Constructing Domain Model based on Logical and Epistemological Analysis*

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Abstract. In modern conditions of active development of new pedagogical technologies and innovative forms of organizing personalized learning in an electronic environment, adaptive learning begins to take the main positions. The development of the structure and content of adaptive e-learning courses, the design and implementation of educational strategies, teaching methods, approaches to assessing results are determined by the educational content model. The purpose of the study is to develop an approach to building a model of educational content for an adaptive e-learning course that provides a formalized presentation of educational material and building a logically grounded learning strategy. The paper presents an approach to its construction based on the integration of logical and epistemological methods of the correlating between the volume and content of concepts with the methods of graph theory. Adaptive e-learning courses, implemented on the basis of the proposed approach, made it possible to present educational content in the form of logically integral educational objects that allow adapting the educational environment to the personal characteristics of students. The proposed approach has been tested in the educational process of students of the training direction "Information systems and technologies" of the Siberian Federal University. In the future, the results of the study can become the basis for the development of a personalized adaptive learning ecosystem of a university in the context of digitalization of education.

Keywords: Educational content model, Domain model, Logical and epistemological analysis, Adaptive e-learning course, E-learning, Adaptive learning, Personalization.

1 Introduction

In the last decade, the goal of specialists in the field of electronic educational technologies has become the development of innovative methods for e-learning and various tools for analyzing the educational process. New pedagogical technologies and inno-

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vative forms of organizing personalized learning in an electronic environment are developing, for example, adaptive learning [1].

The analysis of educational practice in the field of adaptive learning testifies to the diversity of its models and the active development of new approaches and modern technologies for its implementation [2-8]. An adaptive e-learning course (AELC) is an e-course that provides the formation of an individual educational path and provides the student with a personal educational space. Such a space is filled with educational content, the form and content of which is adjusted to the individual characteristics of students and provides them with the necessary information [9]. The design of AELC, the definition and application of approaches to assessing learning outcomes is determined by the structure of knowledge embedded in the domain model - the model of educational content, which is the basis of any AELC [10].

In recent years, the presentation of the educational content of e-learning courses is carried out in accordance with the principles of microlearning, which is teaching a small amount of material in a short period of time [11]. However, despite the intensive use of microlearning, existing educational practices are mainly focused on dividing educational content into fragments. In this case, the key factor is the division of a length of time devoted to its study. This approach often does not include the processing of the content of the educational material and entails the fragmentation and lack of logical coherence of the developed adaptive e-learning courses. At the same time, it should be emphasized that modern requirements for micro-proportions of educational material are that they should be independent fragments of educational content and meet the criteria of logical integrity, independence, logical completeness and verifiability [12, 13].

In these conditions, it seems relevant to develop an approach to building a model of educational content of an adaptive e-learning course that provides a formalized presentation of the educational content of the discipline and the construction of a logical strategy for its study.

2 Domain model

Structuring domain model for AELC discipline serves to perform based on methods of logical and epistemological analysis of concepts [14-16]. The structure of domain model of the discipline, in this case, can be represented in the form of a tree, where the vertices correspond to the concepts of the subject area of the discipline, and the relations between them are the relations of the hierarchy: "genus-species relations" and "part-whole relations" [17, 18]. Two types of models characterize any concept C : phenomenological and structural model. The phenomenological model of a concept has the form:

$$C_f = \{x_1, x_2, ..., x_n\},$$

where $x_1, x_2, ..., x_n$ are essential features of a concept, the minimum set of which is sufficient to identify the concept being described from all concepts in a given subject area, regardless of the current learning goals – external heterogeneity of the concept. The structural model of the concept has the form:

$$C_s = \{A, R\},$$

where A is the set of sub-concepts of the described concept, R is the set of essential features of the sub-concepts of A, which form the phenomenological models of the sub-concepts – the internal heterogeneity of the concept. External and internal heterogeneity of the concept represent two main characteristics of the concept – qualitative and quantitative.

The concept of domain model is characterized by its volume and content. The denotation (extensional, degree of generality) is a set of its sub-concepts and is a set of classes of objects included in the concept. The content of concept (intension) is a finite minimum set of essential features. The intension of a concept can be represented by a class standard, which has averaged values of features within its scope and an acceptable range of values of features. Any concept can be defined by specifying its intension or extension.

Typically, when constructing a tree domain concepts, three types of concepts are distinguished: differentially general concepts, integrally general concepts and collectively general concepts transitional between them [15]. These concepts differ from each other in their logical and epistemological properties and functions. Differentially general concepts represent concepts in which objects in selected essential features are identified in a single class, and other indications are discarded and are not included in the meaning (essence) of this concept. The content of integrally general concepts includes information about all special cases of a feature (information about the subclasses of a given class of objects), which are deduced from them by imposing restrictions or a meaningful classification reflecting the entire historical path of development of the concept.

