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USING ELEMENTS OF GAMIFICATION IN INTELLIGENT LEARNING SYSTEMS: ONTOLOGICAL ASPECT

Abstract. The article considers an ontological approach to the creation and use of intelligent learning systems with elements of gamification. It is expedient to use developed multi-level ontological model in the implementation of learning processes in higher educational institutions. An ontological modeling of the intelligent learning systems based on multidimensional models is proposed. The proposed approach makes it possible to develop the multi-level ontological model of any intelligent learning system that fully reflects the pragmatics of the studied subject area. The proposed multi-level ontological model of the intelligent learning system with elements of the gamification captures and structures knowledge common to the subject area that is being studied. This allows you to reuse it as the basis of a single knowledge model, which ensures logical consistency between individual ontologies when combined to create learning content (for example, online course) with a wider list of the topics and tasks. The application of the ontological approach is an effective way to design and develop the intelligent learning systems. The constructed individual ontological models (of learning content, of tests, ontology of student results and actions, of student knowledge assessments, of the gamification components) contribute to the design of a unified information learning environment (learning content), within which intelligent learning systems that use the gamification elements. The multi-level ontological model proposed in the work helps to increase the efficiency of learning processes, maintaining interest and motivation to study the proposed learning content containing elements of gamification. The result of using the elements of gamification and the ontological modeling in the intelligent learning systems is the ability to make the necessary adjustments to the goals and objectives of the learning process, the learning process, the course of learning, the requirements for the level and competence of students.

Keywords: ontology; ontological model; multi-level ontological model, intelligent learning system, information technology; learning content; gamification; knowledge.

INTRODUCTION

Intelligent learning systems allows you to develop, manage and distribute learning content with sharing rights. Intelligent learning systems are used to conduct e-learning, which includes the processes of obtaining knowledge and testing student knowledge.

In studies on information / intelligent learning systems [1] – [4], both traditional technologies for organizing learning processes (including methods for providing learning content (theoretical material of lectures, tests, tasks for independent work, components of gamification) and new ones, taking into the account the immersion of modern students to the world of digitalization and digital (information, intelligent) technologies.

Online learning content is used in particular as:

– additional support for the main course of study;

– the basics for self-education (in this case, students independently master, for example, ready-made online courses);

– the main training course of study.

The development of the intelligent learning systems in Ukraine is driven by the following trends:

– participation in the processes of globalization and the creation of a single information educational space;

– the presence of a lack of specialists demanded by the market;

– development of new "digital" (information and intellectual) learning technologies;

– growing competition between institutions of higher education.

The advantages of the intelligent learning systems with elements of gamification are, in particular:

– manufacturability;

– accessibility and openness of education (learning, training);

– freedom and flexibility;

– individualization of training for each student;

– increasing motivation for learning;

– involvement in the learning and self-learning processes of various user groups (with different levels of digital learning, different levels of knowledge about the studied subject area (for example, training courses) [17];

– reducing the nervousness of students when passing a test or exam.

The disadvantages of all the intelligent learning systems (including those that use gamification [5]) are, in particular:

– lack of face-to-face communication between students and teacher;

– the need for a personal computer and Internet access;

– the problem of user authentication when checking knowledge;

– control of the relevance and quality of learning content;

– high level of complexity in the process of selecting gamification components for the corresponding online courses;

– high labor intensity of developing online courses.

To ensure the reuse of existing online learning content, the SCORM (Sharable Content Object Reference Model) standard was developed [6]. The standard allows components to be compatible and reusable. Learning content is presented in separate small blocks that can be included in various online courses and used in the intelligent learning systems, regardless of who, where and with what means they were created.

The intelligent learning systems technological component makes it possible to provide learning content not only in text formats, but also using gamification components, which allows the user of the system to better assimilate learning content and motivate him to study difficult or unimportant (in his opinion) elements of learning content (lectures, practical tasks, assignments for self-study, etc.).

According to the theory of double coding, information is perceived through two independent channels. On one channel, oral information is perceived (for example, audio text), and on the other - video, sound illustration of learning content. Assimilation of learning content occurs better when information is perceived through two channels.

