Ontological Modeling of Intelligent Learning Systems with Elements of Gamification

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Abstract

An ontological model of an intelligent learning system with elements of gamification has been built, which captures and structures knowledge common to the corresponding subject area. 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 a training course with a wider list of topics and tasks. The application of the ontological approach is a very effective way to design intelligent learning systems. The constructed separate ontological models (for topics, training courses, etc.) contribute to the design of a unified information learning environment within which intelligent learning systems can operate using gamification elements. Ontological modeling of intelligent learning systems based on multidimensional models is proposed. The proposed approach allows the development of an infological model of any learning system (information or intelligence), which fully reflects the pragmatics of the studied subject area.

Keywords

Ontology, ontological modeling, learning process, intelligent learning system, gamification, educational content.

1. Introduction

Use only The intensive development of information technology and mobile communications is invading all spheres of life, including the educational process: electronic tests are being developed, video lectures are being recorded and broadcast, webinars are being held, wiki resources are being created, universities are creating and supporting distance training courses, online conferences.

Classical teaching methods are modified and supplemented with new modern teaching technologies, tools, and conceptual approaches.

Along with changes in learning technologies and the corresponding tools used in training courses (learning systems), one should take into account the fact that modern students are involved in the world of digital technologies from an early age.

The leader of modern educational strategies is gamification [1].

One of the directions for modernizing learning processes and increasing their efficiency and effectiveness is their intellectualization and attraction of new approaches and tools to attract students to study the material of the training course, increase their level of interest in mastering the relevant educational content (training (educational) material, tests, tasks for independent work, etc.) [2, 3].

One such new approach is the gamification of the learning process.

However, the infrastructure of the modern unified educational information space is not yet sufficiently developed.

And such tools as gamification require not only creative reflection, but a formalized systemic interdisciplinary research both on the part of specialists in specific subject areas, teachers, and psychologists for different age groups of students.

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However, due to the lack of a unified representation of knowledge about the subject areas of learning systems (in particular, distance learning systems, e-learning), as well as the forms of providing educational content and methods of providing and testing students, which are often incompatible, which complicates the process of their unification and unification into a single information learning space, have low semantic interoperability.

Nowadays, there is a low level of integration of heterogeneous electronic educational resources (databases of educational content, databases of methods and tools for both the learning process itself and monitoring the learning process, testing, and monitoring students' knowledge, databases of the components of gamification for studying some training courses).

It should be noted that the elements of gamification are poorly used not only in higher educational institutions but also in schools, where the component of gamification could encourage students to become interested in learning and self-learning (due to their age and gaming addictions).

Improving the quality of learning processes at all levels (providing educational content, monitoring, and controlling knowledge, performing independent tasks, etc.) can be achieved by, in particular, solving the following problems [4–7]:

- Semantic description of knowledge about the studied subject area.
- Development and use of ontological analysis methods.
- Development of ontological models of both individual training courses and the learning system in a separate higher educational institution (or the country as a whole).
- Development and use of a single information learning space, harmonized with European standards.
- Development and use of a unified base for methodological support of learning processes.
- Development and use of a unified information base of unified educational content.
- Development and use of a unified information base of unified tests.
- Development and use of a unified information base of the components of gamification.
- Usage of motivational methods for learning and self-learning.
- Systematic study of the possibilities of gamification in intelligent learning systems.
- Development and use of information learning systems with elements of intellectualization and gamification.

2. Use of Gamification in Learning Processes

When building a training course using the concept of gamification, the following tasks should be distinguished:

- Increasing the efficiency of the organization of the learning process.
- Determining the appropriateness of using one or another element of gamification when providing students with specific educational content.
- Creation of rules for students to pass the educational material of the training course.
- Creating incentives for attending lectures and mastering lecture material.
- Effective use of the time allocated for the independent work of students.
- Monitoring and control of passing by students of control points of a training course.
- Improving the quality of practical work performed by students.
- Search/development of the components of gamification for studying the educational content of the training course.
- Creation of an information base of educational content with elements of gamification.
- Creation of an information base of tests with elements of gamification.
- Development of information technology support for a training course (within a specially developed information learning system or within an existing information (or intelligent) learning system/training course modified with elements of gamification).

