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The knowledge base model of decision support system development for improving the e-learning resources quality

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Summary. The analysis of e-learning resources functional properties which is applied to the task of automated information support to the decision-making for improving the quality of e-learning resources is made. The knowledge base model of decision support system, which is adapted to the complex criterion of quality that takes into account the academic performance, validity, manufacturability and reliability of the learning resources, is developed.
Key words. E-learning, quality, criteria, knowledge base model.

INTRODUCTION

The implementation of the basic concepts of Bologna process is impossible without the active using of e-learning resources in the educational process. The assurance of high quality education [8, 15, 16] requires the continuous monitoring of learning resources throughout its life cycle. Providing the high quality of e-learning resources in situation with wide accessibility to the higher education and rapid obsolescence of information requires an organization of the automated monitoring, analysis and evaluation of e-learning systems educational content using new information technologies.

OBJECTS AND PROBLEMS

To improve the quality of e-learning resources we should take into account the complex evaluation of the functional properties and results statistics of e-learning resources using in learning and training. The decisionmaking automated support is impossible without the decision support system knowledge base model that is adapted to the task of complex evaluation of e-learning resources quality. Analysis of research papers and publications about evaluation of e-learning resources quality [7, 14, 19, 21- 23] has shown that existing systems can only assess the quality of e-learning resources individual indicators and do not provide automated support to the decisionmaking. The purpose of this research is to develop the knowledge base model of decision support system, which is adapted to the to the task of complex evaluation of e-learning resources quality.

THE RESULT OF RESEARCH

According to [2, 4, 5] the main types of learning activities are: lectures, labs, workshops, seminars and self-study. Diversity of species, types and forms of e-learning resources is caused by the diversity didactic approaches to learning and training. The collection of standards and specifications for web-based e-learning SCORM [1, 17] declares no restrictions to the amount and the way of representation of e-learning-resources (the ваѕлайфстайліс blocks of e-learning resources – assets – are the "…electronic representation of media, such as text, images, sound, assessment objects or any other piece of data that can be rendered by a Web client and presented to a learner").

In the context of the task of decisionmaking information support to improve the e-learning resources quality the classification of types and functional properties of e-learning resources is developed. Depending on the type of learning activity the main functional types of educational resources are: theoretical material (theory), training workshop (workshop) and control.

The main purpose of the theory is the orientation function, which describes the framework subject area of the course, topics, tasks, definitions, concepts.

Workshops can include laboratory works, training exercises, individual tasks with calculations and graphics. Educational resources of this type are characterized by a high level of interactivity and require the organization of the feedback. The main purpose of the workshop is to form the skills and abilities. The workshop can be represented by application the wide range of intelligent multimedia and visual instructions, virtual labs and multimedia simulators.

Control can include exam-questions, tests, problematic tasks, qualifying and graduate work. Analysis of scientific publications in the field of teaching jobs [2, 5, 13] showed that the testing control is the most researched activity.

In the context of the task of automated information support the most important e-learning resources functional properties are realization of feedback, cognitive level, form and maintainability.

The e-learning resources can be classified as:

1. Implementation in the text form (**text**). In this case e-learning resource is an electronic copy of a hard copy (book) in any format.
2. **Unilateral multimedia**. There is an implementation of e-learning resources in the form of audio or video streams without feedback there.
3. Implementation in the form of hypertext (**hypertext**).
4. **Intelligent multimedia**. E-learning resources are interactive multimedia with elements of artificial intelligence.

According to the result of the analysis [11, 18] the main life-cycle processes of e-learning resources as applied to the task of automated evaluation of quality are: “Organisation of use” (subprocess of “Implementation”), “Learning Process”, “Analysis”, “Evaluation”, “Optimization”.

The best way to improve the e-learning resources quality must be a least time-consuming. The grading scale for the expert judgments is represented in the table 1. This scale is depended on the ways of e-learning resources implementation and the possibilities of providing access to the learning system repository. The maintainability can be evaluated by experts on the step “Organisation of use” of e-learning resource’s life-cycle. The maintainability will be different for different organizations.

