KAPITEL 8 / *CHAPTER 8* [8]
DATALOGIC PROJECTING FOR APPLIED ADAPTIVE SEMANTIC TESTING

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Introduction and analysis of the current stage problems of adaptive knowledge level control

At present stage one of the most important indicators of a high-quality educational model is the control of knowledge level [1]. The control of knowledge level should be based on the content and material of the educational course in which it is conducted. The basis of the course is educational material that reveals its issues and is the basis for the formation of knowledge. The educational material is complex system that has its own structure with specific elements and relations between them [2]. As the basis of the learning process, the educational material includes all the information that is submitted for learning and promotes learning.

The most objective means for estimation of the knowledge level is currently considered testing, which allows to impartially estimating the academic achievements of students. Computer testing makes it possible to implement the basic didactic provisions of learning control: the principle of individual nature of testing and estimation of knowledge; systematic testing and estimation of knowledge; the principle of subjectivity; the rule of differentiated estimation of progress [3].

Computer testing can be performed in various forms, differing in the technology of combining tasks into a test [4]: traditional testing, parameterized testing and adaptive testing, which the composition of working sample of test tasks is unknown in advance, and subsequent test tasks are selected automatically depending on the answers to previous.

Now it is considered promising to create the required set of test tasks automatically [5]. In general, the existing means of automating the creation of test tasks are focused on methods of artificial intelligence using the theory of ontologies, which

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makes them cumbersome and inefficient.

It is known that increasing the depth of learning of the semantic content of educational material has the effect of learning less and less semantically important units of educational materials. Semantic units of educational materials are key terms, which have different indicators of semantic weight or importance [6]. Therefore, each test task should purposefully check the level of knowledge of specific semantic units of educational materials for a specific fragment of educational material. Depending on the success of the answers, test tasks are offered to check the assimilation of more or less semantically important units of educational material to determine the level of learning of the content of each element of the rubrication of educational material. Based on these results, the final score for the test is calculated [7].

Key aspects of the applied implementation of adaptive semantic testing are the information technology and datalogic model for adaptive semantic testing, which development of is the ***goal of this research***.

8.1. Information model of educational course semantic structure

The information model of the semantic structure of the educational course C [6], developed by the author, is a formal representation of the educational course. It covers the complete semantic structure of the educational material I and the set of test tasks T, contains the relations R of these components and their parameters (Fig. 1). The semantic structure of the course C is presented as follows:

$$C = I \cup T = H \cup S \cup K \cup Q, \quad (1)$$

$$R = R_1 \cup R_2 \cup R_3 \cup R_4 \cup R_5 \cup R_6, \quad (2)$$

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where H – set of headings (rubrics), S – set of sentences of educational material, K – set of key terms, R_1 – set of relations between headings, R_2 – set of relations between headings and fragments, R_3 – set of occurrences key terms, R_4 – set of relations between headings and key terms, R_5 – set of relations between test tasks and fragments, R_6 – set

of relations between test tasks and key terms.

8.2. Information technology for adaptive semantic testing of educational materials level of knowledge

The developed information technology for adaptive semantic testing of educational materials level of knowledge [7] makes it possible to determine the assessment of knowledge level of materials by using indicators of semantic importance of key terms for adaptive selection of test tasks in testing (Fig. 1).

