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The Organization of Topics Sequence in Adaptive e-Learning Systems

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Abstract. The research presented in this article is about acquisition opportunities of a personalized topic sequence in terms of some study course in the adaptive e-learning system. The method to organize acquisition of the course topic sequence that helps a learner to organize learning process by creating a sequence for course topic acquisition adapted to personal needs and knowledge is offered in the article. The method can be used in an open-source learning management system with a structure of learning course topics. There are three topic choice opportunities offered for the learning course acquisition: teacher, learner, and optimal one. The teacher-indicated topic acquisition sequence is based on teacher’s pedagogical experience. Learner's free choice of topics is based on links that are indicated between topics by the course creator. The optimal topic sequence for a specific course is obtained by using an optimal method for topic sequence acquisition described in the paper. The article covers an experiment where learners have an opportunity to manage their learning process on their own by using a teacher-offered topic sequence, by choosing learning topics on their own, or by using system-offered optimal topic sequence that is created for a specific course. The change of a topic sequence is organized with the help of method to organize acquisition of the course topic sequence offered in the article.

Keywords. Topic sequence, learner model, adaptive e-learning system

1. Introduction

The aim of adaptive e-learning systems (AELS) is to ensure personalized approach for each learner. The system-offered content plays a significant role in this process. The diversity of content delivery is one of the most important factors to ensure high quality of the adaptive system [15]. Multiple advantages of the e-learning content adaption are: (a) opportunity to satisfy learner needs and desires [1,15]; (b) adaption of learning system according to learner's behavior [15]; (c) increase of student learning capacity and acquisition of better learning results [3]; (d) opportunity for using obtained data from learning to ensure further adaption [3,15].

In this article a discussion on AELS content organization is proposed by paying attention to course topics, their content, sequence, and opportunities to choose topics. The content of the experimental AELS mastered course for each learner is made dynamic based on the existing groups of course learners where each learner is classified as well as on adaption scenario that is suitable for appropriate group participants [12]. Content adaption for a learner is made based on: (a) learner's personal features (as example, learning style, course pre-knowledge, difficulty level of course

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acquisition, sequence of the chosen course topic acquisition); (b) learning topics that are used based on suitable pedagogical strategies.

Lately the following tendencies have been observed in the adaptive e-learning system organization: (a) open source software utilization; (b) low-cost learning resource utilization [2]; (c) learning course sequence automatization [6]. In the core of an experimental AELS is an open source system that is based on e-learning topics. In most of the cases, course topics in a learning system of this type have been studied in the teacher-defined order. In this article it is called a "teacher topic sequence" (TTS). Additionally, an opportunity for a learner to choose the next learning topic on his own is offered. The option of choosing the topic sequence (TS) is based on the indicated links between topics. In the article it is called a "learner topic sequence" (LTS). An analysis of the learning process gives wider opportunities for providing adaption [3] that is why learning data collection and analysis is performed in the article. As the result, third topic sequence case for a specific learning course is a topic sequence that is based on data obtained from the previous learners. In the article it is called the "optimal topic sequence" (OTS). This topic sequence is obtained using the optimal topic sequence method (OTSM) described in the article. Changes of all three topic sequences and creation of the learning topic sequence are based on the topic sequence organization method (TSOM) described in the article. Methods used in the article are valid in cases when all indicated topics are used for course acquisition.

The paper is organized as follows. Section 2 presents related works. Section 3 describes the background of the presented works. Section 4 describes optimal topic sequence method. Section 5 describes how the course topic sequence is acquired. An experiment is described in Section 6. Finally, conclusions and plans for future research are given in Section 7.

2. Related Work

Different approaches can be used for modeling learning content. For example, in the articles [4,8,9], description of relationships between unities of learning content is made using hierarchical structures. Their creation and maintenance takes a lot of time and system resources. Conditions that describe better learning strategy acquisition depending on learner's actions and results are used to organize sequence in all previous mentioned articles.

Madjarov and Betari [9] describe the network service-based learning infrastructure that uses SCORM content model. The learning objects are organized into a learning cluster tree and are ordered according to learner's actions and responses to the questions and exercises. The learning cluster contains text page with learning content, exercise, and questions. Modeling of the cluster tree is done using Petri Nets. In the offered system learning process is done in the following way. First of all, a learner receives an intro page and then a page with learning content. After familiarization with it, the system offers an exercise. A learner receives questions that are created especially for learner, depending on the exercise results. The goal of this pedagogical strategy is to evaluate the level of the learner's knowledge and his/her comprehension of the already acquired piece of content.

Jabari et al. [8] overviews personalization opportunities in e-learning and virtual classrooms. The problem of how to present learning object according to learner cognition style is solved in the article. Learning objects are arranged in hierarchical way. The delivery sequencing is ensured by IMS Simple Sequencing specification. Petri Nets are used for conditions. They are used to create system reaction to the results of the learning process.

In the article [1] Brusilovsky and Vassileva describe the system for dynamical course generation (DCG) and the concept-based courseware analysis system (CoCoA). CoCoA checks the consistency of the course and its quality in each moment of life. The DCG contains the domain authoring component and the adaptive course automatic generation component. It allows to generate an individual course according to learner's goals and previous knowledge and to adapt the course according to the learner's obtained knowledge.