The elements of gamification of the learning process include:

- Call (the goal to achieve the highest possible grade obtained while observing the training course rules).
- Tasks, tests, and compiled with the components of gamification.
- Competition (between individual students and/or their subgroups).
- Cooperation (performing work on mistakes, mutual assistance in solving

problems, assistance in explaining incomprehensible educational content, etc.).

- Feedback (information about the success of a student acting as a player in the study of a particular training course).
- Accumulation by students of knowledge of the training course and the results of monitoring (or intermediate testing) of this knowledge.
- Rewards (bonus points).
- State of victory (total score, current knowledge score including bonuses, final grade, status in the group, etc.).

The use of gamification elements in the learning process involves:

Table 1.

It is very effective to include one or more of these game elements in the learning process.

While all of these learning strategies focus on core human values, they also help students adapt to learning material quickly and in much greater depth.

Using gamification to aid in cognitive development will increase the activity of brain regions to enable age-appropriate development.

Games designed specifically to enhance cognitive development are often referred to as brainstorming games.

Such games are becoming more and more popular and are based on various questions and problems that the user has to answer or solve.

Studies have shown that games that are used in learning processes can help students, for example, in solving problems such as:

- *Concentration*. Sometimes it is difficult for students to concentrate on studying a certain topic (or a fragment of it), so it can help them to study the learning material that is provided to them in the game environment.
- *Skill development*. Game components of educational content allow students to discover the relevance and importance of the material being studied.
- *Understanding the content*. If a student is having trouble mastering traditionally presented educational content, then the game components of providing educational content can help them understand the material more easily.
- *Use of external motivators* (e.g. virtual trophies, achievement points, competitive spirit, etc.).
- *Availability of quick feedback*. In this case, it is necessary to think very carefully about the result of the educational purpose and develop a game that will motivate students to complete the tasks.
- Restrictions (in particular, on the performance of control/test tasks or tasks for independent work).
- Emotions (curiosity, competitive spirit, disappointment, happiness, etc.).
- Narrative (consistent, continuous storyline).
- Promotion (player growth and development).
- Relationship between the players.

Let's consider the adopted strategy and borrowed the components of gamification in more detail.

The analysis, systematization, and generalization made it possible to identify a list of effective components of gamification references to tables, i.e., please, check

Table 1

The elements of gamification in learning processes

№	Item	Description
1	Mystery	This element requires learners to fill in the gaps of the unknown with the known.
2	Action	Each game begins with an action that forces the learners to make a move. The action is used to immediately involve students in the process of playing learning.
3	Emotional component	These game elements help to encourage learners
4	Risk	The risk elements of the game improve the student's ability to focus and make a strategic move.
5	Uncertainty	In this element, students may not have an idea of what might happen in the development of a particular game situation
6	Visibility of Progress	This game element tells learners what to do (for example, where to start and how long the state of apparent progress in learning content will last) to continue
7	Task	Each trainee, having overcome the corresponding difficulties, is satisfied

2.1. Gamification and Design in Learning

Game mechanics is how the game works: its rules and process.

An important point of the game mechanics used in the learning process is, in particular, that: the structure and dynamics of the game must correspond to the learning content.

For example, if the content describes cybersecurity issues, then the game mechanics, as well as the design of the training course (a topic or its fragment, a separate lesson, etc.) should be related to information security.

For example, organizational game actions to protect the information, knowledge quizzes regulatory support of cybersecurity, a game against the clock to generate a sequence of actions to overcome the danger associated with cracking passwords to protected information, etc.

In the context of competitive study of educational content, for some students, it is not enough just to earn a prize.

Often they just need to brag about their achievements—this increases their self-esteem.

Usually, tournament tables (ratings, honor boards, etc.) are used for this.