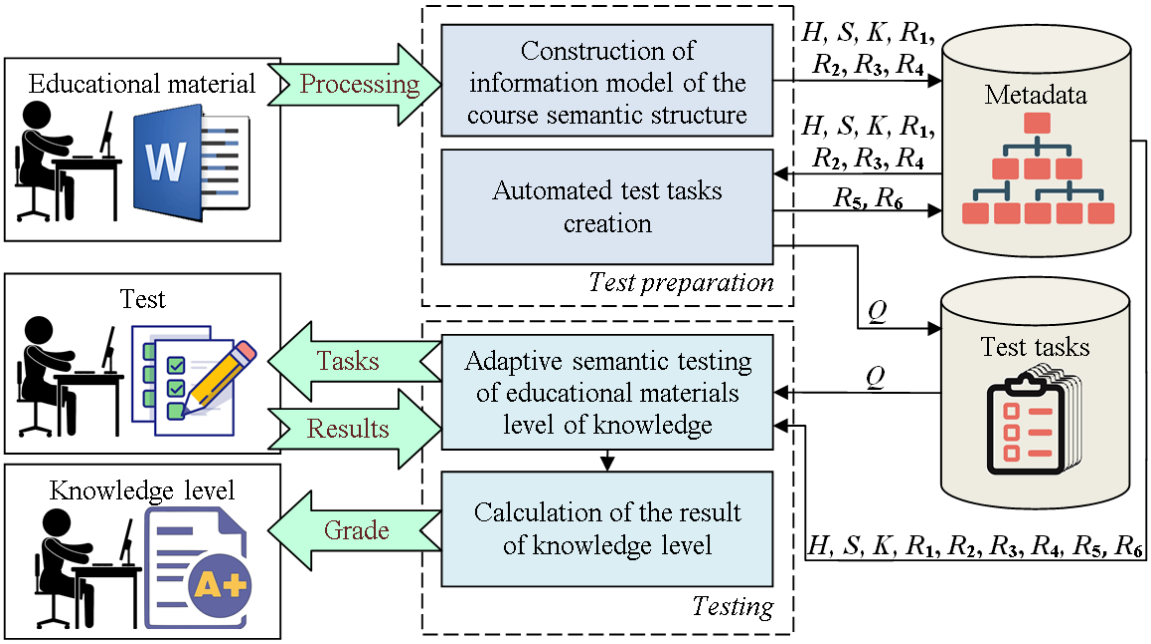

Figure 1 – Scheme of implementation of adaptive semantic testing

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The *input data* of the developed information technology are elements of information model of semantic structure of educational course C, in particular set of test tasks Q and metadata for adaptive semantic testing of knowledge level: set of headings H, set of fragments of educational material S, set of key terms K, set of relations between headings R_1, set of relations between headers and fragments R_2, set of occurrences of key terms R_3, set of relations between headers and key terms R_4, set of relations between test tasks and fragments R_5, set of relations between test tasks and

key terms R_6. The information technology also requires parameters: the element of semantic structure selected for testing, the algorithm for starting testing and the algorithm for assessing the level of knowledge (Fig. 2).

In *Step* 1, within the content of the selected element of the semantic structure for testing, the current subelement $h \in H$ of the educational course C is selected for further testing. In *Step* 2, from the set of semantic units $k \in K$ of the current subelement $h \in H$ of the educational course, the current semantic unit $k \in K$ is selected, the learning of which will be checked in this iteration. The selection of the current semantic unit k is carried out according to the specified test start algorithm. Next, in *Step* 3, is created a sample of all test tasks $Q' \subset Q$, suitable for checking the level of knowledge of the current semantic unit k.