Table 1. The grading scale of maintainability

Gradation	Points	The way of implementation
Impossible	0-1	Unilateral multimedia or intelligent multimedia
Very difficult	2-3	Unilateral multimedia or intelligent multimedia
Difficult	4-6	Unilateral multimedia or intelligent multimedia, hypertext
Possible	7-8	Text, hypertext, unilateral or intelligent multimedia
Very easy to implement	9-10	Text, hypertext

In the context of the task of automated information support the e-learning resource cognitive level taxonomy is developed. This taxonomy joins Bespalko’s taxonomy and Bloom’s taxonomy [3, 6] to cover all types of e-learning resources The ranking levels of educational purposes are made on the interval from 1 to 8 (the level of learning $\alpha \in [1;8]$). The first part of taxonomy contains the simplest cognitive levels (tbl. 2). These levels are used very often and feedback for these resources must be fully automated in the learning process.

Table 2. E-learning resource learning level taxonomy (part 1)

Graduation	Examples of requirements	Cognitive process	α
Perception new information	Percepts new information, demonstrates the primary understanding.	Perceiving	1.0
Knowledge. Exhibit memory of previously learned materials by recalling facts, terms, basic concepts and answers	Recognizes the studied objects and processes, find and selects the objects in a presented set of different.	Recognizing	2.0
	Knows terms, facts, rules, principles, methods, definitions.	Recalling learned material	2.5
Comprehension. The ability to create values that are based on e-learning materials or experiences, to transform of learned material from one form to another. Interpretation and prediction.	Understands the facts, rules, principles. Interprets the study material of various types. Converts, translates course material from one species to another. Predicts the consequences arising from the data.	Interpreting	3.0
		Creating examples	3.1
		Classifying	3.2
		Generalizing	3.3
		Reasoning	3.5
		Comparing	3.7
		Explaining	3.9

The second part of this taxonomy contains levels that can use manually processing or partially automated processing of results (tbl. 3).

The cognitive level can be evaluated by experts on the step “Organisation of use” of e-learning resource’s life-cycle.

The classification of types and functional properties of the e-learning resources which is applied to the task of automated information support to the decisionmaking is shown at fig. 1. The functional properties according to the ways of implementation of e-learning resources are presented in table 4.

Table 3. E-learning resource learning level taxonomy (part 2)

Graduation	Examples of requirements	Cognitive process	α
Application. Using a procedure. The ability to use the material in specific conditions and new situations with applying of the rules, principles, and theories.	Uses the learned material in the new conditions. Applies the learned material in individual situations. Demonstrates the proper using of the method.	Implementing	4.0
		Applying	4.5
Analysis. The ability to break learning material to the components, to structure knowledge, to identify parts of a whole, to identify the relationship between the two entities. Awareness of the principles of organization of the whole.	Allocates latent assumptions. Sees errors in logic reasoning, difference between facts and consequences. Assesses the significance of the data.	Differentiating	5.0
		Organizing	5.3
		Relating	5.7
Synthesis. The ability to develop new unique structures, systems, models, approaches, ideas; creative thinking, operations.	Develops plans or procedures, designs solutions, integrates methods, resources, ideas, parts; creates teams or new approaches, writes protocols or contingencies	Generating	6.0
		Planning	6.5
		Producing	7.0
Evaluation. The ability to judge the value of material for a given purpose	Assesses the logic of learning materials. Assesses the correspondence of conclusions to available data. Assesses the significance of the result (product) of activity.	Examination	7.5
		Critical thinking	8

Table 4. The learning resources functional properties

Type	Implementation	Feedback	Learning level	Maintainability, Forms
Theory	All types		α∈[1;2]	All types
Workshop	Text, hypertext, Intelligent multimedia	Manual and mainly manual processing, partially, mainly automated and full automated processing of results	α∈[2;5]	
Control			α∈[2;8]	