In the article [7] Huang and Shiu describe a user-centric adaptive learning system (UALS), which creates learning material sequencing schemes based on users' collective intelligence and collaborative voting approach that use the item response theory (IRT). The collective voting approach allows learners to cope with difficulties that occurred during learning process together. The system uses sequenced rules to personalize user-oriented learning ways. The IRT helps to evaluate students' skills and offers the most appropriate content for them.

In the article [4] Elouahbi et al. use pedagogical graph SMARTGraph for sequence modeling. Nodes of the graph are learning units and arcs – pedagogical restrictions between units. Creation of the sequence graph is done using Xlink (XML Linking) language.

In the article [6] Gasparetti, Limongelli and Sciarrone describe automatization of the learning process based on semantic analysis techniques to acquire learning resources using online storage. Four computer science courses are analyzed in the article, the content and relations between learning objects of which are created using Wikipedia storage. Semantic analysis methods define corresponding Wikipedia concepts that are mentioned in each learning object.

The optimal topic sequence method that is offered in this article differs from the above-mentioned approaches by the fact that it uses advantages of costless course management system: learning course organization environment, tools for organizing learning process, processes, and a data base. It allows saving time and material resources to adapt the learning process to learner's needs. The offered OTS method is easy-to-use. Working object for these methods are topics that are used in any learning course. In the above-mentioned articles, sequences are organized for smaller content units. It makes the process of course content creation more complicated and time-consuming. In the related articles, hierarchical structures are used for data storage. It requires knowledge to manage the appropriate tools. In the offered OTS method, symbol sequences are used for topic sequence graph storage.

3. Background

Adaptive study environments are based on well-organized models and processes. The AELS consists of three main models: learner model (LM), content model (CM) and adaptation model (AM) [11]. Data about learner are described in the learner model. The con-tent model describes the AELS content and its logical structure. The adaptation model offers appropriate learning content for a specific learner.

3.1. The Learner Model

The experimental AELS learner model is based on data life cycle in the model and includes eight data categories: Personal Data, Personality Data, Pedagogical Data, Preference Data, Device Data, System Experience, Current Moment's Knowledge, and learning process data (History Data) [11]. LM data can be divided into three basic classes by their life length or refreshing frequency: basic data (BasicData), additional data (AdditionalData), and learning process data (LearningProcessData). Wider description of LM data life cycle is given in the article [10]. The BasicData class includes learner data that are constant in system or are changing very rarely. These data include personal data about learner. They are gathered into PersonalData category. The additional data describe the learner individuality. This class contains five LM data categories: PersonalityData, PedagogicalData, PreferenceData, DeviceData, and SystemExperience. The examples of additional data are: learning styles (PersonalityData); data that organize learning process (learning course, course difficulty level, course pre-knowledge) (PedagogicalData); language of the course and course environment preferences (PreferenceData); experience in the course utilization (SystemExperience). Direct additional data are used to ensure adaptation in the sys-tem. Additional data are dynamic data. These data have a tendency to change in the long term. The LearningProcessData class contains data about learner knowledge at the current moment (CurrentMomentKnowledge) and data about learning process (HistoryData). The life length of these data in the learner model is the shortest, because during the learning process they are changed and supplemented constantly. The learning process data are accumulated and processed in the long term and new data that describe the learner are obtained. A more detailed description of the learner model is offered in articles [12,13].

The source of data acquisition for the learner model are: (a) profile of the system user, (b) results of quizzes and tests, (c) individual choices of learner, (d) data of external system, (e) data from the learner group where a learner is classified, (f) data analysis results obtained in course of the learning process [13].

3.2. The Content Model

The content model used in the experimental system is based on the learning object (LO) and application of the different resource formats. A learning course described in the content model consists of one or multiple topics. Each topic is made of one or multiple learning objects. Each LO contains the description of the learning object, theoretical part, practical part, and evaluation part. More information on the content model is given in the article [12]. Each topic in this experiment consists of one learning object (Figure 1). The description part explains the essence of the specific topic, its exercises, and place in the course structure. The theoretical part contains system-offered knowledge and ways of its representation. In case, when the learner has previous knowledge in the course, the basic content of the course is shown with system-offered knowledge represented by activities and resources. Otherwise, if a learner doesn't have pre-knowledge in the course, expanded course topic content is shown. In this case, links to expanded definitions of the concepts are shown in the additional content. The practical part contains activities that are made to strengthen the acquired knowledge. In case of theoretical courses, practical part does not exist. The evaluation part contains activities that ensure course knowledge evaluation. The topic content also differs depending on the difficulty level of the chosen course. The course difficulty level (DL) gives a learner an opportunity to determine the maximal acceptable course grade for himself/herself. The offered exercise level, test difficulty, and also course final grade depends on the chosen DL.