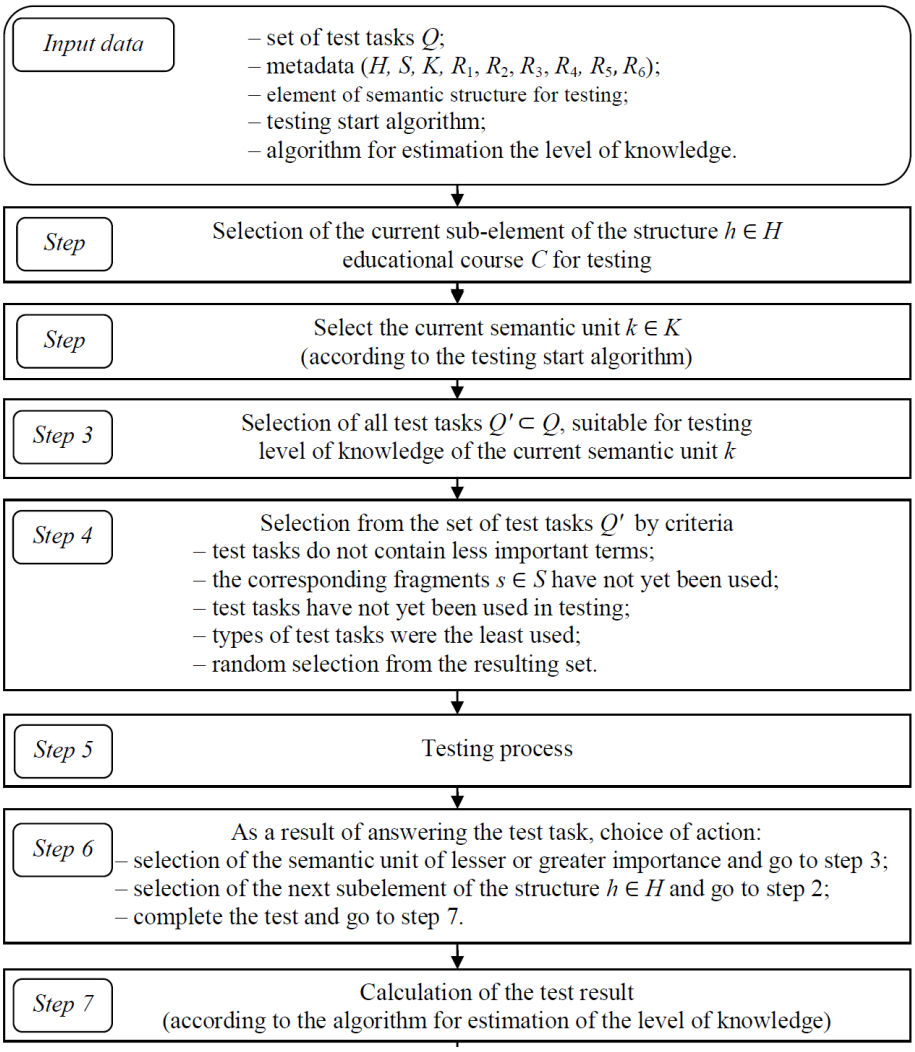

Figure 2 – Scheme of information technology for adaptive semantic testing of educational materials level of knowledge

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In *Step* 4, irrelevant test tasks are removed from the obtained set Q'. Namely, remain (or receive a positive rating) test tasks that accord the criteria: test tasks do not contain less important terms; the corresponding fragments $s \in S$ of the educational material have not been used yet; test tasks have not yet been used in this testing; types of test tasks were the least used.

If in obtained result in set of actual test tasks $Q'' \subset Q'$ there are several test tasks, then a random selection of a test task from Q'' will be applied.

In *Step* 5, is directly the testing process: the test task is provided to the user and the received answer is recorded. Depending on the correctness of the answers to the test tasks, in *Step* 6 the following action is selected:

– applies the selection of the semantic unit k ∈ K of lesser or greater importance and go to *Step* 3 – if the data for estimation the knowledge level of current sub-element h ∈ H of the course is still insufficient;

– applies the selection of the next subelement of structure h ∈ H and go to *Step* 2 – if the data to estimation the level of knowledge of current sub-element h ∈ H of the educational course is sufficient, but there are other untested subelements h ∈ H;

– test is completed and go to *Step* 7 – if the data to estimation the level of knowledge of current subelement of the educational course is sufficient and all subelements h ∈ H are checked.

In *Step* 7, the calculation of the test result is performed according to the selected algorithm for estimation of the level of knowledge. The calculated estimation of the level of knowledge is the output data of the information technology.