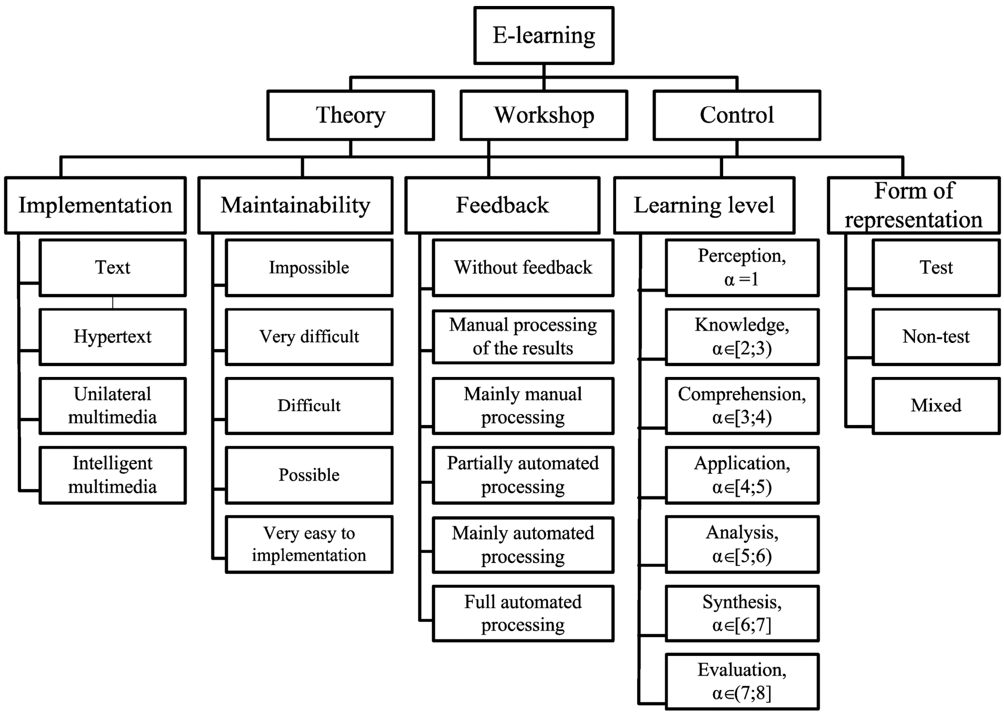

Fig. 1. The classification of e-learning resources’ types and functional properties

The Form of presentation (Test, Non-test, Mixed – e-learning resources are partially in the test-form) is used to describe the form of e-learning resources. It is simpler to automate the feedback for the test-form e-learning resources. So, the transformation into the test-form will be recommended for resources in non-test form with low cognitive levels, and the transformation into the mixed form will be recommended for resources in non-test form with high cognitive levels.

According to [5, 12] the set of quality criteria are the academic performance, validity, manufacturability and reliability. The complex criteria can be written as:

$$Q^f(S_{KOP}) = \prod_{i=1}^{n} (Q_i(S_{KOP}))^{w_i} \quad (1)$$

where:

w_i – weights of criteria, $\sum_{i=1}^{n} w_i = 1$; S_{KOP} – the semantic graph of the discipline; n = 4 – number of criteria: $Q_1(S_{KOP})$ – the academic performance; $Q_2(S_{KOP})$ – the validity; $Q_3\ (S_{KOP})$ – the manufacturability; $Q_4(S_{KOP})$ – the reliability.

The academic performance criteria $Q_1(S_{KOP})$ is:

$$Q_1(S_{KOP}) = \begin{cases} \frac{\sum_{i=0}^{m} x_i}{n}, if \frac{\sum_{i=0}^{m} x_i}{n} \le \varphi_{\max} \\ 1 - \frac{\sum_{i=0}^{m} x_i}{n}, if \frac{\sum_{i=0}^{m} x_i}{n} > \varphi_{\max} \end{cases}, \quad (2)$$

$$x_i = \begin{cases} 1, X_{Si} \ge \Delta y_{\min} \\ 0, X_{Si} < \Delta y_{\min} \end{cases}, X_S \in [0; \Delta y_{\max}],$$

where:

Δy_{min} is a minimum acceptable grade on the local scale of grades (the scale of grades is an interval $\Delta y = [\Delta y_{min}, \Delta y_{max}]$); X_S – primary points of learners; n – number of learners; φ_{max} – maximal academic performance according to the interval of the academic performance $\varphi^I \in [\varphi_{min}; \varphi_{max}]$ (this interval must be set by the e-learning course developer).