Differential general concepts obey the formal-logical law of the inverse relationship between the content and denotation of a concept, which means that the larger the content of the concept, the less its denotation. Integrally general concepts characterize both direct (epistemological) and reverse (logical) relations of their content and denotation. These relations correspond to subordinate and genus-species relations included in this concept.

When constructing a domain model in the tree concepts rupture can occur when you can not establish a relationship between certain concepts. This semantic gap domain violates its unity. This demonstrates the heterogeneity of domain model, and it should be presented as a set of concept trees, and the training materials of the discipline as a separate module for each tree. In this case, each module will have the discipline content integrity. The emergence of a semantic gap in domain model necessitates the use of a training project in the educational process that ensures the interconnection of the course modules.

The concept tree is used as a basis for identifying the minimum portions of theoretical material, which we will call terms. The term can be defined as a sequence of semantic facts and procedural rules having the semantic completeness. Each term represents some fragment of the discipline's concept tree. In this case, the tree of terms is a hypergraph of concepts (tree hypergraph), in which subsets of concepts included in the term are connected by an edge.

The study of terms is carried out sequentially: from general to specific, which allows us to correlate the concepts of a term with their place in the general structure of the course and contributes to the formation of a holistic perception of the discipline. The presentation of domain model in the form of a tree allows you to structure the discipline at the level of basic concepts and lay the foundation for basic educational activities. These activities in the course can be considered the assimilation of concepts in the field of their definition, identifying the main features and properties of the studied objects and identifying structural and logical relationships within the framework of the studied theory [16].

From a didactic perspective, an important component of the educational process in an adaptive e-learning course is the formation of students' competencies in accordance with federal educational standards and an educational program. This can be done through the decomposition of competencies into indicators of their achievement, which are knowledge, skills and labor actions. Further, the indicators are decomposed into a set of verifiable descriptors in the discipline's evaluation tools. Knowledge in work is understood as mastered specialized information in the form of concepts, their main features and connections. Skills are the ability to perform operations on the studied concepts of the subject area of the discipline [9] and, regardless of the subject area, rely on the classically distinguished types of operations on concepts: generalization, restriction, embedding, intersection, union and complement.

The content of each formed term can be expanded by operations on the concepts that are included in the term. This allows the design of a set of command and measuring materials to ensure control of the assimilation of each term and the formation of a coherent micro-proportion of educational content. The construction of command and measuring materials is based on an a priori assignment of a tree of operations or their combination.

The domain model includes two kinds of concepts: operators and operands. The concept-operands are the concepts of the domain model and the concept-operators describe the actions performed on the concept-operands (operations on the concepts that are presented above). During the construction of a tree of operations on concepts, a situation is possible when the combination of one concept-operand with different concept-operators is carried out to form different resulting concepts. An increase in the level of abstraction of operands and operators in the tree of operations increases the complexity of the skills formed in the student. The low-level operand is the basis for constructing various higher-level operands.

As a result, the formation of a skill at each step of training is to form the trainee's ability to independently combine operands and operators of the same level of generality (abstraction) and obtain a new operand (result of the operation) of a higher (lower) level of abstraction. The process of forming abilities carried out at each step in the study of learning next domain concepts.

It should be noted that each step of training is divided into three phases: assimilation of the current concept of the domain model (knowledge component), formation of ability (ability formation operate with the received knowledge), formation of the required skill (the ability to perform an operation on the acquired knowledge at an expertly specified time).

At the same time, skill is considered as a way of performing operations on concepts, brought to automatism and ensuring high productivity in performing professional tasks. After each phase, appropriate measurements are carried out, and the phase is implemented until the learner reaches the normative levels of knowledge – K_{st}, ability – A_{st}, and skills – S_{st}, Fig. 1.

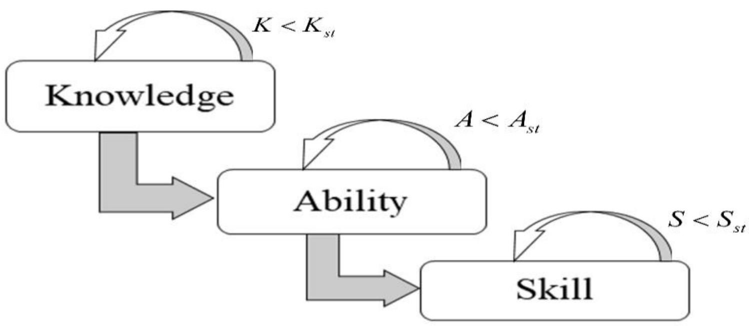

Fig. 1. Step of learning in AELC

3 Conclusion

As a result, the domain model is built from concepts to a tree or a set of trees of discipline terms and operations. The next step is the transition to the formation of the course content corresponding to the developed domain model. At the same time, the terms of educational content are independent fragments, bricks of knowledge, in other words, educational objects [9]. The selection of "educational objects" (structuring the educational material of the AELC) and, accordingly, the formation of a minimum portion of the educational material can be carried out through the indication of the intension or extension of the concepts included in it. Knowledge about the external and internal heterogeneity of concepts, the phenomenological and structural models of the studied concepts, respectively, is a necessary and sufficient content of the essence of the educational object.

