An Approach to Development of Practical Exercises of MOOCs Based on Standard Design Forms and Technologies

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Abstract. The paper describes an approach to the development of interactive practical exercises of the MOOCs on the basis of the standard design forms and technologies and the results of its application in the MOOC "Methods and algorithms of graph theory", first run of which took place in 2015 on a National Platform of Open Education of the Russian Federation. The features and examples of standard design forms of applied practical exercises are given. The results of the application of the course, which confirms the efficiency of the proposed approach, are provided. Analysis of records of assignments in this course points to a tendency of reduction of time spent on exercises throughout the course. It was found that the reduction of time spent on exercise is significantly affected by situational awareness training that provided by the using of standard technologies and design forms to develop interactive practical exercises.

Keywords: MOOC · Interactive practical exercise · Situation awareness training · Virtual laboratory · RLCP-compatible labs · Graph theory · National platform of open education of Russian Federation

1 Introduction

Experimental studies on development and application of Situation Awareness Trainings (SAT) for students of first and second academic years were conducted at the ITMO University in 2014–2015. These studies confirmed that after training sessions students have shown not only the growth of the main indicators of cognitive functions (attention, speed of thinking, etc.) but also increase of e-learning results (score for online exams for a number of disciplines) [1, 2].

These studies were preceded by studies of the positive experience of SAT application in training for pilots, air traffic controllers, etc. that aimed improvement of skill of interaction with complex computer systems in a dynamically changing environment [3]. In the process of training students had to deal with a variety of rapidly changing user interfaces. Changes of tasks, scales, tips should be detected as fast as possible. This ability is also necessary for students in Massive Open Online Courses (MOOC): they have to perform a variety of practical exercises and take tests and online exams while under stress because of the time limit.

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Interactive practical exercises are essential elements of any MOOC. In contrast to the polls that are taken after each video lecture to check the ability to apply knowledge gained, practical exercises may not use technology of tests. Their implementation requires technologies that allow to shape and control skills of solving typical problems of the application domain of the course. Usually complexity of common problems and methods of their solution in the course gradually increases that imposes additional requirements for the technology of the implementation of practical exercises. Firstly, these technologies should use uniform tools for implementation of all variety of practical exercises of the course (forms of task representation and composition of solution, user interfaces, navigation, reference, etc.). Such approach would include the SAT elements for the shaping of transferable skills that allow students to focus all cognitive resources on the application domain of the practical exercise and, thus, reduce the time required to perform each new practical exercise in the MOOC.

This article discusses an approach to this problem based on technology of RLCP-Compatible virtual laboratories, which is used in the development of practical exercises of the course “Methods and algorithms of graph theory” (authored by professor of the ITMO University Lisitsyna L.S., in Russian). The course is being applied on the National Platform of Open Education of Russian Federation since 2015. The article presents the results of practical application of the course, confirming the efficiency of the approach described.

2 Practical Exercises of the Course «Methods and Algorithms of Graph Theory»

This course is studied for 10 weeks, and the total labor intensity of the course - 3 credit units. Expected learning outcomes [3] in this course are LO1 – an ability to show a basic knowledge of mathematics (graph theory); LO2 – an ability to practice effective methods and algorithms for solving typical problems on graphs. The course is an educational module of discipline “Discrete Mathematics” which is a part of the basic educational programs for bachelors of the universities of Russian Federation [9].

Theoretical training includes not only number of video lectures and polls, but also relevant interactive demonstrations which includes a description of the algorithm (method of solving the corresponding problems on graphs) and an example of its usage in practice. Practical exercises (Table 1) are important interactive elements of the course. They help to shape and assess skills of learning outcomes. Each student has a fixed number of attempts to pass each practical exercise. Assessment result of learning outcomes is described with help of a 100-point scale. 70 points can be earned for the practical exercises and 30 points can be earned for the online exam, which is held online on the 10th week of the course. The threshold of passing for both practical exercises and online exam is - 60% of maximum possible points [9].