E-learning should not exclude the possibility of communication with the teacher and other students, cooperation in the process of cognitive and creative activity, and socialization of students. One of the promising ways to improve the quality of the intelligent learning systems is the use of ontologies and semantic technologies in it. Semantic Web [7] and Linked Data [16] technologies make it possible to use ontologies for storing, collecting and distributing data.

One of the advantages of these technologies is data reuse. Automation and development of methods for filling ontologies is one of the main tasks of filling the system with learning content and keeping it up to date.

USING ONTOLOGIES IN THE DEVELOPMENT OF THE INTELLIGENT LEARNING SYSTEMS

Ontology is a system consisting of a set of concepts and a set of statements about these concepts, on the basis of which classes, objects, relationships, functions and theories can be built. In other words, ontology is an explicit description of conceptualization, i.e. the structure of reality, considered independently of the vocabulary of the subject area and the specific situation [8], [9], [18], [19].

The ontology of the intelligent learning systems with gamification elements can be represented as [10]:

$$O_{ILS} = < C_{ILS}, G_{ILS}, R_C, F_C >$$

where C_{ILS} is a set of concepts (elements, terms) of the subject area, which is represented by the ontology O_{ILS};

G_{ILS} is the set of gamification components that are related to domain concepts;

R_C is the set between the concepts of the subject area under consideration;

F_C is the set of interpretation (axiomatization) functions defined on concepts and / or relations of the ontology O_{ILS}.

The main components of an ontology are: classes or concepts, relationships, functions, axioms, examples. There are two alternative approaches to creating and researching ontologies. The first (formal) is based on logic (first-order predicates, descriptive, modal, etc.). The second (linguistic) is based on the study of natural language (in particular, semantics) and the construction of ontologies on large text arrays, the so-called corpora.

Web ontology may include descriptions of classes and their properties, as well as class individuals.

Ontologies play an important role in the organization of Web-based knowledge processing, sharing and exchange between applications. Ontologies, defined as shared formal conceptualizations of specific subject areas, provide a common understanding of the topics of online courses, information on which users and applications can exchange information.

One of the main goals of an ontology is to classify such objects, so they are also included. Thus, classes must correspond to sets of things in the area under consideration, and individuals to real objects that can be grouped into these classes.

Properties allow you to assert general facts about class instances and specific facts about individuals. Properties can describe simple data or complex objects. An important role of properties is to define relationships (dependencies) between ontology objects. Typically, a relation is a property whose value is another object.

The core of an intelligent system is a knowledge base – a collection of knowledge of the subject area, written in a form understandable to the expert and user (usually in some language close to natural).

Semantic networks are widely used in knowledge bases of intelligent systems as a knowledge representation language in solving speech recognition and natural language understanding problems.

For semantic networks, it is mandatory to have the following types of relationships:

– class – element of the class;
– property – value;
– is an example of a class element.

Benefits of Semantic Networks:

– universality achieved by choosing an appropriate set of relations;
– visibility of the knowledge system presented graphically;
– proximity of the network structure representing the knowledge system to the semantic structure of phrases in natural language;
– compliance with modern ideas about the organization of long-term human memory.

The disadvantage of this model of knowledge representation is the complexity of organizing the procedure for searching for inference on the semantic network. The main purpose of the Semantic Web is to store information in a form suitable for computer processing.

The use of the ontological approach and the Semantic Web when storing data contributes to:

– dissemination of knowledge (the ability to use, modify and supplement open data structures in the network);
– logical conclusion of new knowledge;
– reuse of knowledge.

For the development of software tools and the information technologies, standards, formats and protocols have been developed that regulate the interfaces for the interaction of software modules in an intelligent system.

The Semantic Web uses the Resource Description Framework (RDF) model to store data. RDF represents resource claims in a form suitable for computer processing [13].

The structure underlying any expression in RDF is a collection of <subject, predicate, object> triplets. A set of such triplets is called an RDF graph. The subject, object, and predicate are identified by a Uniform Resource Identifier (URI).

Data types in RDF are described using literals. A data type consists of a lexical space, a value space, and a lexical-to-value mapping. Anything represented by literals. A literal can only be an object in a triple. Literals can be untyped or typed.

An untyped literal is a string combined with an optional language tag. An untyped literal can be used for unformatted natural language text.

