatives (MCDMAlgoritm), the class of the method of weighted sums of criteria (AlgoritmWSM), the class of using the ideal point method (AlgoritmMIP), the class of using the method of multi-attribute evaluation (AlgoritmMAVT).

The MCDMWorker class creates a problem of ranking alternatives to be solved based on its model, which is the mathematical core of the virtual STEM center. That is, this class aggregates the results obtained and forms the final result.

The abstract class MCDMAlgoritm provides data preparation for other classes. It uses methods for calculating criterion values by interpreting the criteria, ensures the generation of a single database by reducing the data of specific vertices (criterion values) to a common numerical scale. It also uses algorithms for using weighting coefficients for each criterion.

After the data and criteria required for processing are formed, specialized classes are used to perform calculations using various methods. For example, there are classes for solving the problem of ranking alternatives using the weighted sums of criteria method (WSM; AlgoritmWSM), using the method of ideal point (MIP; AlgoritmMIP), using the method of multi-attribute evaluation (MAVT; AlgoritmMAVT).

The main entities of a virtual STEM center are Author, Editor, Administrator, User, and Material. Each of these entities contains data that is necessary for the processes described in the behavior diagrams of the virtual STEM center. The virtual STEM center contains information about the unique administrator identifier (AdminID), his/her name (Name) and permissions (Prirogatives) related to the administrator entity; the identifier (AuthorID), name (Name), permissions (Prerogatives) and materials (Materials) related to the author; EditorID, Name, Prerogatives, and ValidatedMaterials related to the editor; MaterialID, an array of properties, URL, TextData, Abstract, Published, and TimeStamp related to the materials. A diagram of the relationship between the T-STEM Center entities is shown in Fig. 8.

Conclusions. Prospects for further development

This article addresses the urgent problem of systematizing large volumes of unstructured text in a global environment. The focus is on developing a model, methods, and tools for transdisciplinary representation and integration of this data. This research is important in several ways: The paper demonstrates the use of recursive reduction and other modern techniques to improve the efficiency of information retrieval, processing, classification, and selection. Implementation The transdisciplinary integration that promotes the creation of a modular system in STEM centers contributes to the development of innovative teaching and research methods. Implemented interactive modules and tools, such as "'Synopsis", "Confor", "Editor", significantly improve user interaction with the content of the STEM environment. The recursive reduction method with a number of transformations was used to achieve the predicative form of ontologically specified descriptions, which facilitates deeper analysis and understanding of STEM educational content.

Using UML diagrams, we visualized the functional processes and interactions between different users and components of the virtual STEM center, providing a deeper understanding of its structure and functionality. The proposed virtual STEM center provides high flexibility and scalability, which allows it to adapt to the changing needs of users and expand as needed. The use of the category of transdisciplinarity helps to integrate various educational disciplines, facilitating the processes of synchronization of STEM education disciplines and intellectual exchange and cooperation in teaching the basics of science.

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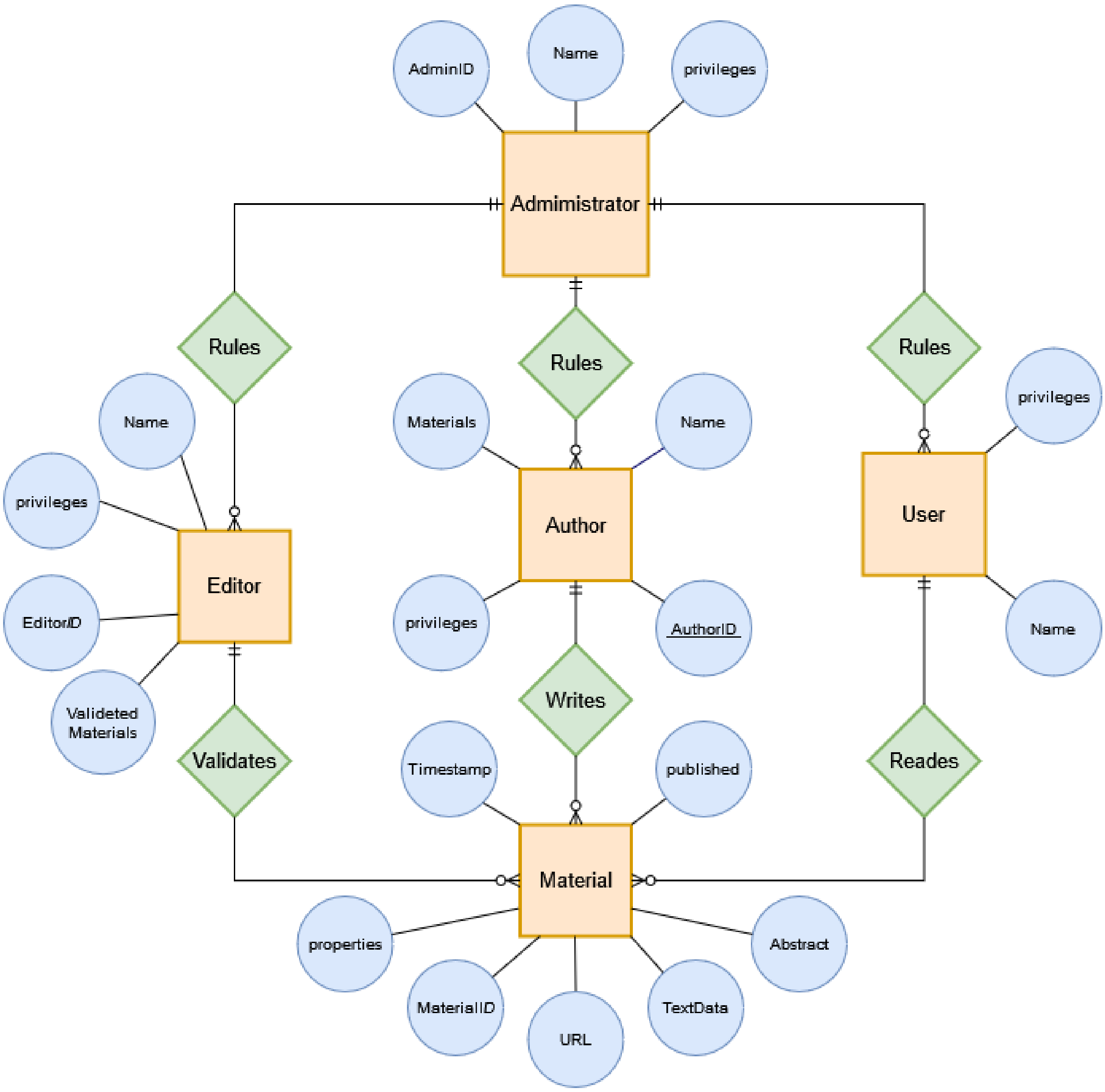