The validity criteria $Q_2(S_{KOP})$ is:

$$Q_2(S_{KOP}) = \frac{\int_{\theta_{\min}}^{\theta_{\max}} I(\theta) d\theta}{\int_{\theta_{\min}}^{\theta_{\max}} I^E(\theta) d\theta}, \quad (3)$$

where:

$I^E(\theta)$ – standard of the information function, $I^E(\theta) = 5.6644$; θ – ability of learners, $\theta \in [-5; 5]$; $I(\theta)$ – the item information function for the two parameter model:

$$I(\theta) = D^2 \cdot \sum_j d_j^2 p_j(\theta) q_j(\theta),$$

where:

D – scaling coefficient, D ≈ 1.7; d_j – parameter of discrimination; $p_j(\theta)$ – probability of success for the task j; $q_j(\theta)$ – probability of unsuccess $q_j(\theta) = 1 - p_j(\theta)$.

For e-learning resources which are presented in the form of tests, when the response is evaluated as 1 or 0, the probability of success can be written as:

$$p_{ij} = \frac{e^{Dd_j(\theta_i - \beta_j)}}{1 + e^{Dd_j(\theta_i - \beta_j)}}, d_j = \frac{r_{bis}}{\sqrt{1 - r_{bis}^2}}$$

where:

r_{bis} – biserial correlation coefficient; β – difficulty of item j.

If result of responses must be integrated to a single grade (for the cases with multi-step task) the learners can take from 0 to m points. For these e-learning resources the conditional probability of success of the step k can be written as:

$$p_{njk} = \frac{e^{Dd_j(\theta - \beta_{jk})}}{1 + e^{Dd_j(\theta - \beta_{jk})}}, d_j = \frac{r_j}{\sqrt{1 - r_j^2}},$$

where:

r_j is Pearson correlation coefficient.

The result of researching of the Birnbaum's function in reference to the e-learning resources monitoring are presented at [Ul'shin, 2012].

The criteria of manufacturability $Q_2(S_{KOP})$ is:

$$Q_3(S_{KOP}) = \frac{\sum_{i=0}^{j} k^T{}_i \cdot k^\alpha{}_i}{j}, k^T{}_i = \frac{t_i}{t_{\max}}, k_i^\alpha = \frac{\alpha_i}{\alpha_{\max}}, \quad (4)$$

where:

$k^\alpha{}_i$ – learning level coefficient of the task i; α is a learning level, $\alpha \in [1..8]$ (table 2, 3); $k^T{}_i$ – manufacturability coefficient of the item i, $k^T \in [0..1]$; t_i is a level of the feedback (fig.1, table 5), $t_{max} = 10$.

Table 5. The grading scale of feedback

Points, t	Gradation
0	Without feedback
1	Manual processing of results
2-3	Mainly manual processing
4-6	Partially automated processing
7-8	Mainly automated processing
9-10	Fully automated processing

The criteria of the reliability $Q_4(S_{KOP})$:

$$Q_4(S_{KOP}) = 1 - \frac{\sum_{l=0}^{n} \sum_{i=0}^{j} k_{il}^\varepsilon}{n}, k_{il}{}^\varepsilon = \frac{L_{il}^\varepsilon}{L^\varepsilon{}_{\max}}, \quad (5)$$

where:

k^{ε}_{il} is a coefficient of the defect of the item i of the attempt l, $k^{\varepsilon}_{il} \in [0..1]$; L^{ε}_{il} is a level of the priority of the defect of the item i, $L^{\varepsilon} \in [1..10]$; n – total number of interaction attempts with the e-learning resources.

The main categories of e-learning resources' defects are: "Uncertainty", "Inaccuracy", "Incompleteness", "Non-balanced". The category "Non-defined" is used for temporary identification of defects that cannot be identified by any of the listed categories. In this situation the decision maker receives a special recommendation to develop and add to the knowledge base the new category of defects. The category "Composited" is used for an identification of defects elements that are located on the nested levels of the e-learning course hierarchy structure. The e-learning resources defects can take status values: "Registered", "Confirmed," "Ignored" or "Fixed".

The knowledge base model of decision support system, which takes into account the complex criterion of quality, is a network of frames (fig. 2). The network contains three hierarchies of frame-prototypes ("Learner", "Structure of the course" and "Learning results"). A frame prototype "LR" is used to describe the learning content, the frame prototype "Gradebook" sets relations between class instances "Group" and class instances "Version" (class "Version" belongs to the hierarchy "Structure of course"). The prototype frames "Feedback ","Defect "," Maintainability", "Learning level" are used to determine the learning resources properties such as the level of learning, the type of feedback, bugs, and maintainability.