A typed literal is an element of the value space of a data type that is referenced by a URI obtained by applying a lexicon-to-value mapping for a literal string.

The primary role of RDF is to provide an object-attribute-value model for metadata. RDF data does not support mechanisms for denoting property names. RDF does not have a syntax for denoting object classes. To express semantics, vocabularies, taxonomies, and ontologies are required.

The dictionary built into the RDF model is the RDFS dictionary (RDF Schema), which provides a set of classes and properties for the RDF knowledge representation model, which forms the basis for describing ontologies using an extended RDF dictionary for the structure of RDF resources [14].

The RDFS dictionary describes [16]:

– classes of resources and data types;
– relationships between objects and subjects in ontologies;
– names and comments to objects;
– class hierarchy;
– class membership.

Using the RDF format allows you to describe, in particular:

– organizational structure of the educational institution;
– personalities of students and teachers;
– training programs, courses (including online courses);
– mechanisms for checking knowledge (tests, assignments for independent work);
– subject terminology, concepts and subject areas;
– auxiliary sources of learning content.

To record the semantics of subject areas in ontologies, the OWL language (Ontology Web Language) is used [15]. OWL is designed for applications that not only provide information to the user, but also perform operations on the data. OWL extends and complements semantic data representation technologies such as XML, RDF, and RDFS.

The language is based on the representation of reality in the data model "object-property" [20]. Each description element in OWL is assigned a URI. OWL allows you to describe the meaning of terms in dictionaries and the relationships between them.

The basic language constructs of OWL are: classes, class hierarchies, class instances (individuals), properties, property properties, equivalence, and incompatibility. One of the advantages of OWL is the focus on independent distributed ontology development, and the disadvantage of OWL is that it does not answer the question of how to work in an ontology with conflicting statements.

SPARQL (Protocol and RDF Query Language) is used to search for and retrieve knowledge from knowledge bases and triplet stores [21]. SPARQL supports extended value testing and query constraint through the original RDF graph. There are two types of SPARQL access points: general purpose and local. General purpose access points can query any specified RDF documents on the Internet. And local access points are able to receive data from only one resource.

As the Web permeates our lives, there is a growing need for direct access to data not yet available from the Web or limited to hypertext links. Linked Data technology provides an approach where not only documents but also data can become full-fledged elements of the Web, extending the Web into a global information space based on open Web data standards.

This concept allows data from one source to reference data from another source. Linked Data support also allows you to create Web documents that can be processed by a machine.

The main principles for publishing data using Linked Data are:

– all elements are defined by means of URI;
– using HTTP URI so that these entities can be referenced and found both by a person and by the corresponding system;
– providing useful information about the entity using standards such as RDF and SPARQL;
– inclusion in the description of a link to other entities (if there are relationships), using the URI of these entities when publishing data on the Web.

As the demand for Web applications in the systems development industry has grown, tools for developing applications using Linked Data technology have emerged, in particular, the

Information Workbench platform, which allows you to create Web applications that use structured and unstructured data from various open sources.

The platform supports the ability to edit datasets with change history support, hybrid data search, and provides a built-in SPARQL access point. Information Workbench is suitable for developing Web applications and Web services to store ontologies and datasets from various sources and support multi-user editing of datasets.

Application of ontologies in the educational process The use of ontologies in the intelligent learning systems provides, in particular, such advantages as:

- exchange of information between learning systems;
- providing platforms for reusing elements of learning content;
- implementation of intellectual and personalized student support;
- the use of visual models of subject areas in teaching various disciplines;
- increasing flexibility in building the educational process, describing models of subject areas of education;
- the use of links between heterogeneous objects of the educational process.

The use of RDF in educational applications reduces the complexity of introducing new specifications by adding a new RDF schema that can interact with existing ones. This possibility is important in the adaptation of educational technologies.

The intelligent learning system, using Semantic Web technology, provides a quick search for the concepts of the subject area, which allows the student to get complete information about the concept of interest to him. Information about the domain concept can be provided with gamification elements and links to other sources and concepts. Structured learning objects and the ability to personalize the intelligent learning systems using Linked Data principles make these systems more flexible.