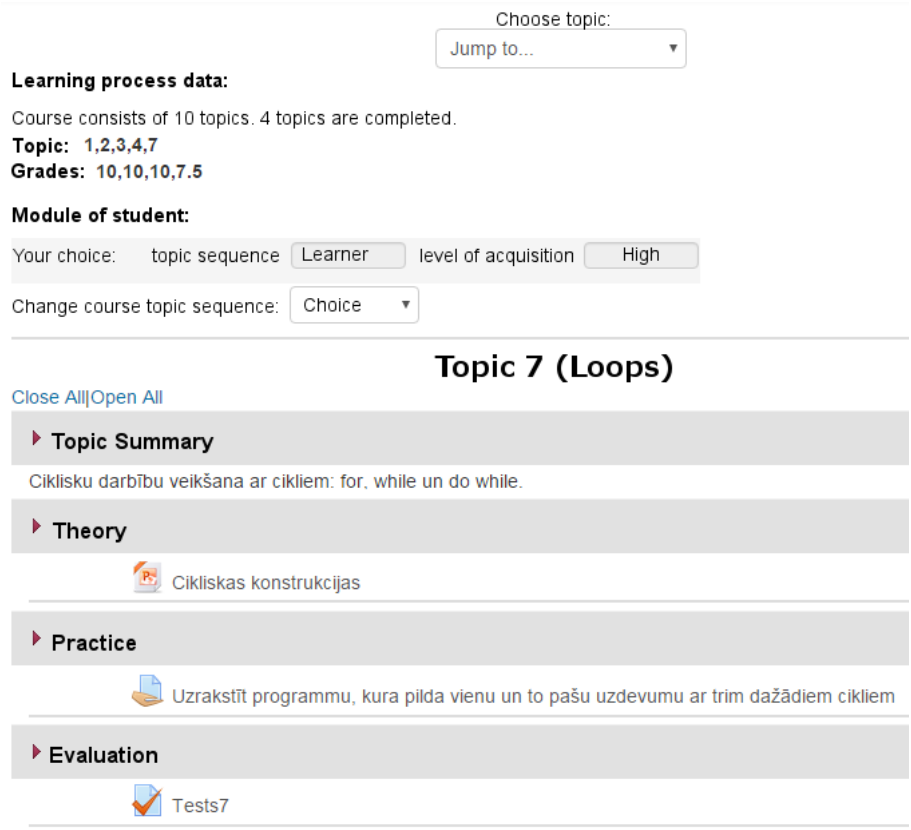

Figure 1. The structure of the "Programming Foundations" course topic "Loops" [14].

The content model describes a wide range of resource types that are created based on learning styles. For instance, if a learner has "Aural" learning style, then in the theoretical part of the topic all resources that correspond to this learning style are shown. For instance, that includes audio recording and audio conferences. A wider range of resource types used in the system is given in articles [12,13].

3.3. The Adaptation Model

A course is created by the course author or in some cases by the course teacher. The course author creates course structure, course content, selects features that will be used in course content adaptation and for learner group creation [13].

Before the course acquisition, the system checks whether it has all necessary data about the learner: (i) the learning style; (ii) the existence or absence of pre-knowledge in course; and (iii) the course difficulty level. Each course learner is classified into some of the created course learner groups based on data that the system has about the learner. In case when learner data are not enough for classification, the learner is classified into the "Group0". Members of this group receive the non-adapted course content. Learner classification into groups is described in the article [12].

4. The Method for Optimal Topic Sequence Creation

E-learning courses are made from learning resources to make the learning process more efficient [6]. This chapter offers the method for optimal topic sequence creation for one course.

4.1. Definitions

All course topics can be considered as one set of topics. The subset of element set that contains elements with specific features is called a selection. The subset of such set that takes into consideration the sequence of elements is called an ordered selection. So, topic sequence is a course topic selection that is ordered by a specific feature.

In this article three type topic sequences are used: (i) the learner topic sequence, (ii) the teacher topic sequence, and (iii) the optimal topic sequence. The learner topic sequence is a topic sequence that is created from the learner-chosen topics during the course acquisition. The teacher topic sequence is a topic sequence that is offered by a teacher for acquisition of a specific course. This topic sequence is based on pedagogical experience of the teacher. The optimal topic sequence is a topic sequence that is obtained using an optimal topic sequence method, which is based on the learner-obtained topic sequences, acquired course results, and links between topics.

Each topic in the topic sequence has an order number or position that describes its position in the sequence. For example, if the course contains topics "1", "2", "3", "4", "5" and a learner has acquired these topics in the following sequence: "1", "2", "4", "5", "3", then the learner topic sequence set will be {1,2,4,5,3}. In this topic sequence, for instance, the number or position of the topic "4" is 3.

4.2. The Principle of Performance of the Optimal Topic Sequence Method

Topic sequences obtained during the course acquisition are saved in the system database. The optimal topic sequence for one course can be obtained by selecting all topic sequences of one course and processing them with OTSM. The essence of the optimal topic sequence method is to take all topic sequences that are obtained from one course acquisition and to unite them in groups by similarities, where one group has equal sequences and for each sequence group the course acquisition grade is calculated. The group of sequences that has the highest average grade is the OTS that was searched for. In case when multiple topic sequence groups have the same grade, the optimal topic sequence is searched between the TS of these groups based on the highest repetition rate of the specific topic sequence position and existing links be-tween topics that are indicated by the course author or teacher. The most frequently repeated topic is inserted into a specific position of the OTS, and this obtained topic has also a link to the last inserted OTS topic. If there is no link, then the next most frequent topic is taken.

Optimal topic sequence method with its formal description and example is available in article [14].