In [3], it is proposed, for example, to use the following game techniques when teaching:

- Reflection in the standings of those achievements and skills that are important for learning purposes.
- Using more than one leaderboard within the same training program for example, you can create separate leaderboards for each group, student, or team of students, as well as for each task in the training course.
- Ensuring the possibility of searching through the standings (if a student sees only the leaders and cannot immediately find himself or his friends in the ranking, the effectiveness of such a ranking is reduced).
- Allowing students to create their standings. So they can quickly evaluate their results in comparison with colleagues and acquaintances.
- Allowing students to react in situations where the leaderboard does not update immediately (this often happens in educational games).
- Resetting the tournament leaderboards at the end of the week so that students can start their competitive training from a clean slate.

In addition to points and leaderboards, there are other examples of game mechanics that will make learning with elements of gamification more interesting, meaningful, and motivating:

- Pattern recognition (for example, recognizing and recognizing trends and familiar sequences of learning content elements in game-based learning content).
- Collecting (for example, collecting decals and other objects related to the training course).
- Surprise and joy from receiving unplanned awards and high results obtained when studying learning content within a training course implemented within an intelligent learning system.
- Organization and order, which involves placing and providing students with elements of educational content in the correct sequence.
- Gifts allow, while studying in a team, to share your points with other students in the team.
- Recognition and achievement, where students are praised for their progress.
- Opportunity for group leaders to lead other students by showing them how to cope with a particular task.
- Obtaining the status of a student for their achievements while studying the educational content of the corresponding training course.

Learning becomes as effective as possible if a student can be involved in the process of mastering learning content through the involvement of gamification.

Some of the named game mechanics are universal, and some are directly related to corporate training.

Thanks to these mechanics, students are increasingly involved in the dynamics of the training course.

It is at such moments that learning becomes most effective.

3. Ontological Modeling of Learning Systems That Use Gamification

Among the developed applied ontologies in the field of informatization of learning processes are models of training courses.

Often such modeling is limited to the development of a thesaurus of the discipline, the use of which allows for the adaptive selection and

ordering of educational content provided to students.

Another approach is the ontological analysis of the structure of the educational content, when, for example, the ontology is based on the semantic relationships between knowledge that are included in the knowledge base of a particular training course.

The overall goal of the ongoing research is to unify the structure of the educational content, which allows for more efficient integration of existing training courses implemented in different information (intelligent) learning systems.

The ontological modeling described in the paper focuses on:

- Structure of knowledge common to the subject area studied and supported by the corresponding intelligent learning systems (this contributes to the repeated use of the developed ontological models as the basis of a single knowledge model, due to which logical consistency is maintained between individual ontologies when they are combined).
- Elements of gamification are used to provide educational content and motivate students to study it.

Ontological models of intelligent learning systems formally describe the main elements (concepts) of the subject area and determine the implementation of the logic of an intelligent learning system.

Learning processes, their structure, and educational content are described in terms of interrelated knowledge elements of the relevant subject area.

An ontology is a specification of a conceptualization of a subject area [8, 9].

This is a formal and declarative representation that includes a vocabulary of concepts and their corresponding domain terms, as well as logical expressions that describe a set of relationships between concepts.

Formally, the ontology is defined by the triple [10–12]:

$$O = < X, R, F >$$

where X is a set of concepts (elements, terms) of the subject area, which is represented by the ontology O; R is the set between the concepts of the subject area under consideration; F is a set of interpretation (axiomatization) functions defined on concepts and/or relations of the ontology O.

It is rather difficult to describe all aspects of educational activity within the framework of a standard approach.

To a certain extent, the problem of a qualitative description of all structural units of the learning process can be solved by using the appropriate thesaurus [13].

A thesaurus is a special kind of dictionary, in which the semantic relations between lexical units are indicated.

Unlike an explanatory dictionary, a thesaurus allows you to discover the meaning not only by using a definition but also using the correlation of a word with other concepts, thanks to which it can be used in intelligent learning systems.

The structure of the thesaurus can be built based on semantic networks, which reflect the semantics of the subject area in the form of concepts and relations and are one of the most convenient ways of presenting knowledge.

