Correlation of Educational Material Ontology with the Individual Knowledge Structure of Students

Aleksandra Vatian, Natalia Dobrenko, Daria Korotaeva, Ekaterina Chikshova
ITMO University
Saint-Petersburg, Russia
alexvatyan@gmail.com, {graziokisa,daria.korotayeva}@yandex.ru, katya.chikshova@gmail.com

Niyaz Nigmatullin, Nikolay Vedernikov, Artem Vasilev
ITMO University
Saint-Petersburg, Russia
{n.nigmatullin, vedernikovnv}@corp.ifmo.ru, vartem.box@gmail.com

***Abstract*— In this paper we experimentally study the influence of the storage structure of the educational material, in particular ontologies, on the effectiveness of its use for students that have various levels of skills. The foreign language is used as a subject domain. The results of the research show that ontological structures are effective for storing the teaching material, but they must be transformable, in order not to cause the conflict with the already existing individual knowledge structure of the students.**

I. Introduction

The transition to personal-centered learning is associated with a change in the approach to storing educational information. Nowadays we can see a transition from traditional relational databases to network structures. The last provide personalized configuration, as well as flexibility and ability to restructure in response to changes in the domain. In modern research practice, such structures are mainly associated with ontologies [1, p. 324]. Ontology is defined as the "formal explicit specification of the shared conceptualization of the domain" and provides a shared understanding of the semantics of objects and their relationships in a particular domain.

Various approaches to the construction of ontological models of domains as a conceptual basis of training courses are presented in literature [2; 3, p. 23-36; 4, p. 67-81; 5]. However, in research practice, aspects of the use of ontology as a storehouse of agreed knowledge are mainly considered. At the same time, special attention is paid to correlating the ontology structure of the educational material with the individual knowledge structure of the trainee. Previous studies demonstrate the opposing views on this problem [5]. In a number of works it is shown that in the process of learning the students' knowledge structure starts to reproduce the structure of the instructor's knowledge. There are also conflicting data: as a result of training, the structure of knowledge of trainees approaches the structure defined by the learning content.

In this paper, one of the aspects of this problem is experimentally investigated, namely, the influence of the ontology structure of the educational material on the effectiveness of its use for trainees of various levels of training.

The article is organized as follows. In Section 2, related studies are presented and the research tasks formulated, Section 3 describes the structure of the developed system and the research methodology, in Section 4 - the results of the experiments and their discussion. Section 5 presents the conclusion and direction of further work.

II. Related work

Despite the fact that research in this field has been conducted for a long time, to date, only a single component of the approach has received full-scale technological realization - ontology of educational materials without semantic links, as well as knowledge bases that have a semantic structure. For example, the TEACH resource (Teaching Core Vocabulary) is positioned as a lightweight vocabulary, which allows teachers to link objects to the electronic courses they create. The AIISO (Academic Institution Internal Structure Ontology) resource is an ontology of the internal structure of academic institutions used to represent the structure of scientific organizations in terms of units and curricula. On the other hand, knowledge databases that have a semantic structure include the DBpedia resource, a project aimed at extracting structured information from data created within the Wikipedia project.

Various aspects of the use of semantic technologies in teaching are widely represented in the literature. Thus, in [6, p. 3675-3683] the semantic structure of storage of the educational information which allows to explicitly distinguish actually educational content, the form of its representation, and also didactic units is offered. This makes it possible to organize the study of each educational object by various didactic means, i.e. Adapt the learning process to the individual characteristics of the trainees. In [7] it is shown that the semantic organization of the teaching material helps in the study of foreign languages, so it allows each trainee to choose the structure of associations closest to him between the studied concept and his personal experience.

In the context of e-learning recommender systems, ontology is used to model the knowledge about the learner and learning resources [1,2]. Like knowledge-based recommender systems, ontology-based systems do not experience most of the problems associated with traditional recommender systems such as cold-start, data sparsity and over specialization due to use of ontology domain knowledge. Personalization of learner profile through the use of ontology makes the recommendations more tailored to the target learner preferences.

In [3] the authors present their e-learning system for knowledge points recommended primarily uses traditional collaborative filtering algorithm. Similarity calculation of knowledge points is often based on user rating above the intersection of knowledge points. The different semantic relations between knowledge points are not well considered, which results in the low recommended accuracy. This paper proposed an Ontology-based collaborative filtering recommendation algorithm, which could help users find the nearest neighbors even if the scores of knowledge points are little or zero. Through experiment, this algorithm was compared to traditional collaborative filtering recommendation algorithms. The new method achieved a better recommendation.