4.3. The Topic Sequence Module

The topic sequence module was made and implemented in Moodle system for the optimal topic sequence acquisition. Figure 2 shows the interaction of the TSM with the system components. Colored figures show TSM that is added to the system and its new tables. Arrows show directions of the data flow. TSM interacts with the system offered course page, the system content model, the learner model, and the adaptation model that are described in Section 3. For TS purposes the following model activity tables were created (Figure 3): course_teaching_parametrs, user_learning_data, and course_teaching_parametrs. Course acquisition parameters such as links between course topics (topic_link), a teacher-indicated topic sequence (teacher_topic_sequence), and an optimal course topic sequence (optimal_topic_sequence) are stored in course_teaching_parametrs table. Data that are necessary for the learning process and data obtained from learning process, e.g., a learner topic sequence (topic_sequence), ways to choose topic sequence (user_ts_choice), topic grades (topic_grade), an optimal topic sequence granted to a learner (user_ots) are stored in user_learning_data table.

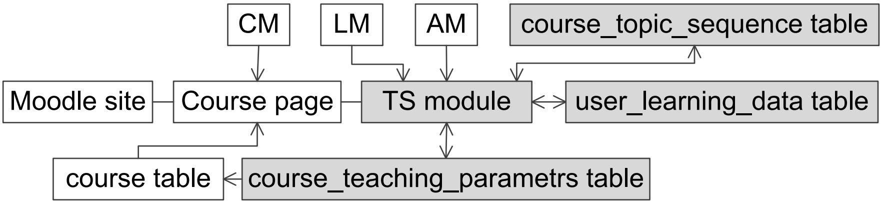

Figure 2. Interaction of the OTS module and system components [14].

The main functions and data flow of the TSM are shown in the picture Figure 3. The main TSM actions are:

- When a learner starts the course acquisition, TSM checks whether a specific course has the optimal topic acquisition sequence in the table course_teaching_parametrs. In case if it has, it is written into user_learning_data table. The newly-created course has no data about learner topic sequences that is why this course has no optimal topic sequence. At the beginning, teacher topic sequence can be assumed as the optimal topic sequence;
- The next step in TSM is collection of the learner study process data into user_learning_data table;
- After the successful course acquisition, the topic sequence created for a specific course is saved in course_topic_sequence table;
- To refresh course parameters, a teacher creates a new OTS. TSM the topic sequence created for a specific course and course grades from course_topic_sequence table. A new course OTS is created and saved in course_teaching_parametrs table with the help of OTS method.

During the course acquisition the OTS does not change for a specific learner. Course OTS can change after the course parameters are refreshed, and for other learners it will be different.

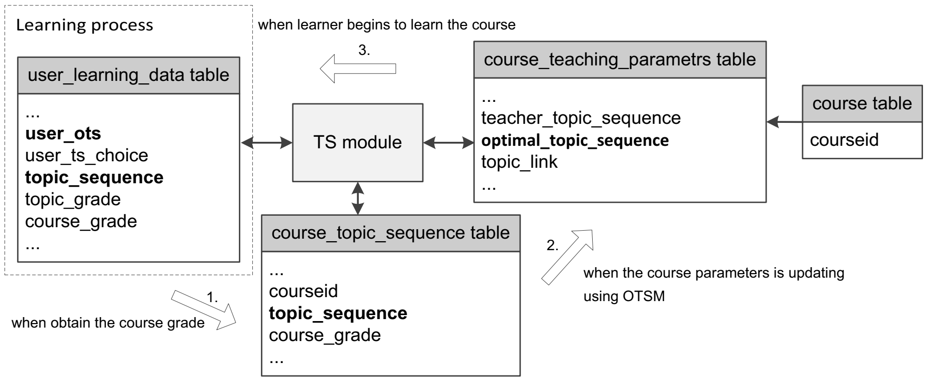

Figure 3. A sequence of the data flow for OTS acquisition [14].

5. The Method of Course Topic Sequence Organization

Nowadays, learners have a tendency to take control over their learning process and to determine it [5]. The method for learning topics sequence organization was developed to help a learner use one of the three topic sequence options in the experimental ALS: (i) using a teacher-proposed topic sequence, (ii) by choosing topic sequence on their own, or (iii) using a system-offered optimal topic sequence that is described in the previous section. Regardless of the chosen topic sequence, the first course topic is always offered at the beginning of the course.

5.1. Description of Choice Options of the Topic Sequence

In this work the following topic sequence cases are used: (a) a teacher topic sequence; (b) a learner topic sequence, and (c) an optimal topic sequence.

Teacher TS. When creating a course, its author/teacher indicates the desirable topic sequence based on the pedagogical experience. Most often topics are placed in order, first of all 1, then 2, then 3, etc. A teacher-indicated topic sequence is stored in course_teaching_parametrs (teacher_topic_parametrs) table (Figure 3).

Learner TS. A learner chooses a topic from the system-offered topic list, which is created based on links between course topics. Links between topics are indicated by the teacher during the course creation. Links are saved in the topic_link field of the table course_teaching_parametrs (Figure 3). If a learner has acquired the last topic, but all other topics are still not acquired, the system checks, which topics are still not acquired, and offers these topics in an increasing order of their order numbers.