8.3. Datalogic design for applied adaptive testing

To implement adaptive knowledge testing, organize data, and store intermediate stages of adaptive testing, a datalogic model was designed, the structure of which is shown in Figure 3. The datalogic model was developed in accordance with the processes and functions of adaptive knowledge testing, so the tables "Paragraphs",

"Test Task in Samples", "Answers", "Titles", "ISM", "Key Terms", "Users" were created, "Test Task Completion", "Sentences", "Attempts", "Terms", "Terms in Sentences", "Test Tasks", "Test Tasks in Samples", "Paragraph Types", "Task Types", "User Types", "Sentence Types", "Test Types".

Figure 3 – Datalogic model for applied adaptive testing

Author's development

The "ISM" table is designed to store data about the educational materials. The "Titles" table is intended for storing data about the structural unit of the educational materials – titles. The "Sentences" table contains a list of all sentences added to the database. The "Terms" table contains data about the terms of the educational materials; the "Terms in Sentences" table provides the relationship between terms and sentences, including their current forms. The “Task Types” table contains the types of test tasks. The "Test Tasks" table stores the text of the task, its relationship to the key term and sentence. The “Answers” table contains answers to the task, their text, connection with the sentence, and the correctness score.

Another separate block of datalogic model for adaptive knowledge testing is the "Users" and "User Types" tables. The "User Types" table contains information about the types of users in the developed information system. The “Users” table stores personal data of system users. The "Sample of Test Tasks" table contains information about samples created by teachers using test items. The "Test Tasks in Samples" table is a pivot table between the "Test Tasks" and "Sample of Test Tasks" tables. The "Attempts" table contains information about test attempts associated with the "Sample of Test Tasks", "Task Types", and "Users" tables. The "Test Task Completion" table is linked to the "Test Tasks" and "Attempts" tables.

Designed datalogic model facilitates the implementation of applied adaptive testing tasks, allows organization of data, stores intermediate stages, and ensures comfortable performance of knowledge-level adaptive testing.

8.4. Practice implementation and experiments

For investigation the effectiveness of the developed information technology with datalogic model for adaptive semantic testing, this practice implementation as special software was developed, that provides the ability to conduct traditional and adaptive testing (Fig. 4).