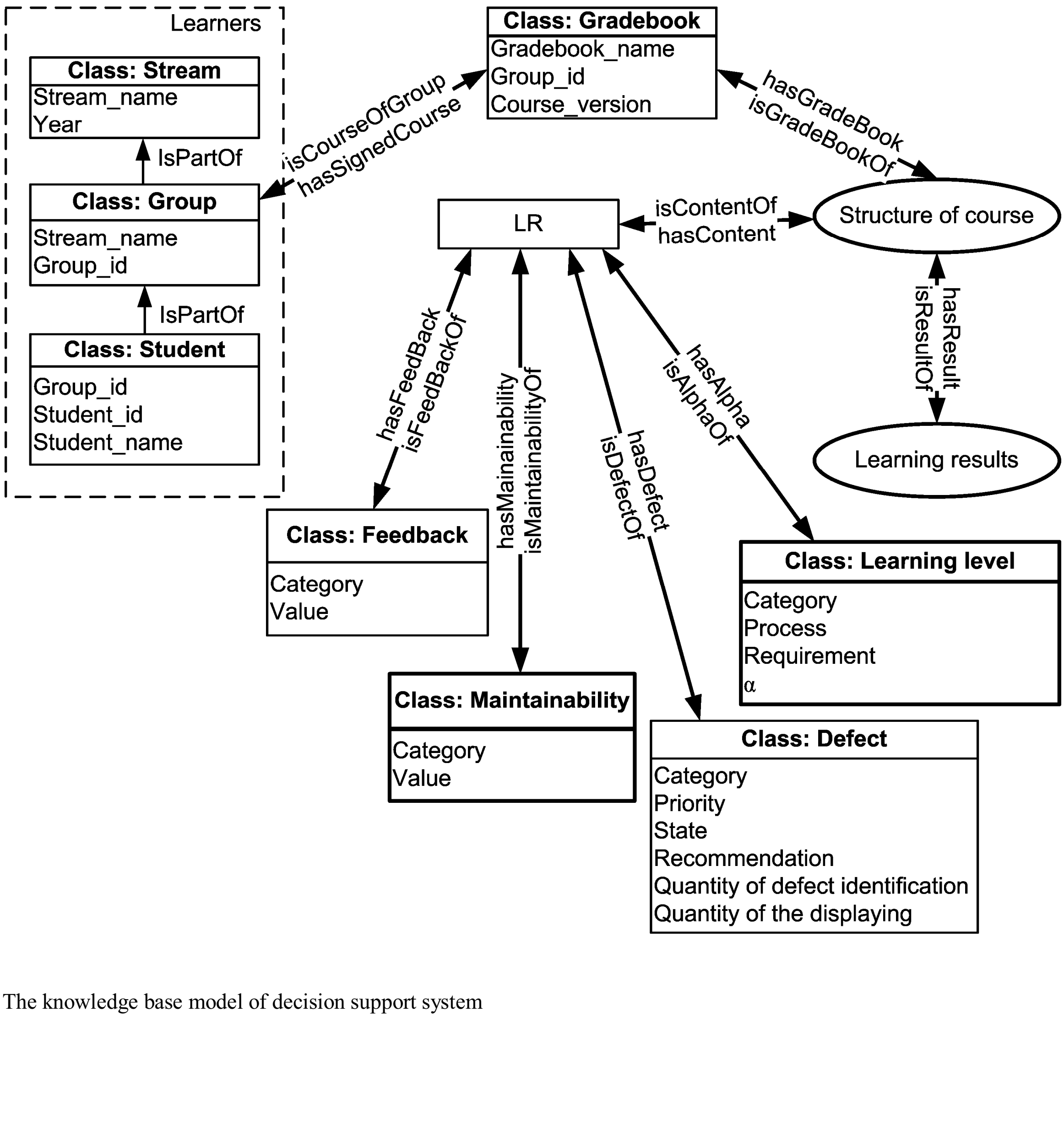

Fig. 2. The knowledge base model of decision support system

Hierarchy "Structure of course" contains six levels of the inheritance. The set of frames of the hierarchy "Structure of course" $S = \{ scf^{C}_{1}, scf^{C}_{2}, scf^{C}_{3}, scf^{C}_{4}, scf^{C}_{5}, scf^{C}_{6}\}$, scf^{C}_{1} – the frame-prototype of the class «Course», scf^{C}_{2} – the frame-prototype of the class «Version», scf^{C}_{3} – the frame-prototype of the class «Modul», scf^{C}_{4} – the frame-prototype of the class "Theme", scf^{C}_{5} – the frame-prototype of the class «Task», scf^{C}_{6} – the frame-prototype of the class «Step». The frame-prototype of class Version is presented in the table 6.