The user of the intelligent learning system has the ability to customize the structure of the data provided to him, depending on his own preferences. Storing and distributing data using the ontological approach makes it possible not only to easily integrate existing internal and external learning content into the developed or modified intelligent learning systems but also to analyze them based on the assessment of relationships between objects in the ontology (the ontological model).

Using ontologies to describe learning content allows you to analyze content of the intelligent learning system using certain indicators and methods for evaluating ontologies.

Ontological models make it possible to organize not only the educational process, but also the research process on the basis of a single intelligent learning system.

One of the new trends in education in Ukraine is the competency-based approach. With the competency-based approach, the intelligent learning system evaluates the student's competencies, reflecting his knowledge, ability to self-educate, social and personal qualities. To assess these competencies, The intelligent learning system must integrate and analyze statistical data related not only to testing students' knowledge, but also to their interaction with learning content and other users of the intelligent learning system.

Semantic technologies allow aggregating data from social networks in order to analyze the social and personal qualities of a student. The development of communication technology makes it possible to organize virtual lectures and conferences.

Modern intelligent learning system should not only be focused on students of a particular university, but provide online courses to everyone. Support for intelligent learning system, designed for a large number of users, requires huge information resources. The problems with such the intelligent learning system are:

- filling the system with online courses and learning content;
- maintaining the relevance of learning content;

– assessment of coverage of theoretical materials of the online course by practical tasks;
– organization of testing students' knowledge.

The use of ontologies and technologies of Semantic Web and Linked Data in the intelligent learning systems allows solving these problems.

This approach allows you to implement in the intelligent learning systems:
– automatic analysis of learning content;
– aggregation, harmonization and integration into the system of learning content from external sources;
– automatic processing of materials for testing students' knowledge with the publication of the results.

MULTI-LEVEL ONTOLOGICAL MODELING OF THE INTELLIGENT LEARNING SYSTEMS

The main functions of an intelligent learning system based on a multi-level ontology are:
– extracting learning content from external sources and converting them to the intelligent learning systems format;
– provision of learning content in various formats and at different levels of presentation complexity (details);
– editing existing and creating new online courses (fragments of learning content);
– linking learning content with external sources (electronic libraries, multimedia resources, social networks, etc.);
– analysis of the relevance, completeness and balance of learning content and online courses;
– providing the ability to search for the necessary fragments of learning content.

The use of ontological models makes it easier for the system to support different languages. Any ontology object can have a set of localized names represented as value properties. This feature allows the system to store learning content in different languages.

The main task of language detection is to determine which of the natural languages a text belongs to, so that later it is possible to more accurately analyze texts, form new semantic connections, and much more.

Using NLP (Neural Linguistic Programming), which is based on mathematical algorithms of machine learning and linguistics, the intelligent learning system works with natural language.

When forming data, NLP usually performs the following steps:

1. *Tokenization* – splitting the text into separate sentences [11], [12]. Sentences are divided into separate words, and to create various connections between them and improve the result, use:
   – translation of words to the lower case;
   – removing extra characters from the text;
   – analysis of each word to determine the part of speech and a set of various grammatical attributes (degrees of comparison, tense, gender, etc.).
   – morphological analysis of each word (definition of suffixes, roots, etc.).

With the help of tokenization, a knowledge base is created, which will contain information about the results of text analysis. Most often, the words in the knowledge base are selected from the training sample, each word has its own number, by which the call is performed.

2. *Definition of stop-words* – words that cause strong interference in the neural network calculations, because they appear very often in different fragments of the text.

One of the ways to deal with such words is, in particular, the following: When adding a word (lexeme, token) to the knowledge base, count the number of times this word occurs in the analyzed text.

Then, all the received data on the linguistic analysis serve as the basis for the system to make the appropriate conclusion (either to exclude a word (lexeme, token) from the training sample, or to set an additional importance parameter for each word (lexeme, token)). Fig. 1 and fig. 2 show the performance of the text language recognition system [10].