3.1. Ontologies for Structural and Informational Support of Learning Processes with Gamification

Let's consider the main trends and perspectives of using ontologies of learning processes that use the concept of gamification.

An ontology defines the terms of the subject area, gives their interpretation, and contains statements that limit the meaning of these terms.

They are used to record knowledge about any area of interest and define terms or concepts that relate to the chosen subject area and also specify the relationship between these terms.

In the process of computer training (e-learning, distance learning, etc. [14]), the following participate informational (or intelligent) learning systems (educational systems) that play the role of a teacher and a learner (pupil, cadet, student, training course listener, etc.).

Based on this, the knowledge base of the intelligent learning systems should contain the expert's knowledge of the subject area (the so-called pedagogical knowledge) and the knowledge of the learner (the so-called personal knowledge).

That is, the main task of ontological modeling of knowledge in intelligent learning systems is to build adequate models based on ontologies.

The educational content of the intelligent learning systems with gamification is a set of subject elements—didactically completed blocks that reflect the content of the learning (training) discipline.

If the intelligent learning system in the learning process supports the concept of gamification, then the knowledge base of game components should be organized accordingly in the information base of the information (or intelligent) learning system.

Relationships between elements of educational content (subject elements) reflect the structure of the educational (training) material (educational content).

But in this context, subject knowledge is a system of knowledge consisting of elements of educational content and relationships between them, which reflect knowledge about the composition and structural properties of educational content (training material).

If gamification elements are added to the teaching of educational content in the learning process, then two types of relationships are added to the relationships between the elements of the educational content:

- Relationship between the educational content element and the gamification component.
- Relationship between gamification components.

We denote by *E* the set of subject elements and by *Ga* the set of gamification elements.

The structural relations of the subject elements are defined by a binary relationship, which we denote by $Se \subset E \times E$ and will call the structural relationship in the subject area of the training course.

Structural connections of subject elements are determined by a binary relationship, which we denote by $Sge \subset E \times Ga$ and will call the structural relationship between the educational content of the training course and the elements of gamification.

Structural connections between gamification elements are defined by a binary relationship, which we denote by $Sg \subset Ga \times Ga$ and will call the structural relationship between gamification elements.

The set $P = E\ U\ Ga$ and the structural relation $S = Se\ U\ Sge\ U\ Sg$ are formed by an expert—a developer of an electronic training course (hereinafter—training course, course).

The basic subject elements from which set *E* is formed are topics.

Let us denote by *T*—the set of topics presented in the intelligent learning system in the chosen subject area. *T* is a finite, discrete, strictly ordered set.

The basic structure of subject knowledge is determined by a binary relationship $Se_t = T \times T$ —"subtopic of the topic", such that

$$(t_i, t_j) \in S_i, i \in [1, n], j \in [1, n], i \neq j$$

if the educational content of the topic t_i reveals the educational content of the topic t_j.

Among all the topics of the training course $T_m \subseteq T$, it is possible to single out a subset of supporting topics, the levels of mastery of which the student determines the success of the learning process.

At the standard level of knowledge of the main topics, students receive a set of abilities, skills, and competencies that meet today's requirements for relevant specialists in this subject area.

We will call the set T_m the set of learning goals. When formalizing the learning process, as a rule, necessary and sufficient learning goals are distinguished.

The necessary learning goal is a set of topics and the diagnosis of the reference knowledge which is necessary during the completion of the training course to be allowed to continue the training course.

A sufficient learning goal is a set of topics, in case of not reaching the reference level of knowledge, these topics are recommended for repeated study, while the student has access to any topic of the training course.

Highlighting several goals at the same time gives the expert more opportunities when building a training course.

According to modern requirements for intelligent learning systems, the content of the electronic training course should be adapted to the students.

Accordingly, the content of the topics should be supplemented with an adaptive part:

- blocks of educational content, which we will call individual versions.
- gamification elements that motivate students and brightly "highlight" certain elements of educational content.

Alternative individual versions of the topic differ in the degree of detail and depth of presentation of the educational material, which helps to adapt the content of the training (learning) course to different levels of preliminary training of students.