Table 6. Class „Version"

Name of slot	Date type	Way to get	Demon
Name	[String]	External source	
Year	[Date]	External source	
Q^f	[REAL]	AP	EvQ^f
Q_1	[REAL]	AP	EvQ_1
Q2	[REAL]	AP	*EvQ2*
Q_3	[REAL]	AP	*EvQ3*
Q_4	[REAL]	AP	EvQ_4
The maximum score	[REAL]	External source	
Failure of information function	[LIST]	AP	*EvExtr*
Technological factor	[REAL]	AP	*EvkT*
Learning Level	[REAL]	AP	*EvAlpha*
Discriminatory parameter	[REAL]	AP	*Evd*
Difficulty	[REAL]	AP	*EvBeta*
Defect	[LIST]	AP	*EvDef*
Maintainability	[REAL]	AP	*EvMaintain*

The class „Theme" and its descendants contains additional slots for establishing hierarchy associative relation 'hasContent-isContentOf' with frame "LR" and relation "hasResult-isResultOf" with frame "Learning Result" . Class "Version" makes relation "hasGradebook-isGradebookOf" with frame "Group" of hierarchy "Learners" for connecting the instances of class "Group" to instances of class "Version".

The associated procedure (AP) of this hierarchy is executed according to the current level of the inheritance. *EvQ* performs the calculation of the complex criteria according to the (1); EvQ_1, EvQ_2, EvQ_3, and EvQ_4 perform the calculation of local criteria according to (2), (3), (4), (5) respectively. *EvExtr* provides information about the failures of the information function according to [Ul'shin, 2012], *EvBeta* provides data about the difficulty of tasks, *Evd* calculates the discriminatory ability; *EvkT* returns the value of the manufacturability coefficients, *EvAlpha* returns the values of the learning levels, *EvMaintain* – returns the values of the maintainability, *EvDef* provides information about defects and recommendations for fixing defects.

The prototype of knowledge base model is constructed by the ontology editor Protégé [11]. The hierarchy of entities is present at fig. 3.

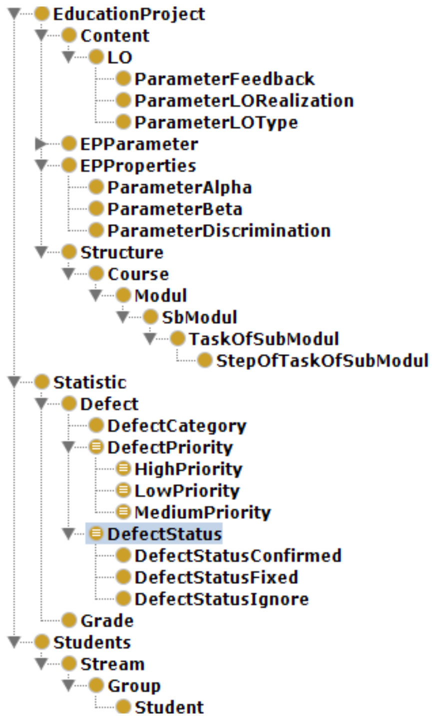

Fig 3. Entity Hierarchy of the knowledge base model

The semantic graph of the knowledge base model that is generated by Protégé is presented at fig. 4.

The consistency of the developed ontology was tested and confirmed by reasoners Fact ++ [20] and Pellet [9].

CONCLUSIONS

The analysis of e-learning resources functional properties which is applied to the task of automated information support to the decisionmaking for improving the quality of e-learning resources is made. The main functional properties are: implementation, maintainability, feedback, learning level, form of representation.

The grading scale of maintainability and feedback are proposed. In the context of the task of automated information support the e-learning resource cognitive level taxonomy is developed.