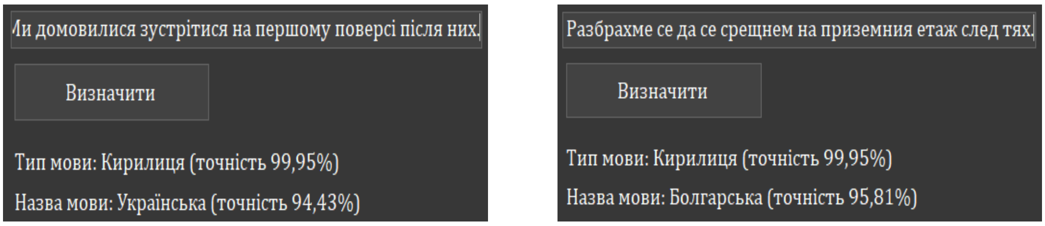

Fig. 1. Examples of recognizing the language of text

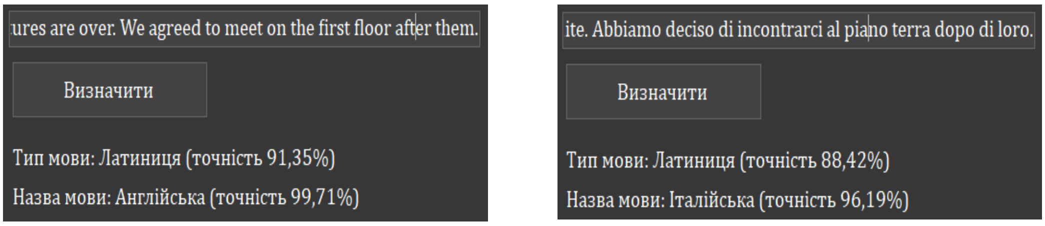

Fig. 2. Examples of recognizing the language of text

MULTI-LEVEL ONTOLOGICAL MODEL OF LEARNING CONTENT DESCRIPTION

To store data in the intelligent learning systems, several ontologies have been developed that are part of a multi-level ontological model with the following characteristics:

– the possibility of aggregating model data from third-party sources;
– dynamic data linking between different levels and data areas;
– distributed storage and access to model data at different levels and areas.

Analysis of open educational resources, subject areas and models (including ontological ones) of already existing the intelligent learning systems contributes, in particular, to the definition of:

– the level of subject areas,
– the type of learning content (lectures, tests, visual display of information, soundtrack of the course, questions for self-examination, assignments for independent work, etc.), the degree of its detail and the form of presentation,
– statistical data on the actions of users (authors, students, teachers, methodologists) in the system.

The levels of the intelligent learning systems ontological model are semantically linked to each other to ensure the interaction of resources of different levels, which makes it possible to analyze subject areas, learning content and student actions.

The domain level is the basis of model of the intelligent learning systems and contains information about the concepts of domains and the relationships between them. A domain

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concept is a taxonomy concept, method, hypothesis, theorem, or other entity used in domains.

Data for this level is collected from third party knowledge bases, taxonomies and other sources (DBpedia, Yago, Freebase, Mathematics Subject Classification, etc.).

Linking learning content elements with domain concepts is done automatically in the intelligent learning systems. To link objects, linguistic text processing algorithms are used, which makes it possible to extract semantic objects from the text and create links between them. For example, using such binding, one can search for concepts of the subject area in the texts of tasks (tests).

Linking learning outcomes and statistical data on user actions in the system with learning content (its elements) occurs automatically in the intelligent learning system.

The developed multi-level ontology of the intelligent learning system consists:

– ontology of learning content, which describes the relationship between courses, lectures, tests, practical tasks and concepts of the domain model;

– ontology of tests, which describes test options, test content, questions and answer options;

– ontology of student results and actions in the intelligent learning system, which allows storing relevant statistical data about the student's learning process in the intelligent learning system, including correct and incorrect answers to tests, lectures and exam results.

– ontology of student knowledge assessments, which allows storing indicators and assessments of students' knowledge in certain concepts and subject areas;

– ontology of gamification components (elements of games, which take into the account recommendations of psychologists, teachers, students, etc.).

The developed multi-level ontological model can be dynamically modified by creating new and integrating existing ontologies. One of the features of the developed ontological model is the possibility of direct and indirect interdisciplinary linking of online course objects. An example of an indirect connection is the connection between a lecture and a test through the concepts of the domain ontological model.

The ontology of learning content describes the relationship between online courses, elements of learning content (lectures, tests, practical work, subject areas and concepts).