At the same time, all alternative individual versions present the basic content of the topic,

which is necessary for studying the topic for all students, regardless of their training.

Let us denote by *C*—the set of individual versions of all topics of the training course. The set *C* is discrete, finite, and strictly ordered.

The expert, forming the training course, establishes the relationship $S_c \subseteq C \times T$ — "individual version of the main topic (or subtopic)" so that $(c,t) \in S_c$ if the content of the individual version *C* is agreed with the content of the topic *t*.

Alternative individual versions of the topic (or subtopic) of the training course can be presented at different levels corresponding to the student's preparation.

We will call these levels difficulty levels.

The expert assessment of the degree of complexity of each variant of the individual version of the topic is subjective and linguistically uncertain, which makes it difficult to apply precise quantitative methods in its formal description based on the appropriate ontological model of the training course.

In addition to theoretical material, the training course should be accompanied by diagnostic material intended for knowledge control.

As a rule, in an intelligent learning system, operational control of knowledge is carried out with the help of tests consisting of a suitable set of test tasks (tests).

A test is a clear and precise task from a specific subject area that requires a clearly defined answer or the execution of an appropriate algorithm of actions.

The representation of subject knowledge in the information base of the intelligent learning system is displayed by an oriented graph.

The set of vertices of the graph reflects the set of elements of educational content and elements of gamification, the set of arcs—the structural relations highlighted above.

Vertices and arcs are marked with the values of the membership function of established sets and relations.

The composition and structure of the ontology of personal knowledge reflect an oriented graph

$$\tilde{G}' = \left(E', S', \mu_{\tilde{G}'}(e'), \mu_{\tilde{G}'}(s')\right).$$

The oriented graph reflects the presentation of personal knowledge in the information base of the intelligent learning system.

The vertices of the graph G' reflect the composition of diagnosed subject knowledge—a subset $E' \subseteq E$, $Ga' \subset Ga$—a subset of gamification components.

The arcs of the graph G' reflect the structure of diagnosed subject knowledge—sub-relationships $S' \subseteq S$.

The purpose of building personal knowledge is to establish the degree of achievement of the learning goals by students and to find a subset of the topics recommended for study by the established degree of achievement of the goals.

Let us denote through $T'' \subseteq T$ —a set of topics offered for study.

The task of the expert is to determine the composition of the set T'' and determine the relevant elements of gamification.

The degree of students' mastery of educational content of the training course material is reflected by the set $\tilde{T} \subseteq T$ —"reference mastery of the topic (or subtopic)".

On the set *T* there are also given sets $\tilde{N}$ and $\tilde{D}$, characterizing the necessary and sufficient learning goals, respectively.

Then the set $\tilde{N} \setminus \tilde{T}$, set on the set of topics *T*, reflects the degree of students' achievement of the required learning goal.

The set membership function has the form:

$$\mu_{\tilde{N}\setminus\tilde{T}}(t) = \max\left\{\mu_{\tilde{N}}(t) - \mu_{\tilde{T}}(t), 0\right\}$$

In this case, the carrier of this set is the subset

$$N \subseteq T', \; N = \left\{t \middle| \mu_{\tilde{N}\setminus\tilde{T}}(t) > 0\right\}$$

is a set of uncounted topics (or subtopics).

If there are uncredited topics, the student will not be able to continue studying the course, that is, in this case $T'' = N$.

The degree to which the student has achieved a sufficient learning goal is reflected by the set $\tilde{D} \setminus \tilde{T}$ given on the set of tested topics

$$D = \left\{t \middle| \mu_{\tilde{D}\setminus\tilde{T}}(t) > 0\right\} \; \left(D \subseteq T'\right)$$

the membership function of which.

At the same time, many enrolled topics are provided for repeated study.

In the case of establishing topics for which a sufficient learning goal has not been achieved, these topics, together with the ones not yet studied, make up a set of topics that should be studied by the student.

Then $T'' = D \cup \bar{T}'$, where $\bar{T}' = T \setminus T'$ is the set of unstudied topics of the training course.