The ranking levels of educational purposes are made on the interval from 1 to 8 ($\alpha \in [1;8]$).

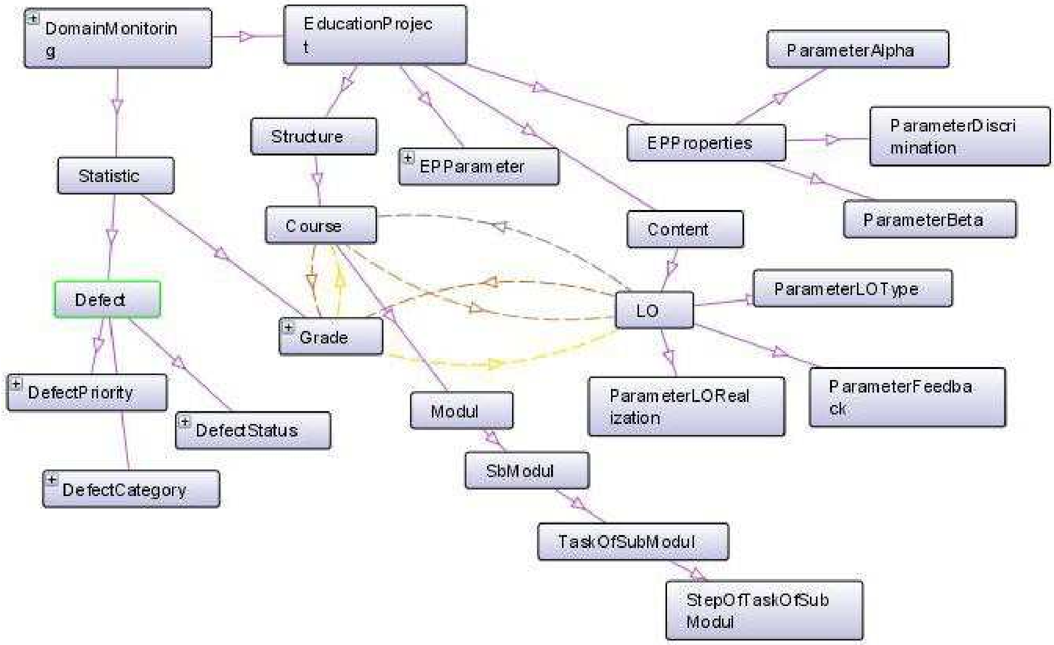

Fig. 4. The semantic graph of the ontology

The knowledge base model of decision support system, which is adapted to the complex criterion of quality that takes into account the academic performance, validity, manufacturability and reliability of the learning resources, is developed.

The prototype of knowledge base model is constructed by the ontology editor Protégé. The consistency of the developed ontology was tested and confirmed by reasoners Fact ++ and Pellet.

REFERENCES

1. **Advanced Distributed Learning (ADL), 2004.:** Sharable Content Object Reference Model (SCORM®) 2004 2nd Edition Overview. ADL, Available at: http://www.adlnet.gov/wp-content /uploads/2011/07/scorm.2004.3ed.confreq.v1.0.pdf.
2. **Alekseev A.N., 2005.:** Distance learning for engineers.: Monograph. Sumy, 333.
3. **Anderson, L. & Krathwohl, D. R., 2001.:** A Taxonomy for Learning, Teaching and Assessin: A revision of Bloom's Taxonomy of Educational Objectives. –New York: Longman, 2001.
4. **Atanov G. A., 2001.:** Active approach to teaching. Donetsk. «EAI-press», 160.
5. **Avanesov V.S., 2006.:** Fundamentals of the training task theory. Pedagogical dimensions. №2. 26-62.
6. **Bespal'ko V. P., 2002.:** Education and training with computers (the pedagogy of the third millennium. MPSI, MODEK, 2002, 352 (In Russian).
7. **Bocula M. P., Morgun I. A., 2008.:** About the problem of quality assessment materials online courses. Scientific works of VNTU, 2008, Vol. 4, 1-6.
8. **Bodnar B. E., Matusevich O. O., 2012.:** Systems for quality management according to the standard ISO 9000 in high school. Bulletin of Dnipropetrovsk National University of Railway Transport named after Academician V. Lazaryan. 2012, issue 40, 167-172.
9. **Clarc & Parsia, 2011.:** Pellet Reasoner Plug-in for Protégé 4. [Electronic resousces]. Available at http://clarkparsia.com/pellet/protege/
10. **Shulgin S K., Danchenko A. L., 2011.:** Analysis of the process of improving the quality of e-learning resources. Sofrware engineering. No 2(6). 73-77.
11. **Danchenko A. L., 2012.:** The ontology of the system for supporting the decision-making of improving the quality of educational resources.Proc. materials of the conference "Web Development and Internet Technologies WebConf2012». June 5-7, 2012. - Minsk. BSU, - 15.
12. **Danchenko A.L., Ul'shin V. A., 2012:** Development of a comprehensive quality criterion of educational resources. Bulletin of Volodymyr Dahl East Ukrainian National University, vol. 4 (175). 117-122.
13. **Kim V.S., 2007.:** Testing of educational achievements. Monograph. Ussuriisk, 214.
14. **Krasnyuk A. V., Ulchenko T. V., 2011.:** Modular system as a means of improving during the study descriptive geometry students of technical universities. Bulletin of Dnipropetrovsk