One example of an ontology used in the educational process is the AIISO (Academic Institution Internal Structure Ontology) ontology. AIISO allows you to describe courses, modules, faculties, research groups and other structural objects of an educational institution. AIISO uses ontologies to describe the personalities and roles of all those involved in the educational process.

The Bibliographic Ontology (BIBO) is an ontology that describes bibliographic resources. In the ontology of learning content, the BIBO dictionary is used to describe recommended literature, scientific publications, manuals, monographs, etc.

The Ontology for Media Resources (MT-ONT) is an ontology that describes media resources. With the help of MT-ONT classes and properties in the ontology of the learning content, lectures are linked to video materials.

The main classes of the ontology of the learning content are: online course, lecture, test, questions for the exam, practical lesson, subject area, concept of the subject area (concept), information resource.

The ontology of the learning content is based on ontologies of subject areas and their concepts, which describe the relationship between concepts and objects of the ontology of the learning content.

The main classes of *the test ontology* are: a test, a group of tasks (variant), a task (for practical work, for an exam, for independent work, etc.), a typed question, a typed answer. The use of test ontology provides automatic semantic linking of test items with domain concepts.

The ontology describes a test as a set of variants of task groups.

Depending on the type of question, the task may have a different set of correct and incorrect answers. Associating domain concepts with tasks allows you to describe the content of the question and the answers of the task. Based on this description, students' answers to the tests of the online course are analyzed.

The ontology of student actions in the intelligent learning system stores personal data of students, student actions in the system. In particular, information about a student watching a video lecture, passing a test, or completing a course can be written into the ontology.

The ontology includes classes that describe the results of students when passing tests and studying the theoretical part of the learning content.

The main classes of the ontology of student actions are: student, learning outcome, learning progress, test attempt, test element.

To store the answers to the tests of a particular student in the ontology, linking with the ontology of tests is used. Based on the data from the ontology of student actions, the analysis of user actions in the intelligent learning system is performed.

After passing the test, the student can receive not only an assessment, but also a list of subject area concepts and materials for repetition or more detailed study, compiled on the basis of his answers to the online course test. The intelligent learning system supports alternative navigation through the online course, which provides students with the opportunity to familiarize themselves with the structure of the online course and the relationships between its objects.

The main classes of *the ontology of student knowledge assessment* are: assessment (for example, for passing an intermediate test, final test, etc.), description of correct and incorrect answers, subject area rating, subject area concept rating.

This ontology allows you to add new scoring classes to store new metrics when you change the scoring algorithms. The ontology of student knowledge assessment is integrated into the ontology of student actions in the intelligent learning system.

This integration allows you to link the actions of students in studying the learning content of the online course with the assessments of students' knowledge.

The ontology of gamification components is integrated into the domain ontology, the learning content ontology, and *the test ontology*. The main classes of this ontology are: game, psychologist's recommendation, teacher's recommendation, students' wishes.

The intelligent learning system collects data from electronic libraries. Bibliographic data is described using the BIBO top-level ontology and other applied ontologies published on the web.

USING NATURAL LANGUAGE IN THE CREATING ONTOLOGIES

To fill the intelligent learning system (knowledge base, learning content, ontologies), not only data from external sources, but also internal data of the system itself are used. Using ontologies allows you to create new relationships based on certain rules. In this case, NLP-algorithms are used.

Harmonization of the ontological model by creating links between existing objects contributes to the extraction of semantic links from the textual information of the ontology object.

The developed approach allows ontology-based the intelligent learning system to use NLP-algorithms to search for domain concepts. To extract the concepts of subject areas, a linguistic platform is used, which has a search mechanism that allows you to combine different templates into a single grammar for querying the text.

To process the Ukrainian text, a set of dictionaries was developed that completely cover the dictionary of test tasks. The algorithm for extracting concepts of subject areas from the text of a test (task) consists, in particular, of the following steps:

– linguistic analysis of the test (task);
– using the developed dictionaries;
– formation of text with annotations containing morphological and semantic information about each word (lexeme, token) of the test (task);
– formation of a list of candidate-concepts.