Practical exercises are based on technology of RLCP-Compatible virtual labs. This technology was designed in ITMO University in order to organize processes involving virtual labs. It allows to perform most of operations in fully automated mode and easily adapt to large amount of students which is helpful in MOOCs [5]. Each RLCP-Compatible virtual laboratory consists of virtual stand and RLCP-server.

Table 1. Practical exercises of the course

#	Typical graph problem	Algorithm	Max score
1	Search shortest route	Lee algorithm	5
2	Search route with minimal weight	Bellman-Ford algorithm	6.5
3	Search for Hamilton loops	Roberts-Flores algorithm	6.5
4	Search for minimum spanning tree	Prim algorithm	6.5
5	Search for minimum spanning tree	Kruskal algorithm	6.5
6	Search for largest empty subgraphs	Magu-Weismann algorithm	6.5
7	Minimum vertex coloring of graph	Method based on Magu-Weisman algorithm	6.5
8	Minimum vertex coloring of graph	Greedy heuristic algorithm	6.5
9	Search perfect matching in a bipartite graph	Hungarian algorithm	6.5
10	Detecting of isomorphism of two graphs	Algorithm based on ISD method	6.,5
11	Graph planarization	Gamma-algorithm	6.5
		TOTAL	70

Virtual stand is a tool, which is used by a student to get details of the given task and to compose a solution including all intermediate results. That solution is checked by RLCP-server. RLCP-server is a special TCP-server that provides the interface for RLCP (Remote Laboratory Control Protocol). RLCP-server is also responsible for the composing task variants and performing special intermediate calculations that must be held in safe environment. These two modules are not aware of each other and interact through a special control environment, which automatically manages each session of task solving. Such structure provides protection against unauthorized access. Because of lack of such environment in the National Platform of Open Education, virtual laboratories are deployed on the base of LMS AcademicNT of the ITMO University [6], which performs as an external assessment service. The interaction of the systems is implemented at a level that provides seamless sessions and registration of the achieved results in both systems.

Virtual labs of the course are aimed to shape and evaluate skills of solving typical tasks using known algorithms, that requires rigid action sequences and logical methods. On the one hand, this type of task requires variability of the tasks in conjunction with strict control of the complexity of variants. To solve this problem each virtual lab uses special algorithm to compose variants of specified class of complexity [7, 8]. On the other hand, this type of tasks allows to check the all intermediate results of the solution comparing it to solution provided by the reference algorithm. This allows to detect exact stage of the solution at which student made a mistake and provide him useful comment about it.

3 Standard Design Solutions in Practical Exercises of the Course

Following standard design solutions were developed to shape transferable skills of usage of RLCP-Compatible virtual labs for practical exercises of the course.

The standard form of the task frame with embedded virtual stand (Fig. 1). At the top of the frame, a general description of the task and description of the variant are arranged. Then embedded virtual stand goes. Information about time passed and time left is located below virtual stand as well as a button to finish the task solving.

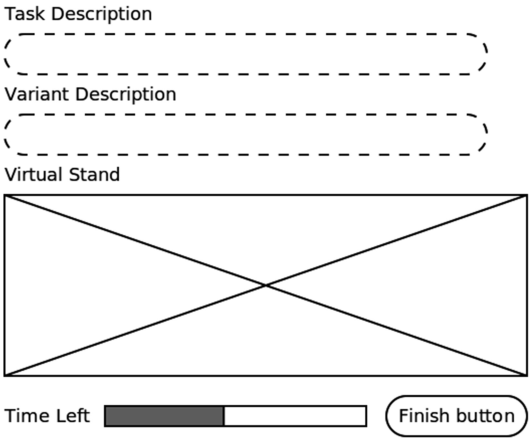

Fig. 1. The standard form of the task frame

Next standard form is a virtual stand for composing of solution (Fig. 2). There is a header with the name of the laboratory and help button at the top of the virtual stand. Under the heading on the left side an area of variant details is located, which usually contains an interactive graph. To the right of it – an area of solution composing where students specifies intermediate data of solutions.