The approach proposed by the authors has been tested and has shown its effectiveness in the educational process of students in the areas of training in the field of computer technologies at the Siberian Federal University. Adaptive e-learning courses, built on the basis of the approach proposed by the authors, allow structuring the subject area of the discipline: moving from concepts to terms - logically integral microproportions of educational content. The peculiarity of the proposed approach to the construction of a model representation of the educational content is a formalized representation of educational material and the possibility of constructing a logically reasonable sequence of its study.

References

1. Vainshtein, I.V., Shershneva, V.A., Esin, R.V., Noskov, M.V.: Individualisation of Education in Terms of E learning: Experience and Prospects. Journal of Siberian Federal University. Humanities & Social Sciences 9 (12), 1753–1770 (2019) doi: 10.17516/1997–1370–0481
2. Brusilovsky, P.: Adaptive and Intelligent Web-based Educational Systems. International Journal of Artificial Intelligence in Education 13,156-169 (2003) doi:10.1.1.363.9506
3. Rastrigin, L.A., Erenshtein, M.K. Adaptive learning with a learner model [in Russian]. Zinatne, Riga (1988).
4. Shershneva, V.A., Vainshtein, Yu.V., Kochetkova, T.O.: Adaptive system of web-based teaching. Program Systems: Theory and Applications 4(39), 159-177 (2018) https://doi.org/10.25209/2079-3316-2018-9-4-179-197
5. Esichaikul, V., Lamnoi, S., Bechter, C.: Student modelling in adaptive e-learning systems. Knowledge Management and E-Learning 3(3), 342-355 (2011) https://doi.org/10.34105/j.kmel.2011.03.025
6. Komleva, N.V., Vilyavin, D.A.: Digital Platform for Creating Personalized Adaptive Online Courses [in Russian]. Open Education 24(2), 65-72 (2020) https://doi.org/10.21686/1818-4243-2020-2-65-72
7. Golikova E.A.: An experience of the structure construction of the course "discrete mathematics" with tracking of logical relations between its components [in Russian]. Modern problems of science and education, 5 (2018) https://www.elibrary.ru/item.asp?id=36367971
8. Bronov, S., Stepanova, E.: Automatic generation of methodological materials in the study of technical and engineering texts in a foreign language. IOP Conference Series: Materials Science and Engineering, 862, 052068 (2020) doi:10.1088/1757-899X/862/5/052068
9. Tsibulskii, G.M., Vainshtein, Iu.V., Esin, R.V:. Development of adaptive e-learning courses in the LMS Moodle [in Russian]. Siberian Federal University, Krasnoyarsk (2018) https://www.elibrary.ru/item.asp?id=36819677
10. Vainshtein, Y., Shershneva, V., Esin, R., Tsibulsky, G., & Safonov, K. Adaptation algorithms of mathematical educational content in e-learning courses. SHS Web of Conferences, 48, 01010 (2018) https://doi.org/10.1051/shsconf/20184801010
11. Fernandez, J.: The microlearning trend: Accommodating cultural and cognitive. Santa Rosa, CA. (2014) https://www.learningsolutionsmag.com/articles/1578/themicrolearning-trend-accommodating-cultural-andcognitive-shifts
12. Dolasinski, M.J., Reynolds, J.: Microlearning: A New Learning Model. Journal of Hospitality & Tourism Research, 44(3), 551–561 (2020) https://doi.org/10.1177/1096348020901579
13. Shershneva, V., Vainshtein, Y., Kochetkova, T., & Esin, R.: Technological approach to development of adaptive e-learning system. SHS Web of Conferences, 66, 01014 (2019) https://doi.org/10.1051/shsconf/20196601014
14. Voishvillo, E.K.: Concept as a form of thinking: logical-and-gnoseological analysis [in Russian]. MGU, Moscow (1989).
15. Tyukhtin V.S.: Reflection, Systems, Cybernetics: The Theory of Reflection in the Light of Cybernetics and the Systems Approach [in Russian]. Science, Moscow (1972).

16. Atanov, G.A.: Modeling an academic domain or a student's domain model [in Russian]. Educational technology & society, 1(4), 111-124. (2001) https://www.elibrary.ru/item.asp?id=7560714
17. Simko, M., Bielikova, M.: Lightweight domain modeling for adaptive web-based educational system. Journal of Intelligent Information Systems, 52, 165–190 (2019) https://doi.org/10.1007/s10844-018-0518-3
18. Vrablecova, P., Simko, M.: Supporting semantic annotation of educational content by automatic extraction of hierarchical domain relationships. IEEE transactions on learning technologies, 9(3), 285-298 (2016) doi: 10.1109/TLT.2016.2546255