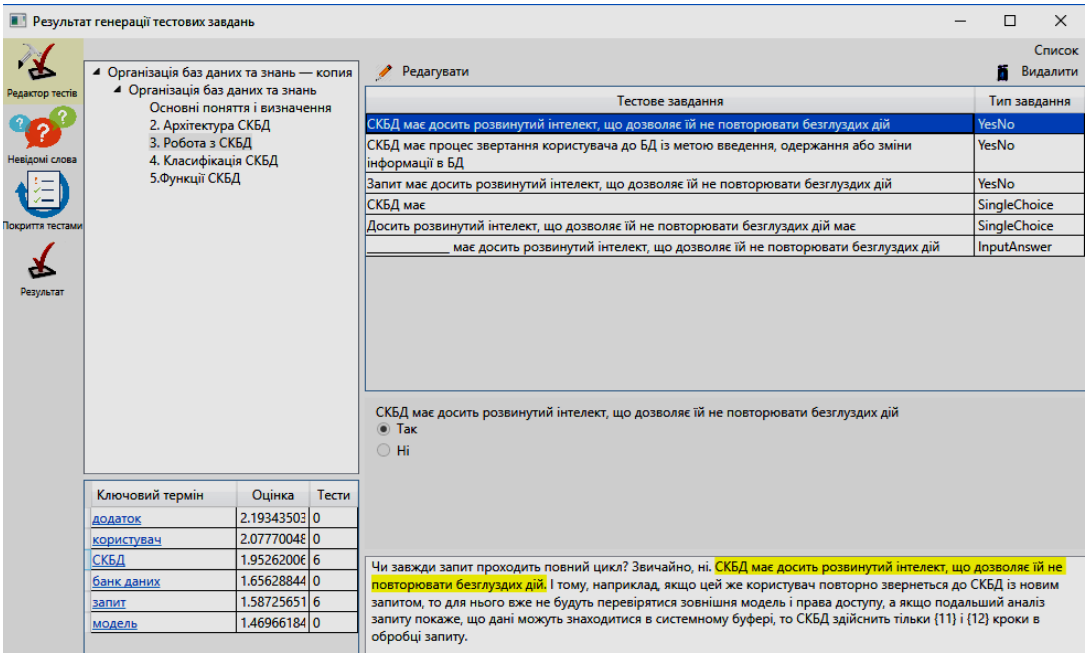

Figure 4 – Applied adaptive semantic testing using developed datalogic model

Author's development

According to the developed auxiliary elements and the scheme of information technology for adaptive semantic testing and datalogic model, in the developed information system the only obligatory user function is the choice of the file of informational educational material document for processing. The next steps, leading to the formation of test tasks set and the corresponding metadata, the system is able to perform independently. The process of knowledge level testing is similar to testing in well-known learning environments.

8.5. Results of adaptive semantic testing by information technology

The use of developed information technology for automated test tasks creation allows in 100% of cases to achieve the goal of creation of test tasks sets in less time (on average by 60.25%) compared to the manual creation of test tasks. At the same time, 46.56% of the test tasks accepted for work does not require adjustment or change. The obtained results showed that on average adaptive testing provides faster passing of the test and the test requires fewer tasks. For example, for the median start algorithm

and the average knowledge estimation algorithm, adaptive testing compared to traditional testing provided an average of 20.53% faster test.

At the same time, to determine the level of knowledge, it was necessary to use an average of 19.33% fewer tasks. In particular, when using the same set of test tasks, the adaptive testing algorithm reduced the average time required to pass the test: for the assessment of "F/FX" by 47.92%, for the assessment of "D/E" by 42.99%, for the assessment of "B/C" by 16.71%, to assess "A" by 2.89%. The average number of test tasks obtained using the traditional testing algorithm was 15.22 units, while using adaptive testing - 11.95 units.

The developed information technology with datalogic model for adaptive semantic testing provides realization of the basic properties of adaptive testing, in particular selection of test tasks at testing depending on result of the answer to previous test tasks, and support of various algorithms of start, dynamics and estimation of testing. It is assumed that increasing the depth of learning of educational material semantic content has the effect of learning less semantically important units of educational materials. Accordingly, the information technology allows to calculate the estimation of knowledge level by using indicators of semantic importance of key terms for adaptive selection of test tasks in testing.

Conclusion

The results of research allow to conclude, that the developed information technology with datalogic model for adaptive semantic testing provides a full-fledged tool for adaptive semantic testing of educational materials level of knowledge, which provides a complete semantic and structural coverage of educational material in testing. The designed data logic model allows to organize the storage and use of data, store intermediate data and provides adaptive testing of the knowledge level. As the result, all sections of automated testing of knowledge level from loading of the document of educational material till the calculation of an estimation of level of its studying are

provided.

Applied investigations of the effectiveness of the developed information technology in comparison with the traditional algorithm for selecting test tasks established, that testing speed increased an average of 20.53% faster test, and to determine the level of knowledge required the use of an average of 19.33% fewer test tasks. The developed information technology with datalogic model for adaptive semantic testing makes possible to use different algorithms for starting testing (regressive, progressive, medianic, etc.) and different algorithms for knowledge level estimation (average, absolute limit, etc.). As a result of adaptive selection of tasks, their maximum possible diversity in final set is reached.

Especially effective is the use of adaptive testing according to the developed information technology with datalogic model for testing the level of knowledge of educational material, which contains mainly textual content. In this case, each test task allows to purposefully check the level of knowledge of separate semantic units of educational materials, which related to the semantic structure of educational material in the form of rubricational system. Test tasks are related to fragments of educational material content, the knowledge level of which they test. In the process of testing, the level of knowledge of each of semantic structure elements of the educational material is consistently adaptively determined, and the final grade is calculated based on these results.