Optimal TS. A system offers the optimal topic sequence for a specific course acquisition based on the previous learner-used topic sequences (described in Section 4) that is taken from the table course_teaching_parametrs (optimal_topic_sequence) and saved as learner study process data in the table user_learning_data (user_ots) (Figure 3).

The OTS is based on the previous learner data, which is why in case of a new course it is not offered or might be similar to the teacher topic sequence. It is useful to create the OTS for a course only when the amount of the learner topic sequences obtained is large enough (for example, when one learner group has already finished the course).

5.2. Description of the Working Principles of the Method for Course Topic Sequence Organization

During the course adoption, two cases of application of the topic sequence option are possible: (i) the chosen topic sequence option is not changed; (ii) the chosen topic sequence has been changed once or multiple times. In the first case, by choosing topic sequence option a learner uses it during the whole process of the course acquisition and system does not need to make changes in the offered topic sequence. In the second case, after changing one topic sequence to another, a system must review acquired and chosen topic sequences, and as a result, create new and still not acquired topic sequence.

In case of switching between topic sequences options, to obtain an acquired topic sequence, the topic sequence organization method is used. TSOM activity is shown in the activity diagram (Figure 4). Designations used in Figure 4 are described further. Topic sequence options are denoted with the corresponding letters: T – teacher, L – learner, and O – optimal topic sequence. A topic sequence option chosen by a learner is denoted with S, for example, S=T means that a learner has chosen the topic sequence offered by the teacher. TS option change is denoted with an arrow. For instance, T->L means that the teacher topic sequence has been changed to the learner topic sequence. Generally, there are six ways to change a topic sequence option: L->T, L->O, T->L, T->O, O->T, and O -> L. A change of the topic sequence option is possible only in case when topic has been acquired. It is defined by the filled in test grade in the topic evaluation part. In Figure 4 it is denoted with the letter "G". The lowest grade in an experiment that defines that topic is acquired is the grade 4.

Since the topic order plays a big role in the course topic sequence, the following designations TSN, TSL, TST, TSO, TSI, and TSTemp will be introduced to denote arranged selections that contain topics in a specific order, respectively:

- TSN – a topic sequence which indicates a topic sequence of not acquired topics that learner should use;
- TSI – topics that a learner has already acquired and are written into user_learning_data (topic_sequence) table ;
- TSL – a learner topic sequence that at the beginning of the course consists of one element {1};
- TST – a teacher-indicated topic sequence for example: {1;2;3;4;...;n}, where n is the number of the last topic;
- TSO – an optimal topic sequence that has been created for each course individually and can change throughout the course;
- TSTemp – topics that have been obtained from links of the last viewed topic.

A topic sequence is an ordered selection that contains topics in a specific order that is why the difference between selections will be used to create new topic sequences. For example, when two selections A and B are given, the difference between these selections will be C=A\B. That means that selection B is subtracted from selection A, and the result is selection C, which contains elements from selection A (with the same sequence) that are not present in selection B.

The difference between selections can be used for transition from the TSO to the TST and contrariwise. In case when the topic sequence option has changed to the learner topic sequence, the difference between selections cannot be used, because the TS is created dynamically during the course acquisition process. These are the two cases: T->L and O->L. In these cases the next topic choice is based on links between already acquired topics. When making a transition T->L, a system offers the next topic/-s that is/are obtained from the previously acquired topic links. In the O->L case the TS is created from topics that are obtained from already viewed topic links and are not yet acquired (TSN=TSTemp). After the next topic acquisition, TSTemp is supplemented with topics that are obtained from links of the just acquired topics. In case when TSTemp is empty (for example, the last topic of the course is acquired), a system reviews all course topics and searches for not yet acquired topics. In case when such topics exist, they are written in TSTemp, otherwise, it means that all course topics have been acquired.

5.3. The Essence of the Method for Course Topic Organization

With previously introduced designations, the essence of the method for topic sequence change can be described as follows (parentheses include acquisition of the new TS selection):

- L->T and O->T (TSN=TST\TSI);
- T->O and L->O (TSN=TSO\TSI);
- T->L and O->L (TS=TSTemp).