This area usually contains tables that should be filled manually or by interaction with the interactive elements of the graph, for example, to specify a set of vertices and edges student just clicks on them on the image of the graph after selecting the desired row or cell of the table or the input field. The solution may consist of several steps, navigation between which is performed by the standard buttons "Next step" and "Prev step". The student specify the final answer for the given task in an area at the bottom of the stand.

The third standard form is a virtual stand for composing solution for tasks having a variable number of steps (Fig. 3). Sometimes the main part of the solution includes a series of identical steps, the amount of which depends on the complexity of the variant of task. In general, one or more initial steps precede that series. So, a special tool is embedded between the area of initial steps and the area of the final answer to manage

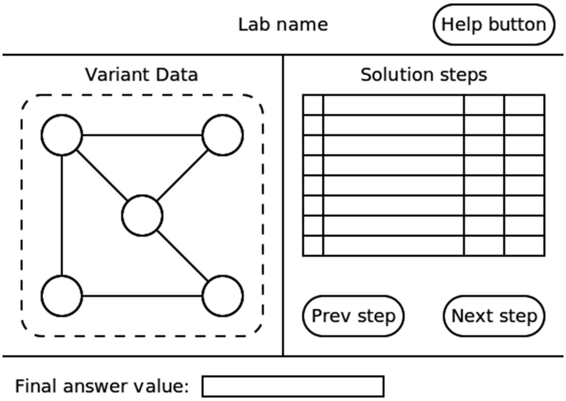

Fig. 2. The standard form of a virtual stand for composing of solution

the list of serial steps. The student can add new steps to the end of the list or remove steps from the end of the list. Typically, the area of the main part of the solution equipped with its own scroll bar that allows student not to lose sight of the variant data and the area of the final answer.

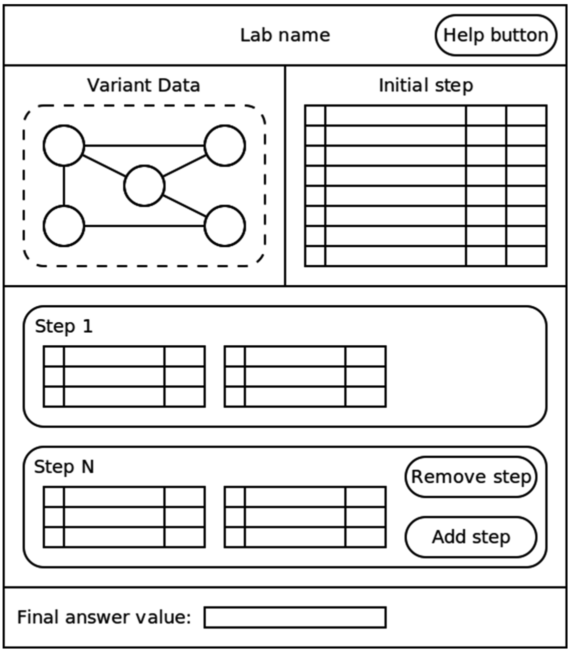

Fig. 3. The standard form of a virtual stand for composing of solution for tasks having a variable number of steps

All virtual stands are decorated in the same style; all control elements of different virtual stands have similar appearance and method of interaction. The course provides a special video lecture to explain how to use practical exercises: how to work with interactive pictures of graphs, where one can get help on input, how to navigate between the solution steps, how to edit the resulting solution, how to complete solution and get a report with the evaluation results. During the course these skills are shaped by practicing due to each new exercise requires that students use them over and over again, thus reducing the time required to solve the next task.