In [4] the authors offer a novel method to efficiently provide better Web-page recommendation through semantic-enhancement by integrating the domain and Web usage knowledge of a website. Two new models are proposed to represent the domain knowledge. The first model uses an ontology to represent the domain knowledge. The second model uses one automatically generated semantic network to represent domain terms, Web-pages, and the relations between them. Another new model, the conceptual prediction model, is proposed to automatically generate a semantic network of the semantic Web usage knowledge, which is the integration of domain knowledge and Web usage knowledge. A number of effective queries have been developed to query about these knowledge bases. Based on these queries, a set of recommendation strategies have been proposed to generate Web-page candidates. The recommendation results have been compared with the results obtained from an advanced existing Web Usage Mining (WUM) method. The experimental results demonstrate that the proposed method produces significantly higher performance than the WUM method.

The [5] paper proposes to use ontologies for modeling e-learning process in organizing the educational information in Healthcare Human Resource Management in Romania (HHRM), in order to use existing health workforce data and information systems for decision making and human resource management and support. One of the main objectives of this e-learning system is related to the need for training the managers in charge with the health care system management in order to increase the system's quality and safety. The main benefit of the proposed e-learning method for the Romanian healthcare system is a tailored training system adapted to the needs of the professionals working in different areas of the management in a high degree hospital. This will be achieved by implementation of a modern e-learning technologies and specific ontologies. The proposed model particularity consists in implementation of domain specific ontologies using Protégé environment using a personal methodology according to the student's knowledge profile. The settling of the students' profile is based on processing their entry data to allow the training process personalization, automatically generated by the intelligent system. The student's profile is identified by integrating a static and a dynamic model. Due to this methodology, students will be able to receive the learning material by an e-learning system, according to their level of knowledge, preferences and interests: a personalized model – driven approach.

The effectiveness of the semantic organization of educational material was studied in [8, p. 90-115]. It is experimentally shown that such a material distribution organization helps trainees find, compare and remember information, but only after teaching the work in a semantically organized learning environment. Similar results were obtained in [9, p. 69-82] using the example of a specially developed tool EduOnto: the effectiveness of its use compared to traditional methods was higher only in the group where the trainees had the opportunity to build their own learning trajectory, i.e. Coordinate the capabilities of the instrument with its own individual characteristics. In [10], the effectiveness of individualization of the supply of educational information is shown depending on the psychological type of trainees (according to Jung's typology).

Thus, the conducted analysis shows the relevance of studies of the interrelationship of the semantic structure of the educational material with the individual structure of knowledge of trainees. At the same time, existing training resources do not allow organizing such a study: they do not have a separation according to the levels of user training, and the semantic structure of the resource is not explicitly provided to the user. In connection with this, the following problems were solved in the present paper:

1) development and software implementation of the storage system for educational material in the form of ontology using semantic networks, adapted according to the levels of competence of trainees;

2) enabling users to see and use the semantic structure of the system while working with it;

3) experimental study of the influence of the semantic structure of the teaching material on the effectiveness of its use for trainees at various levels of training.

III. Methods and materials

A. Choosing a domain

Despite the fact that the natural sciences have a more precise structure of the organization of teaching materials, the search for them can be difficult because of the large number of formulas and terms in the Latin alphabet. Unlike other humanities, a foreign language does not imply an obligatory academic approach to learning and can be targeted at students with different experiences. In addition, the variability in the approaches to learning a foreign language assumes a different sequence in the study of its basic concepts.

In this connection, a foreign language is used as a subject domain, since its study can be organized variatively and is oriented to students with different experiences. Accordingly, the training resource being developed should have a tree structure rather than a tree structure, and a much richer semantic structure, which allows for more effective research.

B. Selection of basic software

Analysis of analogs shows that the most suitable environment for the formation of a semantic network, as well as for the organization of educational materials, is the Wiki site. It provides a platform with a flexible organization for working with materials of any orientation, easily scalable to the needs of a specific group of users. Wiki markup, used on such sites for text processing, also allows you to simplify access to the capabilities of the HTML language and successfully applied in the field of education. It is worth noting that the popularity of knowledge bases on the basis of Wiki from Internet users makes it easy for potential users to get acquainted with the system being created.