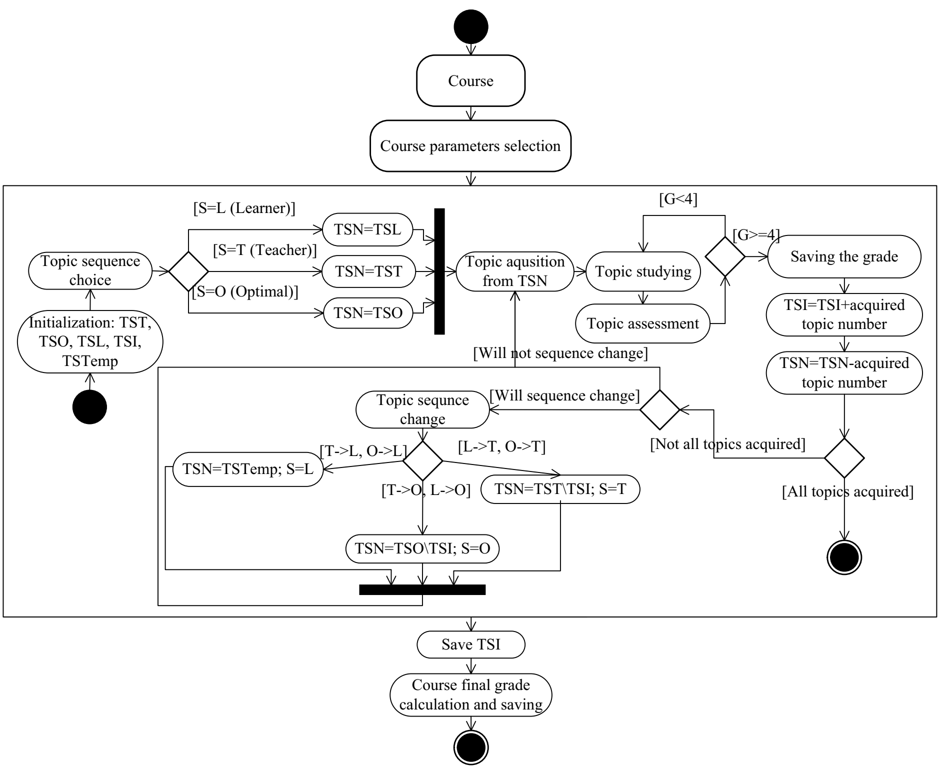

Figure 4. The activity diagram for the course topic sequence organization.

5.4. Example

The following example will demonstrate how the topic choice organization method works. Let's assume that la earning course consists of 10 topics. The teacher topic sequence is TST={1;2;3;4;5;6;7;8;9;10}. The optimal topic sequence is OTS={1;2;5;6;8;10;3;4;7;9}. Links between topics are showed in the Figure 5 as a course topic graph. An arrow indicates a link between two topics. Links between topics define which of them will be offered as the next one. More about topic graph see in the article [14]. This graph is saved in the system as a set {1:2,3;2:3,5;3:4;4:5,7;5:6;6:4,7,8;7:3,8,9;8:2,5,9,10;9:10;10:2}. In this set the order number of a topic is separated from links with ":" sign, and links between themselves are denoted with "," sign. One portion of "topic:link" is divided from the next one with ";" sign.

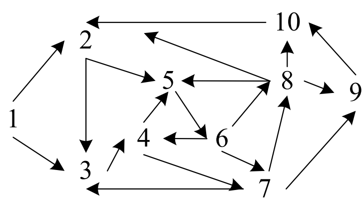

Figure 5. The graph of course topic acquisition [14].

Let's take a look at how the calculation of topic acquisition sequence (TSI) of the course is done using the topic sequence organization method. All possible options of the topic sequence change will be used in the example. The scenario for TS change is the following: T->L->T->O->L->O->T. Table 1 shows the values of variables and sequences that are used in the example. Designations used in the table are described in Section 5.2. Each table row (Step) describes the process of one topic acquisition.

Table 1. The example of organization of the course topic sequence

Step	S	TSN	TSI	Remarks
1.	T	{**1**;2;3;4;5;6;7;8;9;10}	{1}	TSN=TST
2.	T	{**2**;3;4;5;6;7;8;9;10}	{1;2}	TSN=TSN – acquired topic
3.	L	{3;**5**}	{1;2;5}	T->L, TSN=TSTemp, learner can choose
4.	T	{**3**;4;6;7;8;9;10}	{1;2;5;3}	L->T, TSN=TST\TSI
5.	O	{**6**;8;10;4;7;9}	{1;2;5;3;6}	T->O, TSN=TSO\TSI
6.	L	{**7**;8}	{1;2;5;3;6;7}	O->L, TSN=TSTemp
7.	O	{**8**;10;4;9}	{1;2;5;3;6;7;8}	L->O, TSN= TSO\TSI
8.	T	{**4**;9;10}	{1;2;5;3;6;7;8;4}	O->T, TSN=TST\TSI
9.	T	{**9**;10}	{1;2;5;3;6;7;8;4;9}	TSN=TSN – acquired topic
10.	T	{**10**}	{1;2;5;3;6;7;8;4;9;10}	TSN=TSN – acquired topic

Step 1. At the beginning of the course acquisition, the system offers a learner the first topic and an opportunity to choose one topic sequence option (see Figure 4). It is a teacher topic sequence (S=T) by default, and the not yet acquired topic sequence equals the teacher offered TS (TSN=TST). The topic chosen by the learner is showed in bold in the TSN column of the Table 1. After the topic acquisition, topic sequence TSI is supplemented with the acquired topic (TSI={1}), and the acquired topic is being deleted from the not yet acquired topic sequence. *Step 2* is similar to the first step.

Step 3. After acquisition of the topic "2", a learner changes the teacher topic sequence to the learner topic sequence (T->L). In this case, the system creates the not yet acquired topic TS using links from the last topic to the next topics. Figure 5 shows that topic "2" has links to the topics "3" and "5", which is why TSN=TSTemp={3;5}. In this case, a learner chooses the topic number "5" from the offered topics. After this topic acquisition it is being added to the acquired topic sequence.

Step 4. After acquisition of the topic "5", a learner makes a topic sequence change L->T. In this step, the topic sequence that a learner needs to use to acquire the rest of topics is calculated. For this purpose the teacher topic sequence is taken, and already acquired topic sequence is subtracted from it (TSN=TST\TSI). That is why TSN={1;2;3;4;5;6;7;8;9;10}\{1;2;5}={3;4;6;7;8;9;10}. From the obtained TSN follows that the topic number "3" will be offered as the next topic. After acquiring this topic, it will be added to the TSI and deleted from the TSN.