4 Considerations on Results of the Application of the Course

For the first run of the course «Methods and algorithms of graph theory» on the National Platform of Open Education of the Russian Federation in 2015 there were 2605 students who registered to the course, but only 239 students started to perform practical exercises (9.2% of participants). Table 2 describes their evaluation results. Students who scored 60 points (39.3% of all active students) received certificates. Each forth active student gained certificate with honors (90 points or more), while 4.2% of active students scored the 100. For each exercise student had maximum of five

Table 2. Processed data on the time spent on practical exercises

#	Related algorithm	Amount of processed records	Average time, sec. (a)	Average time in the first half of attempts, sec. (f)	Average time in the second half of attempts, sec. (s)	Reduction of time to complete exercise, % $p = (f - s)/a$
1	Lee algorithm	173	307,7	386,5	246,4	42,2
2	Bellman-Ford algorithm	110	1103,1	1338,4	890,9	37,4
3	Roberts-Flores algorithm	130	861,1	1057,5	720,0	34,2
4	Prim algorithm	60	837,5	894,6	804,1	9,6
5	Kruskal algorithm	45	696,0	795,3	605,5	25,6
6	Magu-Weismann algorithm	95	1770,5	1920,7	1627,9	15,2
7	Method based on Magu-Weisman algorithm	62	1609,5	1734,2	1489,6	13,2
8	Greedy heuristic algorithm	74	521,1	588,7	438,3	25,6
9	Hungarian algorithm	77	762,3	837,9	714,8	16,9
10	Algorithm based on ISD method	56	1489,7	1698,1	1339,4	17,9
11	Gamma-algorithm	79	371,0	436,7	341,6	17,2

attempts, including attempts to improve the previous score and 96% of students in average coped with the task and 85.4% of students in average gained maximum score, which demonstrates the efficiency of application of interactive practical exercises in the course [9].

We next consider the results of the time spent on practical exercises in the course. All records of performed exercises were processed to collect statistics with the exception of those that were interrupted by students (student opened a task, but decided to quit the assignment). There were 311 of "student-exercise" pairs that were selected by condition that student used to perform the exercise at least 2 times. It resulted to 1656 processed records for 152 students. All attempts were split into two parts (the first and the second half of the trials). "Average time" value is actually counted as average value of average time to complete the exercise per student.

The data in Table 2 shows that the reduction of the time of re-assignments decreases during the first weeks of exercise, and then set in a certain range. Main point of interest is a persistent tendency of reduction of time to complete an exercise, despite the increasing complexity of theoretical material for their implementation. Reduction (p) of execution time of each practical exercise based on two factors:

$$p = p_1 + p_2,$$

where p_1 – reduction by transferable skills of usage of RLCP-Compatible virtual labs in practical exercises (SAT); p_2 – reduction by training of solving problems on graphs using the corresponding method (algorithm).

It is obvious that the proportion of $p1$ will gradually decrease during the course, and the proportion of $p2$ in general depends on the complexity of the relevant method. This, for example, leads to a huge reduction of time for practical exercise #4 (Prim's algorithm is simple to understand).

Thus, the analysis of the dynamics of reduction of time to complete practical exercises confirms our hypothesis that the use of the standard design forms and technologies for interactive practical exercises in the MOOC improves performance of the course (high scores, reduction of time to complete exercises).

5 Conclusions

Thus, the approach to develop of practical exercises for MOOCs that is based on the standard design forms improves performance of the course. This is confirmed by the results of the application of the MOOC "Methods and algorithms of graph theory" in 2015 on a National Platform of Open Education of the Russian Federation, in which all 11 practical exercises were implemented on the basis of technology of RLCP-Compatible virtual laboratories. Almost all active students have coped with the these exercises, and 85.4% students to have reached the maximum score for exercises despite of fixed number of attempts (up to 5). Perhaps the most important result of this study is confirmation that throughout the course there is a tendency to reduce the time required to complete practical exercises, despite the increasing complexity of the theoretical material. It was found that the SAT makes a significant contribution to the reduction of time to complete practical. Therefore, developers of MOOCs should use standard design forms and technologies for interactive practical exercises to improve the efficiency of their courses.

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