Thus, the developed resource is created on the basis of MediaWiki, and the Semantic MediaWiki extension allowed using semantic tags, which are the basis of the semantic network. Subsequent Pages.

C. Filling the content of resource

As a source for the content of educational materials, the Native English website was used, designed for self-study of English by Russian-speaking users. Note that although the Native English site offers the possibility of a non-linear order of language learning, the semantic structure of all content to users is not available.

To conduct experiments in our work, a section of English grammar was chosen, such as verb tenses, the relationship between which is represented on an abstract model (Fig. 1). In accordance with this model, a semantic structure of the section was built.

The basis of semantic relationships are statements related to the elements of the semantic network. The statement is a triplet. Subject-Predicate-An object where the Subject is an element of an ontology, in our case a separate wiki page. The object is information about the subject in this category. For example, for the subject "Present time" one of the predicates may be "part of speech", and the object - "verb". The predicate category uses the tag category. Each category of the tag refers to a separate section of the training, for example, when learning a language, you can consider different types of knowledge (grammar, vocabulary), parts of speech (verb, noun), as well as more specific - case, tense, etc

Based on the assertions with the help of the installed software, semantic tags are formed. They can be divided into two groups: semantic (related to the concepts of the subject domain) and organizational (related to the structure of the proposed curriculum discipline). Examples of predicates of semantic tags are Part of speech, Verb tense, Type of knowledge, Morphological sign.

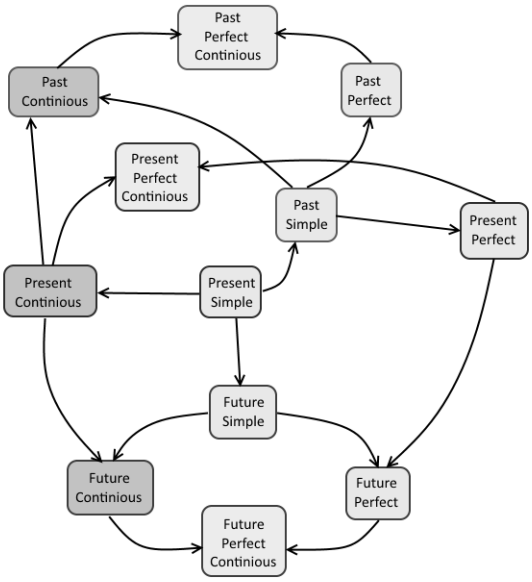


Fig. 1. Abstract model of the sequence of studying the verb tenses in English

Organizational include tags Learned in lectures, Test, Previous topic, Previous lecture, etc. (Fig. 2). In addition, there is also a predicate Level, which provides for a different degree of immersion in the material being studied and different input levels of users.The non-linear order of material research is displayed in the tags "Previous / Next Lecture" and "Previous / Next Topic". This organization of information provides a consistent study of the topics needed to understand the selected material.

D. Methods of research

The effectiveness of the use of educational material, presented through its semantic structure, was evaluated by testing the characteristics of information retrieval on the developed resource. Depending on the level of competence, trainees were divided into two groups: experts (users) and ordinary users (casual users).

For more successful adaptation of users to the specifics of semantic search, various search interfaces were provided, including: a graphical representation of the semantic structure of the resource with instructions for working with it, tags at the bottom of the page, hyperlinks in the text, a search string.

Twenty users of different ages, social status and competence in the field of information technology were

involved in the testing, half of those surveyed referred to experts (expert users), and the second half to casual users.

For the search, the developed resource, the Native English website, and the Internet search engines (in particular, the Russian-language search engine Yandex) were used in parallel.

Three groups of quests for searching (in Russian) were compiled for various information on the verb tenses with an increasing level of complexity.

The study consisted of several stages. At the first stage, the user independently chose the preferred method of searching. Then he was given the opportunity to master the semantic search and execute queries using it. At the same time for users who do not have experience in this area (casual users), the semantic search was presented in a simplified form - as a list of semantic properties. At the third stage, a search was made for similar requests on the Internet and on the Native English website, until the user himself was satisfied with the answer to the query.

The effectiveness of user actions was assessed using objective criteria:

- the time spent performing a single search request,
- the number of mouse clicks made during a single search,

and also through questioning of users after full passing of testing (Table I).