National University of Railway Transport named after Academician V. Lazaryan. Issue 36, 185-188.
15. **Pawlowski J. M, 2010.:** The Quality Adaptation Model: Adaptation and Adoption of the Quality Standard ISO/IEC 19796-1 for Learning, Education, and Training [Electronic resource]/ J. M. Pawlowski // Educational Technology & Society. – №10 (2). 3-16. – [Access mode]: http://www.ifets.info/journals/10_2/2.pdf.
16. **Plaza I., 2010.:** Quality and innovation in Higher Education: Code of Good Practices [Electronic resource]/ I. Plaza, F. Arcega, F Ibáñez.// Frontier in Education. – IEEE. – Wachington. – [Access Mode]: http://fie-conference.org.
17. **Richards T., 2008.:** Core SCORM Study Group Final Recommendation: ISO/IEC JTC1 SC36. Available at: www.adlnet.gov.
18. **Stracke C M., 2009.:** "Quality Development and Standards in e-Learning: Benefits and Guidelines for Implementations"; in: Proceedings of the ASEM Lifelong Learning Conference: e-Learning and Workplace Learning. Bangkok (Thailand). Available at: http://www.qed-info.de/downloads.
19. **Tkach V., 2010.:** The adaptive control of higher education process quality of a university on a "Teacher – Student" level. Teka Kom. Mot. i Energ. Roln. – OL PAN, 10B, 241-247. – ISSN 1641-7739
20. **Tsarkov D., 2013.:** Factplusplus. [Electronic resousces]. Available at https://code. google.com/p/factplusplus/.
21. **Ul'shin V. A., Danchenko A.L., 2012.:** Researching the Birnbaum's function in reference to the e-learning resources monitoring. Proceedings of Volgograd State Technical University. Vol 13, no. 4, 113-117.
22. **Ulshin V., Smoliy V., Fomyn Y., 2012.:** Mathematical design and operations of electronic vehicles management and introduction of results of researchers in an educational process. Teka. Comission of Motorization and energetic an agriculture. – OL PAN, Vol. 12, 279-285. – ISSN 1641-7739.
23. **Vorobkalov P.N, Kamaev V.A., 2009.:** Assessment of quality of e-learning systems: // Management of large systems. M.: IPU RAN. 2009, issue 24. 99-112.

РАЗРАБОТКА МОДЕЛИ БАЗЫ ЗНАНИЙ СИСТЕМЫ ПОДДЕРЖКИ ПРИНЯТИЯ РЕШЕНИЙ ПО СОВЕРШЕНСТВОВАНИЮ КАЧЕСТВА ЭЛЕКТРОННЫХ ОБРАЗОВАТЕЛЬНЫХ РЕСУРСОВ

Алла Данченко

Аннотация. Выполнен анализ функциональных свойств электронных образовательных ресурсов применительно к задаче автоматизации информационной поддержки принятия решений по совершенствованию качества электронных образовательных ресурсов. Разработана модель базы знаний системы поддержки принятия решений, адаптированной к комплексному критерию, который учитывает успеваемость, валидность, технологичность и надежность электронных образовательных ресурсов.
Ключевые слова. Электронный образовательный ресурс, качество, критерий, база знаний