Candidate-concepts for which no corresponding domain concepts of the intelligent learning system have been found can be written into the ontology as new system domain concepts. In the intelligent learning system ontology, a new concept of the subject area is created based on the candidate-concept and linked to the test items. If there is no match, the candidate-concept is marked as a false concept.

To apply the proposed ontological approach in other subject areas and in other languages, it is necessary to form the appropriate dictionaries, grammars and templates for extracting the concepts of subject areas.

The developed multi-level ontology makes it possible to analyze indirect links between heterogeneous objects in the intelligent learning system. This analysis is used in the analysis of the completeness of the online course. An example of such an indicator is the coverage ratio of lectures with tests, practical tasks and elements of gamification M_c.

As a result of filling ontologies, the elements of learning content can be associated with certain concepts of the subject area. The intelligent learning system can provide statistics on the number of domain concepts used in the learning content or its corresponding component. If the concept of such an element of learning content as a lecture is used in a test task, then it is considered covered.

The corresponding coefficient is calculated using:

– domain model concepts related to:
  - lectures $C_l = (C_{l1},..., C_{ln})$ of the online course,
  - additional learning content $C_{dl} = (C_{dl1},..., C_{dln})$ to the lectures of the online course;
– concepts related to:
  - practical tasks $C_p = (C_{p1},..., C_{pn})$ of the online course;
  - tests (intermediate $C_{it} = (C_{it1},..., C_{itn})$, final $C_{ft} = (C_{ft1},..., C_{ftn})$);
  - tasks for independent work $C_{iwt} = (C_{iwt1},..., C_{iwtn})$ and self-development $C_{tss} = (C_{tss1},..., C_{tssn})$;
– concepts related to gamification elements for:
  - visual representation of lecture content $C_{gl} = (C_{gl1},..., C_{gln})$;
  - visual presentation of practical tasks $C_{gpl} = (C_{gp1},..., C_{gpn})$ of the online course;
  - visual representation of tasks for independent work $C_{giwt} = (C_{giwt1},..., C_{giwtn})$ and self-development $C_{gtss} = (C_{gtss1},..., C_{gtssn})$.

$$M_c = \mathrm{l}(C_l \cup C_{dl}) \cap (Cp \cup C_{it} \cup C_{ft} \cup C_{tss}) \cap (C_{gl} \cup C_{gpl} \cup C_{giwt} \cup C_{gtss})\mathrm{l} / |C_l|$$

The coverage ratio of lectures with tests, practical tasks, tasks for independent work and self-development, as well as the corresponding elements of gamification allows you to control the semantic correspondence of the theoretical part of the learning content (for example, lectures and additional material for these lectures) with the corresponding practical components and components of the gamification of the online course.

Links between concepts, subject areas and learning content allow you to analyze the content of the online course and the level of its balance. The analysis is based on an assessment of the links between the concepts and lectures of the course. The subject area, the concepts of which have a large number of links with the lectures of the course, has a greater share of use in the online course.

When analyzing the elements of learning content in an online course, problematic concepts of the subject area are identified, which are concepts that students have the most difficulty learning.

The rating of a problematic concept is calculated as the difference between the number of correct answers and the number of incorrect answers to questions related to this concept. This calculation can be complicated due to the complexity of the tasks, the number of attempts to pass the test and the time it takes to pass the test.

Individual operational monitoring of the process of learning a subject area by a student in the intelligent learning system is based on the analysis of statistics on students' actions in accordance with a multi-level ontology. Such monitoring allows teachers to receive a detailed integral assessment of students' knowledge at the level of subject areas and concepts.

Using information about students' knowledge allows teachers to make the adjustments to the learning content (its content, structure, forms of display and provision of content elements, etc.) of the online course in order to improve the quality of the educational process.

The assessment of a student's knowledge of a subject area is based on the calculation of the student's knowledge rating of the corresponding subject area. The student's knowledge rating of the subject area depends on the student's knowledge ratings of the concepts included in this subject area, and their significance in this subject area.

Subject areas and concepts in accordance with the developed model do not depend on the learning content and can be reused in many online courses. Relationships between concepts that describe the need for one concept to study another, allow us to calculate the significance of the concept in the educational process.

The more concepts, for the study of which the considered concept is necessary, the higher the significance of this concept.