Thus, in the general case, the set of topics that should be studied by students to obtain a complete image of knowledge from the course is a subset $T'' \subset T$ such that

$$T'' = \begin{cases} N, N \neq \varnothing \\ D \subset \bar{T}', N = \varnothing \end{cases}$$

3.2. Design of the Ontological Model of Learning Processes

The process of developing ontologies includes several steps.

First of all, the terms of the subject area and the relationship between them are defined, then the concepts of the subject area itself are defined.

The next step is the organization of concepts into a hierarchy and the definition of attributes and properties of classes (subclass—superclass), imposing restrictions on their values.

Then the individuals or instances are defined and attributes and properties are assigned values.

The development of ontologies is a cyclical process and always begins with the processing of elementary sets of concepts of a given subject area and the description of how these concepts relate to each other.

The structure of an ontology, as a rule, consists of two parts: the naming of important concepts and information or knowledge about these concepts [15, 16].

The process of forming an ontology consists of the fact that having a description of some concepts, they can be fixed coherently in the form of objects using ontology construction.

In addition, in the process of designing the ontology, properties are set that are not concepts but allow forming of relationships of objects.

Ontology can be presented as the main component of an intellectual educational system, performing the following functions:

- Defines a common terminological base for all users of the intellectual educational system.
- Allows formulation rules and precedents using the same concepts of subject areas.

The semantic approach to the analysis of situations allows an expert or a group of experts to describe with the help of a single standardized language the general ontological model of the subject areas [17] studied by students and the educational content with the corresponding elements of gamification is supported by the corresponding subsystems of the intelligent learning system.

Based on the integrated ontology of knowledge management, models of knowledge presented in the form of rules and decision-making precedents in problem situations are built, which are associated with independent (programming, literary, creative, etc.) tasks provided to students together with the educational content of the corresponding training course.

3.3. Ontological Model of Presentation of Educational Content

When modeling the process of extracting information, an important role is played by the presentation ontological model of educational content and elements of gamification for training courses.

The essence of this ontological model, in particular, is:

- Unified support for all stages of processing the content of educational content, including the content of topics and subtopics of training courses and relevant elements of gamification.
- Usage of “external” expert annotation to terminological concepts and gamification components, synchronized with the educational content of the educational course of the relevant subject area.

The educational content presentation ontological model is a set of content coverages when the intermediate processing results are objects of the same type with a given projection on the content.

This approach allows you to visually interpret the results and highlight the knowledge that is contextually related to each element.

The ontological model of the presentation of educational content in intelligent learning systems is defined as follows:

$$OM_{ECG} = <C_A, C_L, C_G, C_{Th}, C_{IO,} C_{CG}>,$$

where:

C_A is a graphemic cover containing many elementary objects of the subject area (an elementary object is an object associated with a fragment of the educational content of a training course (for the subject area) consisting of symbols of the same type).

C_L is terminological coverage containing a set of lexical objects, the parameters of which are:

- Dictionary term.
- Grammatical characteristics of the term.
- Set of the semantic features.
- Positions in educational content.

C_G is segmented (genre) coverage that reflects the logical and compositional structure of the educational content and includes many segments, the parameters of which, in particular, are:

- Type or formal segment of the genre model of the educational content.
- Position.
- Links with other segments that determine their relative position in the educational content.

C_{Th} is thematic coverage, which is determined by a set of thematic fragments.

C_{IO} is an information coverage containing a set of information objects, the main parameters of which are:

- Ontological object or an instance of a concept defined by the ontology of the subject areas.
- Positions.
- Set of information dependencies of the object.

C_{CG} is a game cover containing a set of gamification components, the main parameters of which are:

- Game element mechanisms.
- Game element design adequacy to the subject area being studied.
- Student orientation (for independence or teamwork).

Depending on the problem being solved, other types of coverage can be distinguished. The presented model is focused on the tasks of semantic analysis and information extraction.