Table I. User questionnaire

Question	Scale of answers
How clear was the task for making a search query?	from 1 (poorly defined) to 5 (clearly defined).
How wide application does the information you find can have?	from 1 (wide application) to 5 (only for a specific purpose).
What are your knowledge in the field of the task for the search?	from 1 (minimum knowledge) to 5 (significant knowledge).
How would you evaluate the usefulness of this study for yourself?	from 1 (no benefit) to 5 (one-digitally useful).
General text	from 1 (unsatisfactory) to 5 (excellent).
How satisfied are you with the use of ontology to find information?	Variants: semantic search, use of the search line, use of hyperlinks in the text, use of tags at the bottom of the page. (you can choose 2 answers)

IV. Results and discussion

The results of the questionnaire on questions 1-5 for different groups of subjects are shown in Fig. 3.1. The results of the questionnaire on question 6 are presented in Fig. 3.2 for custom users (1) and experts (2).

Analysis of Fig. 3.1 indicates that all users, regardless of their level of competence, are satisfied with the use of ontology to search for information and believe that the task for compiling a search query was clearly stated. At the same time, experts, unlike ordinary users, have higher evaluated the usefulness of this research for themselves.

The results of Fig. 3.2 show that, in general, the majority of the respondents preferred the use of hyperlinks in the text as a method of semantic search, and full-scale semantic search is in the second place, with the difference in the estimates between the first and second places for experts (2) being significantly less than for Ordinary users (1)

In Fig. 4.1, 4.2 shows the results of measuring the speed of finding information for different levels of complexity of requests and different groups of users, in Fig. 5.1, 5.2 - the number of clicks required by the search engine, respectively. The analysis of the diagrams shows that in all cases the semantic search wins in comparison with traditional search engines and with a specialized resource by speed and the necessary number of mouse clicks. Comparison of Fig. 4.1 and 4.2, as well as 5.1 and 5.2, shows that on average, experts perform faster and with fewer clicks simple queries and mid-complexity queries, while the average speed of performing complex queries in both groups of subjects is approximately the same.

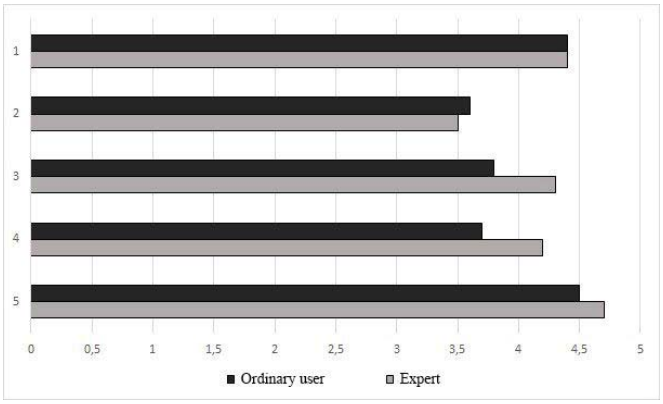
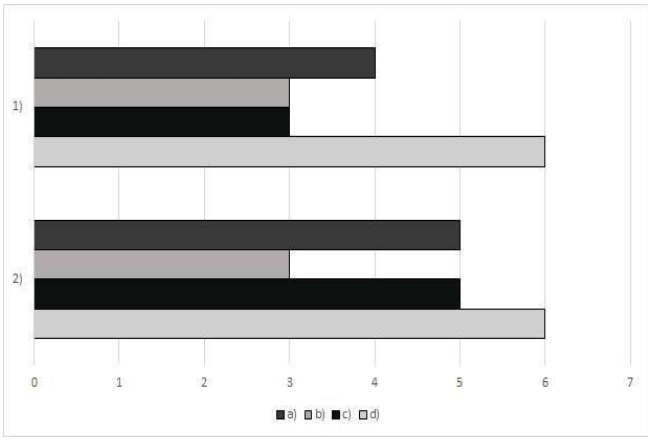


Fig. 3.1 Results of the questioning of users. Legend: a) semantic search, b) use of tags at the bottom of the page, c) a search string, d) - hyperlinks in the text.



.

Fig. 3.2 Results of the questioning of users. Legend: a) semantic search, b) use of tags at the bottom of the page, c) a search string, d) - hyperlinks in the text.