The presented approach allows for an integral assessment of a student's knowledge of a subject area based on a set of studied online courses (using gamification components), completed practical tasks, tests, and independent work.

CONCLUSIONS

An ontological approach to the construction of intelligent learning systems using elements of gamification is proposed. It is advisable to use the developed multilevel ontological model in the development of intelligent learning systems in order to intellectualize and optimize learning processes, increase students' interest and motivation in studying individual training courses, learning topics, performing independent tasks, etc.

The constructed multi-level ontological model contributes to the improvement (optimization, efficiency increase, etc.) of learning processes, supporting the joint use by students and teachers of common educational content containing elements of gamification.

The result of using elements of gamification and ontological modeling of both educational content and learning processes is the ability to make the necessary adjustments to the set of goals and objectives of the learning process, directly to the learning process, the course of study, and the requirements for the level and competencies of students.

The developed multi-level ontological model of learning processes makes it possible to form learning content with the help of gamification elements.

The proposed approach uses the integration of such technologies as: ontological modeling, intellectualization and informatization, as well as gamification technologies. The use of these technologies makes it possible to predict the occurrence of emergency situations in the learning process.

The main results of the work:

1. A multi-level ontology has been developed that models in the intelligent learning system, using elements of gamification, heterogeneous elements of learning content and events of the educational process in conjunction with the concepts of the studied subject areas.

2. The developed multi-level ontological model contributes to the integration and logical linking of various and heterogeneous elements of learning content, including gamification components.

3. The developed ontology contributes to the collection, annotation and reuse of learning content, which allows you to automate the process of creating a new online course in the intelligent learning system and keeping it up to date.

4. The developed approach to the processing of semantic links in a multi-level ontological model makes it possible to analyze the completeness and balance of online courses in the intelligent learning system. The developed method allows the author to control the consistency of the learning content at the level of concepts of models of subject areas of study, in order to improve the quality of learning content.

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ВИКОРИСТАННЯ ЕЛЕМЕНТІВ ГЕЙМІФІКАЦІЇ В ІНТЕЛЕКТУАЛЬНИХ НАВЧАЛЬНИХ СИСТЕМАХ: ОНТОЛОГІЧНИЙ АСПЕКТ

Анотація. У статті розглянуто онтологічний підхід до створення та використання інтелектуальних навчальних систем з елементами гейміфікації. Розроблену багаторівневу онтологічну модель доцільно використовувати при реалізації процесів навчання у закладах вищої освіти. Запропоновано онтологічне моделювання інтелектуальних навчальних систем на основі багатовимірних моделей. Запропонований підхід дає можливість розробити багаторівневу онтологічну модель будь-якої інтелектуальної навчальної системи, яка повністю відображає прагматику досліджуваної предметної області. Запропонована багаторівнева онтологічна модель інтелектуальної навчальної системи з елементами гейміфікації фіксує та структурує знання, загальні для предметної галузі, що вивчається. Це дозволяє повторно використовувати її як основу єдиної моделі знань, що забезпечує логічну узгодженість між окремими онтологіями при об'єднанні для створення навчального контенту (наприклад, онлайн-курсу) із ширшим переліком тем і завдань. Застосування онтологічного підходу є ефективним способом проєктування та розробки інтелектуальних навчальних систем. Побудовані індивідуальні онтологічні моделі (навчального контенту, тестів, онтології результатів і дій студентів, оцінювання знань студентів, компонентів гейміфікації) сприяють проєктуванню єдиного інформаційного навчального середовища (навчального контенту), в рамках якого реалізуються інтелектуальні навчальні системи, що використовують елементи гейміфікації. Запропонована в роботі багаторівнева онтологічна модель сприяє підвищенню ефективності процесів навчання, збереженню інтересу та мотивації до вивчення запропонованого навчального контенту, що містить елементи гейміфікації. Результатом використання елементів гейміфікації та онтологічного моделювання в інтелектуальних навчальних системах є можливість внесення необхідних коректив щодо цілей і завдань навчального процесу, процессів навчання, вимог до рівня та компетентності студентів.

Ключові слова: онтологія; онтологічна модель; багаторівнева онтологічна модель, інтелектуальна система навчання, інформаційні технології; зміст навчання; гейміфікація; знання

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