Step 5, Step 6, Step 7, Step 8 are similar to steps 3 and 5.

In *Step 9* and *Step 10* the topic sequence option is not changed. That is why after next topic is acquired, it is added to the TSI and deleted from the TSN.

6. Experiment

The optimal topic sequence method and topic sequence organization method was created for testing purposes in a topic sequence module (Section 4.3). It was implemented in AELS of the standard learning course management system Moodle that is described in Section 3. The structure of the learning course "Programming Foundations" was created according to the described AELS content model. The structure of the course consists of 10 topics: (1) "C++ program structure. Data output", (2) "Data types. Data input", (3) "Mathematical functions", (4) "Conditional constructions", (5) "User-defined functions", (6) "Parametric functions", (7) "Cyclic constructions", (8) "One-dimensional numeric arrays", (9) "Multi-dimensional numeric arrays", and (10) "Symbolic arrays". An order number of each topic is given in brackets. Each course topic is divided into four parts: topic summary, theory, practice, and evaluation (Figure 1). Evaluation part of each topic consists of the created tests depending on the course difficulty level chosen by a learner. Similarly as in the example from Section 5.4, a course teacher indicates links between topics with the help of the set {1:2,3,5;2:3,4,5;3:4,5;4:5,7;5:6,7;6:7;7:5,8,10;8:9,10;9:10}.

38 first-year students of the professional higher-education bachelor study program "Information technologies" of the University of Daugavpils took part in the experiment in the academic year 2015/2016. The number of experiment participants is based on real number of students in course "Programming Foundations" that was used in experiment. Data about learners that would provide adaptation of the course content were obtained. Tests and quizzes, created in Moodle, helped to acquire data about learning styles of each learner (visual, aural, kinesthetic, reading, visual-aural), pre-knowledge in the course (yes, no), and the desirable course acquisition level (low, average, high) (Section 3.3). There were 30 learner groups made in the course based on the possible values of the learning style, course pre-knowledge, and course acquisition level [13]. Learner groups created in the course defined a scenario that was used for adaptation (Section 3.3).

25 students were classified into 13 groups created in course based on the obtained data about learners. Other students with lack of enough data were classified into

"Group0". In this group participants do not get any adaptation scenario. Learner groups in this experiment were used to make analysis of the learner model based on the course acquisition results. LM analysis is out of scope of this article. Learner group utilization does not affect the results of the OTS method application.

The experiment lasted for one semester. As the result of acquisition of the course "Programming Foundations", 38 learner-created TSs were obtained. These TSs were divided into 11 groups where each group had equal TSs. A course average grade was calculated for each obtained TS group. Obtained data are shown below: TS group number in square brackets, followed by TS and calculated average course grade in parenthesis: [1] 1,2,3,4,5,6,7,10,8,9 (6.944); [2] 1,2,3,4,5,6,7,8,9,10 (7.487); [3] 1,2,3,4,5,7,6,8,9,10 (7.917); [4] 1,2,3,4,7,10,5,6,8,9 (8.167), [5] 1,2,3,4,7,5,6,8,9,10 (7.917), [6] 1,2,3,6,4,5,7,9,8,10 (9.375), [7] 1,2,5,3,4,6,7,8,9,10 (7.542), [8] 1,2,5,6,7,8,9,10,3,4 (6.167), [9] 1,3,2,4,5,7,8,10,6,9 (8.292), [10] 1,3,5,7,8,9,10,2,4,6 (8.917), [11] 1,5,6,7,10,2,3,4,9,8 (8.583). The highest grade 9.375 was for the topic sequence {1,2,3,6,4,5,7,9,8,10}. This topic sequence is also taken as OTS described in the experiment.

7. Conclusions

This article presents a method for topic sequence organization and OTS acquisition that is based on previous learner results obtained during the learning process. The offered OTS method gives multiple benefits: (a) it gives learner an opportunity to manage his/her own learning process based on his/her wishes and interests; (b) it gives an opportunity to obtain data that can be useful for learner course evaluation; (c) the offered method can also be implemented in a standard course management system to ensure a dynamic change of the topic sequence; (d) the OTS method is easier than one of the approaches described in the related work (Section 2). The OTS method takes advantage of the content units (i.e. topics) of any study course. A system should ensure the ability to save learner-used topic sequences and grades received in the course. Then, having analyzed those topic sequences with the OTS method, a new OTS for this course is acquired, which can be further used by succeeding learners for better results; (e) the OTS method works with simple data structures such as symbol sequences.

With the help of the TSOM, an experiment was performed by means of allowing students to manage their learning process on their own. For experiment purposes, "Programming Foundations" course with 10 topics was prepared. Students had an opportunity to use the teacher topic sequence or to use a choice option of the learner topic sequence depending on links between course topics. 37 students used topic sequences, and according to them course acquisition results were obtained in the experiment. The optimal topic acquisition sequence for a described experimental course (Section 6) was created using the method for OTS acquisition presented in Section 4. The optimal topic sequence acquired is OTS={1,2,3,6,4,5,7,9,8,10}.