Fig. 8. Diagram of relationships between T-STEM center entities

In general, the study provides a significant contribution to the development of scientific approaches to managing large amounts of information, especially in the context of transdisciplinarity of educational narratives, becoming an important element in the field of STEM education and research and education activities.

Prospects for further development of the research presented in this article promise to be large-scale and diverse, as they cover a number of key areas of use and improvement of scientific and educational disciplines. The main directions for further development can be outlined as follows:

Given the success of designing ontology-driven transdisciplinary representation of educational narratives as large arrays of unstructured information, the possibility of expanding their use in teaching disciplines is being considered. This may include public administration, industry, science, education, media, and other areas where effective information processing and structuring is key. The structured representation of information implemented in the virtual STEM center environment creates the basis for the implementation of decision support systems in the course of performing educational and research tasks. This can significantly increase the efficiency of the scientific and educational process.

The use of the developed virtual STEM center in education and science opens up new opportunities

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for improving the quality of the educational process and research. In particular, it can help to better engage students and researchers in deeper study of various disciplines.

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ТРАНСДИСЦИПЛІНАРНА ІНТЕГРАЦІЯ ЗНАНЬ У СЕРЕДОВИЩІ ВІРТУАЛЬНОГО STEM-ЦЕНТРУ

Предмет дослідження – роль онтологічних систем у вдосконаленні процесів структурування та аналізу наукового контенту, особливо в контексті STEM-освіти. **Мета** роботи полягає у дослідженні та аналізі застосування онтологічних систем у контексті управління навчальними матеріалами в STEM-освіті. Використання таких підходів зосереджене на розробленні ефективних методів структурування та подання навчальних знань в освітній системі STEM, з огляду на важливість інтеграції різних наукових дисциплін для оптимізації навчального процесу. Відповідно до мети визначено такі **завдання**: розробити методологію створення та впровадження онтологічних систем у STEM-освіту та розробити архітектуру віртуального STEM-центру як платформи трансдисциплінарної інтеграції систем знань (T-STEM), що впроваджуються в STEM-освіті. Проведені дослідження ґрунтуються на таких **методах**: для розроблення архітектури віртуального STEM-центру застосовано UML-діаграми; створено UML-діаграми ролей та активностей, що ілюструють взаємодію різних користувачів і систем, а також демонструють робочі процеси та взаємодії у мультиагентних системах. Особлива увага приділяється діаграмам активностей, що відтворюють оброблення запитів користувачів і взаємодію агента *stemua.science* з іншими компонентами STEM-центру. Досягнуто таких **результатів**: розроблено та описано за допомогою UML-діаграм архітектуру модульної системи віртуального STEM-центру, що передбачає такі ролі, як адміністратор STEM-центру, редактор, автор і користувач, а також адміністратор КІТ "Поліедр". Детально описано взаємодію цих ролей з віртуальним STEM-центром та водночас розкрито механізми їх взаємодії та спільної роботи, спрямовані на створення, наповнення та редагування контенту в середовищі віртуального STEM-центру. Також розглянуто процес оптимізації робочих процесів у модульній системі віртуального STEM-центру. Визначено шляхи наповнення та використання T-STEM центру в онтологічному форматі. Проаналізовано взаємодію програмних сутностей T-STEM центру в онтологічному вигляді. **Висновки**. На основі проведеного дослідження зроблено висновок, що використання онтологічних систем у контексті управління навчальними матеріалами в STEM-освіті є ефективним методом структурування та подання наукового контенту, що сприяє інтеграції різних наукових дисциплін та оптимізації навчального процесу. Визначено, що онтологічні системи є ефективним методом структурування та подання наукового контенту, що сприяє інтеграції різних наукових дисциплін та оптимізації навчального процесу. Установлено, що модульна архітектура віртуального STEM-центру забезпечує ефективну взаємодію різних ролей та автоматизацію робочих процесів. Інтеграція з мультиагентною системою дає змогу використовувати зовнішні джерела інформації та забезпечує інтероперабельність з іншими системами. Для подальшого розвитку віртуального STEM-центру необхідно дослідити підвищення ефективності взаємодії різних ролей та автоматизації робочих процесів. Також планується вивчити інтеграцію віртуального STEM-центру з іншими системами STEM-освіти.

Ключові слова: онтологічна системи; STEM-освіта; структурування контенту; аналіз даних; наукові матеріали; знання; освітній процес.

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