The main stages in the formation of an ontological model for the presentation of educational content are:

- Preliminary preparation and processing of educational content (the result is, in particular, the formation of the structure of the training course, the construction of ontologies of the subject areas, etc.).
- Analysis of educational content (the result is well-formed lexemes, sentences in the subject area language, graphemic coverage of educational content, etc.).
- Conducting lexical analysis of the educational content (the result is the terminological coverage of the content).
- Carrying out genre typification and fragmentation of educational content (the result is segment coverage of educational content).
- Carrying out the thematic classification of educational content (the result is thematic coverage of educational content).
- Carrying out semantic analysis of the educational content, which uses gamification components (the result is the information coverage of the educational content).

The graphemic coverage of educational content is the result of its grammatical analysis, during which the content is divided into elementary atoms.

The main task of this stage is to group characters of the same type in a sequence and give them an interpretation.

An important property of this representation is that the coverage elements define all possible element boundaries for all subsequent representations.

The terminological coverage consists of vocabulary terms found in this educational content of training course (courses), taking into account possible homonymy and intersections of multi-word terms.

Terminological coverage of educational content is a lexical content model that is built based on the lexical ontological model [18, 19] of the subject area language and includes found terms concerning the position in the educational content of training course(s).

The segment coverage reflects the structural division of the educational content into logical (paragraph, sentence, heading, etc.) and genre fragments (elements).

Genre coverage is one way of reflecting the formal structure of educational content, which uses gamification components.

When analyzing educational content, splitting into genre fragments helps to narrow the search area for information of certain type and improve the quality of analysis.

The thematic coverage is built over terminological and genre coverage.

It defines the educational content boundaries of the training content areas for each considered subject of training courses implemented in intelligent learning systems.

The information coverage describes the found information (element of educational content) in the form of a semantic network model of objects of the particular subject area.

The information coverage of the educational content represents the results of the semantic

processing of the training course implemented in intelligent training systems.

To build information coverage, it is necessary to have a data format that specifies the structure of the presentation and storage of the information received.

The educational content of the intelligent training system built based on ontology is a set of instances of ontology classes.

Information objects are formed based on fact models. In this case, information dependencies are generated between the objects that act as model arguments and its result.

To accurately describe these dependencies, an attributive model for extracting information is used.

The advantage of such a model, in particular, is:

- Visualization of the results of the educational content analyzer.
- Formal description of educational content processing algorithms and proof of their properties.
- Using the formal description of algorithms as a top-level abstraction for their software implementation.
- Ensuring the reliability of the result, which will allow a wide range of corpus studies.

The proposed approach is based on the informational connectivity of information objects extracted from the given educational content of training course(s).

The conflict resolution subsystem of intelligent learning systems must resolve all ambiguities in such a way that the intelligent training system is free from conflicts and at the same time preserves the maximum possible number of objects and relationships.

The identification of intelligent learning systems involves the selection of certain groups (clusters) from elements of educational content and groups of gamification components, depending on the role and principles of using these systems in learning processes in certain higher education institutions.

4. Conclusion

The proposed approach to the design of intelligent learning systems based on the use of ontological models, including elements of not only learning content but also the corresponding gamification components, provides, in particular, the following advantages:

- Ontological modeling allows you to assemble a single, structured, transparent system of training courses, which helps teachers to navigate the construction of new and development of already existing training courses (or their clusters), thereby ensuring the implementation of the principle of systematicity and sequence of learning.
- Ontological modeling allows you to assemble a single, well-structured system of gamification components agreed upon with psychologists and other experts, which helps teachers in building new and developing existing training courses, thus ensuring the implementation of student motivation for learning and self-learning.
- ontological modeling enables students to understand logic and systematicity in the content of the acquired knowledge, as well as to have a new source of information regarding the subject area being studied.
- Ontological modeling contributes to obtaining new knowledge about the subject area being studied, using, in particular, queries to the relevant knowledge base of the intelligent learning system.
- Ontological modeling contributes to the structuring of the subject area, designing the structure in the form of a corresponding ontograph.
- Ontological modeling can be used to find and form appropriate educational content.

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