Future work will be connected with effectivity tests of the obtained OTS, detailed topic sequence choice development, and also a search for a solution to change the OTS in cases when the course structure is being changed.

A lot of study courses have been developed for a certain accreditation period. The target of OTS application was a course with a stable structure developed during several years. Even when changes in a course appear, they mostly affect the content of the topic rather than topics as such. For courses with still unstable structure, two cases must be for seen: (i) essential, and (ii) not essential content changes. In case of essential changes, a teacher-advised sequence can be taken as an OTS. In case of not essential changes, when the basic structure of a course remains the same, it is important to save the obtained OTS. In this case, new topics can be added at the end of OTS in ascending order.

References

[1] Brusilovsky P., Vassileva J. Course sequencing techniques for large-scale web-based education. *International Journal of Continuing Engineering Education and Life Long Learning*, 2003, 13(1-2), 75-94.

[2] Dai Y., Asano Y., Yoshikawa M. Course Content Analysis: An Initiative Step toward Learning Object Recommendation Systems for MOOC Learners. In: Barnes T., Chi M., Feng M. (eds) *Proceedings of the 9th International Conference on Educational Data Mining, EDM16, 29 June-2 July, Raleigh, USA.* 2016. 347-352.

[3] Doroudi S., Holstein K., Aleven V., Brunskill E. Sequence Matters, But How Exactly? A Method for Evaluating Activity Sequences from Data. In: Barnes T., Chi M., Feng M. (eds) *Proceedings of the 9th International Conference on Educational Data Mining, EDM16, 29 June-2 July, Raleigh, USA.* 2016. 70-77.

[4] Elouahbi R., Abghour N., Bouzidi D., Nassir M.A. A Flexible Approach to Modelling Adaptive Course Sequencing based on Graphs implemented using XLink. *International Journal of Advanced Computer Science and Applications*, 2012, 3(2), 7-14.

[5] Fung A.C.W, Yeung J.C.F. An object model for a web-based adaptive educational system. In: *16th World Computer Congress 2000: Proceedings of Conference on Educational Uses of Information and Communication Technologies, ICEUT'2000, August, China*. 2000. 420-426.

[6] Gasparetti F., Limongelli C., Sciarrone F. A content-based approach for supporting teachers in discovering dependency relationships between instructional units in distance learning environments. In: *Proceedings of the 17th International Conference on Human-Computer Interaction, 2-7 August, Los Angeles, USA.* Springer International Publishing, 2015. 241-246.

[7] Huang S.L., Shiu J.H. A user-centric adaptive learning system for e-learning 2.0. *Journal of Educational Technology & Society*, 2012, 15(3), 214-225.

[8] Jabari N.A., Hariadi M., Purnomo M.H. Intelligent Adaptive Presentation and E-testing System based on User Modeling and Course sequencing in Virtual Classroom. *International Journal of Computer Applications, IJCA*, 2012, 50(9), 23-31.

[9] Madjarov I., Betari A. Adaptive learning sequencing for course customization: A web service Approach. In: *Asia-Pacific Services Computing Conference, APSCC'08*. IEEE, 2008. 530-535.

[10] Vagale V. EPortfolio Data Utilization in LMS Learner Model. In: Hammoudi S., Maciaszek L., Cordeiro J., Dietz J. (eds.) *Proceedings of the 15th International Conference on Enterprise Information Systems, ICEIS2013*, *4-7 July, Angers, France*. Portugal: SCITEPRESS, 2013. 489-496.

[11] Vagale V., Niedrite L. Learner Model's Utilization in the e-Learning Environments. In: Čaplinskas A., Dzemyda G., Lupeikiene A., Vasilecas O. (eds.) *Databases and Information Systems, Proceedings of the 10th International Baltic Conference on Databases and Information Systems*, *DB&IS 2012, 8-11 July*, Vilnius, Lithuania. Vilnius: Žara, 2012. 162- 174.

[12] Vagale V., Niedrite L., Learner Classification for Providing Adaptability of E-Learning Systems. In: Haav H.-M., Kalja A., Robal T. (eds.) *Databases and Information Systems VIII*, *Proceedings of the 11th International Baltic Conference, DB&IS 2014, 8-11 June, Tallin, Estonia.* Tallin: TUT Press, 2014. 181-192.

[13] Vagale V., Niedrite L. Learner group creation and utilization in adaptive E-learning systems. In: Haav H.-M., Kalja A., Robal T. (eds.) *Databases and Information Systems VIII: Selected Papers from the Eleventh International Baltic Conference, DB&IS 2014*. Amsterdam: IOS Press, 2014. 189-202. (Frontiers in Artificial Intelligence and Applications; 270).

[14] Vagale V., Niedrite L. The Application of Optimal Topic Sequence in Adaptive e-Learning Systems. In: Arnicans G., Arnicane V., Borzovs J., Niedrite L. (eds.) *Databases and Information Systems: Proceedings of the 12th International Baltic Conference, Baltic, DB&IS 2016, 4–6 July, Riga, Latvia.* Switzerland: Springer, 2016. 352-365. (Communications in Computer and Information Science; 615).

[15] Vassileva D. Adaptive e-learning content design and delivery based on learning styles and knowledge level. *Serdica Journal of Computing*, 2012, 6(2), 207-252.