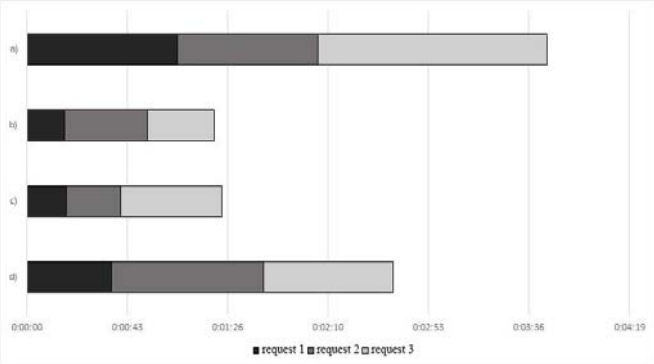


Fig. 4.1 The speed of finding information by experts. Notation: a) Yandex, b) Native English, c) arbitrary search, d) semantic search

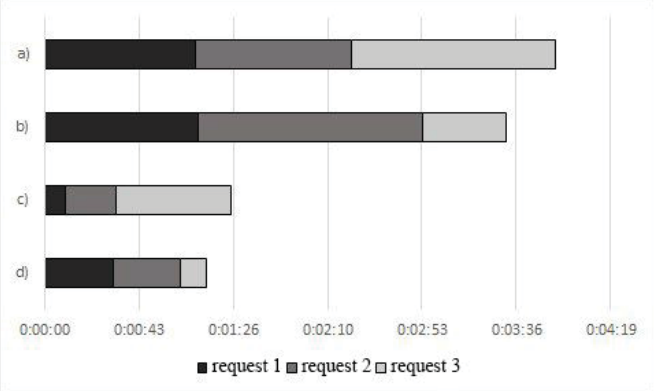


Fig. 4.2 The speed of finding information by ordinary users. Notation: a) Yandex, b) Native English, c) arbitrary search, d) semantic search

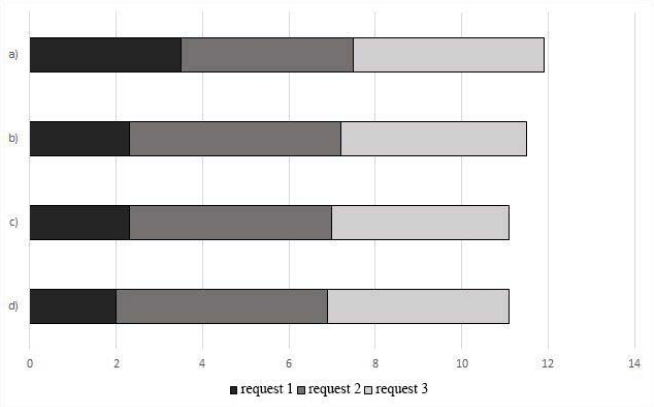


Fig. 5.1 The number of mouse clicks made by experts when searching. Notation: a) Yandex, b) Native English, c) arbitrary search, d) semantic search

Attention is drawn to the fact that the speed of query execution on the Native English resource is much higher among experts than among ordinary users, while the self-organization of semantic search has the opposite picture. Note that for advanced users semantic search was presented in complex form with direct input of tags in the field of semantic search, unlike ordinary users who just passed by properties.

Thus, our studies not only confirm the result described above [5], but also allow us to draw the following conclusions:

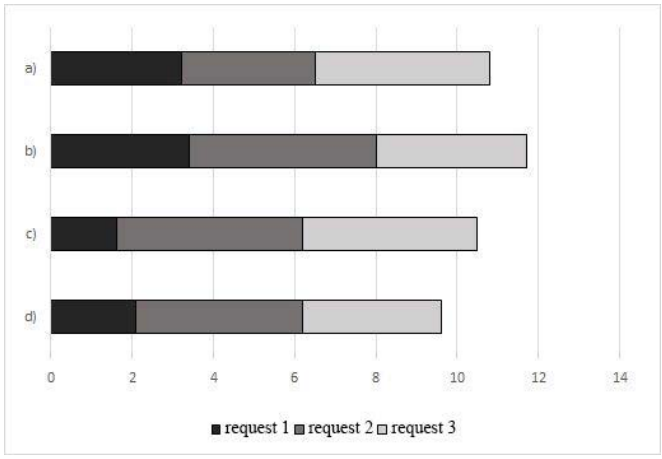


Fig. 5.2 The number of mouse clicks made by ordinary users when searching. Notation: a) Yandex, b) Native English, c) arbitrary search, d) semantic search

- the effectiveness of the use of educational material in its presentation through the semantic structure is higher, regardless of the level of the user's competence;
- each user group is dominated by its own search structure, while experts gravitate toward the generally accepted semantic structure of the domain, and ordinary users - to the structure offered in this training session.

Given that the current state of the individual knowledge structure of trainees can not be predicted in advance, it is advisable to use ontological-type structures to store the learning material, but with the possibility of the current transformation, so as not to cause conflict with the already existing individual knowledge structure of trainees..

V. Conclusions and future work

The influence of the semantic structure of storage of educational material on the effectiveness of its use for trainees at various levels of training is experimentally investigated. For this purpose, a training resource was developed and implemented programmatically on the basis of MediaWiki, and a foreign language was used as the subject domain. The effectiveness of the use of educational material, presented through its semantic structure, was evaluated by testing the characteristics of information retrieval on the developed resource of trainees with different levels of competence. The results of the research show that structures of the ontological type are effective for storing educational material, but must allow the current transformation, so as not to cause conflict with the already existing individual knowledge structure of trainees.

The results of experiments can find application in the design and implementation of training resources. In particular, it is advisable to improve the semantic search module, improve the tag system, and add ready-made templates for typical queries. All this is the direction of development for our work.

References

[1] *L. Bajenaru, A.-M. Borzan, I. Smeureanu, Using ontologies for the E-learning system in healthcare human resources management, Inform. Econ. 19 (2015) 15–25.*

[2] *S. Shishehchi, S.Y. Banihashem, N.A. Mat Zin, S.A.M. Noah, Ontological approach in knowledge based recommender system to develop the quality of e-learning system, Aust. J. Basic Appl. Sci. 6 (2012) 115–123.*

[3] *Z. Zhang, L. Gong, J. Xie, Ontology-Based collaborative filtering recommendation algorithm, Adv. Brain Inspired Cogn. Syst. (2013) 172–181.*

[4] *T.T.S. Nguyen, H.Y. Lu, J. Lu, Web-page recommendation based on web usage and domain knowledge, IEEE Trans. Knowl. Data Eng. 26 (2014) 2574–2587.*

[5] *L. Bajenaru, A.-M. Borzan, I. Smeureanu, Using ontologies for the E-learning system in healthcare human resources management, Inform. Econ. 19 (2015) 15–25.*

[6] *Lucke U., Martens A. Utilization of Semantic Networks for Education: On the Enhancement of Existing Learning Objects with Topic Maps in <ML>³ // EdMedia: World Conference on Educational Media and Technology, Jun 27, 2011 in Lisbon, Portugal. In T. Bastiaens & M. Ebner (Eds.), Proceedings of EdMedia: World Conference on Educational Media and Technology 2011.*

[7] *Dunn J.D. Utilization of Semantic Networks in the Teaching of Vocabulary // Language Education in Asia, Volume 4, Issue 2, 2013..*

[8] *Martin P.A. Semantic Networks to Support Learning // ceur-ws.org/Vol-354/p58. Supplementary Proceedings of the 16th International Conference on Conceptual Structures (ICCS'08). Vol-354*

[9] *Marzano A., Notti A.M., (2015), Eduonto: an ontology for Educational Assessment, Journal of e-Learning and Knowledge Society, v.11, n.1.*

[10] *Abrahamian E., Weinberg J., Grady M., Stanton M.The Effect of Personality-Aware Computer-Human Interfaces on Learning // J.UKM - Journal of Universal Knowledge Management, v.10 (2004)*

Факты: Времена глаголов в английском языке RDF источник

Время глагола	Present Simple +, Past Simple +, Future Simple +, Present Continuous +, Past Continuous +, Future Continuous +, Present Perfect +, Past Perfect +, Future Perfect +, Present Perfect Continuous +, Past Perfect Continuous + и Future Perfect Continuous +
Предыдущая лекция	Глагол +
Следующая лекция	Future in the Past +
Таблица	Неправильные глаголы. Часть I + и Неправильные глаголы. Часть II +
Тест	Тест Simple Tenses +, Тест Continuous Tenses +, Тест Perfect Tenses + и Тест Perfect Continuous Tenses +
Тип занятия	Лекция +
Тип знания	Грамматика +
Уровень	Базовый + и Продвинутый +
Часть речи	Глагол +

Fig. 2 Fact table for the page "Verb tenses in English"