Development of an Online-Course Syllabus "Operations Research Oriented to Cloud Computing in the CoCalc System"

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Abstract. This discussion paper provides an insight into the issue of developing a course syllabus for mastering Operations Research. The study focuses on implementing cloud computing while solving optimization problems. The research analyzes practical experience of using mathematical modeling in planning technological, biological and vital processes. This analysis confirms the relevance of using cloud environment CoCalc while teaching students how to solve Operations Research tasks. The discussion paper describes the study of the specific features of online-courses on Operations Research with the help of the Deductive Approach to Content Analysis guidelines that give recommendations on developing syllabus for on-line courses. The study presents the development of the course syllabus for students who study the Operations Research course, or those who want to study Operations Research methods independently. The study shows the analysis of the survey results that allowed reviewing students' and teachers' opinions on improving the course with the use of computer mathematics systems. This study also discusses the course annotation and aim, requirements to course users, learning organization of course modules targeted at acquiring certain competencies. There was ground to make a conclusion concerning the importance and relevance of developing Operations Research Oriented to Cloud Computing in the CoCalc System online course on the Higher School Mathematics Teachers platform.

Keywords: online-course, syllabus, Operations Research, cloud computing in the CoCalc system.

1 Introduction

1.1 Problem Statement and Its Topicality Substantiation

The standards for training Mathematics teachers, developed by the Association of Mathematics Teacher Educators [1], brought out the problem of training mathematics teachers for technical and economical higher schools as the most relevant one. Among the ways of solving the issue connected with students' mobility support, the Association highlighted the development of online courses with interdisciplinary integrated content. On the one hand, such courses help students to see more closely into the perspectives of their studies on the chosen specialities. On the other hand, they meet educational requirements set by students of technical and economic specialities. But as the research by K. Vlasenko et al. [2] showed, the insignificant number of respondents, including students of mathematics departments from pedagogical universities of Ukraine, noted the skill of developing mathematical models on which the majority of interdisciplinary courses are based. Operations Research refers to the disciplines that study the system approach to the stated issue. The essence of the approach is that any task should be considered with the regard for its influence on the criteria of functioning the system as a whole. It is typical for Operations Research that while solving any problem new tasks may occur. An important feature of Operations Research is its focus on searching the optimal solution for the task (the principle of "optimality"). However, it is impossible to find such a solution in actual practice: the absence of methods that enable to find a globally optimal solution for the task and the lack of existing resources that make it impossible to implement exact methods of optimization.

Moreover, the emphasis in learning modern courses on Operations Research is made on routine computing procedures but not on the process of creating mathematical models that are interrelated with designing technical and technological processes, with the distribution of limited resources and planning the work of enterprises and, finally, with solving problems that occur in a person's everyday life. Therefore, Operations Research training requires an informed choice of computer mathematic system to support the course. After analyzing the articles on selecting CMS [3, 4, 5], we can make a conclusion that researchers pay attention mainly to commercial aids for teaching and organizing calculations (MathCAD, MATLAB and Maple). At the same time, the powerful capabilities of the non-commercial CoCalc system [6] are not taken into account. Among the advantages of CoCalc are its being a cloud-orientated and open source software. In addition, due to a number of components of this CMS, we can make the Operations Research course more efficient: the LaTeX editor provides the ability to prepare high-quality teaching materials, and the IPython interpreter can be used to develop dynamic models. Consequently, the necessity to develop a course, which will consider the issues of implementing cloud computing for solving optimization tasks with approximation to reality, is timely and relevant.

The objective of this paper is to perform a theoretical analysis of the features of resources that offer teaching Operations Research and focus on the use of cloud computing, in particular CoCalc. In addition, we present the development of the syllabus

for the online-course “Operations Research Oriented to Cloud Computing in the CoCalc System” [7].

The condition for achieving the objective lies in solving the following research tasks:

• the analysis of existing Operations Research courses and the needs of the target audience;

• the definition of the objective, tasks, educational content for Operations Research;

• the choice of aids for organizing the teaching of the course.

1.2 Analysis of the Latest Researches and Publications

While searching for research papers dedicated to teaching Operations Research, we analyzed the studies [8, 9] in which the researchers put emphasis on the importance of learning this discipline through solving practical tasks. The scientists believed that the teacher has to focus more on mathematical modeling of various processes and phenomena. We studied the experience of the scientists who considered the practice of using mathematical modeling in designing technological [10, 11] and biological processes [12]. While analyzing the researchers’ works we concluded that learning Operations Research exclusively through practical tasks has its disadvantages. The built models have a considerable number of variables, and it complicates the process of finding a solution with its further analysis. Taking it into consideration the fact that the majority of the Operations Research courses are overloaded with theoretical material that does not encourage the formation of students’ coherent insight into solving practical tasks.

The development of computer technologies and current computer mathematics systems allowed removing this disadvantage. Several scientists used efficiently different systems of computer mathematics in the process of learning Operations Research [13, 14, 15]. However, the analysis showed an insignificant number of scientific papers dedicated to the use of CoCalc cloud environment. I. Lovianova et al. [16] offer to use CoCalc during optional classes “Optimization classes” but the level of offered learning tasks and technologies is oriented at pupils of the 10th-11th grades of specialized schools and doesn’t include distance education. It is more interesting to study the experience by O. Markova et al. [17] about the use of CoCalc while teaching Mathematical Basics of Information Technology to the students of technical specialities, but the authors rely on the fact that students can code at an adequate level. In the opinion provided by M. Shyshkina [18] the usage of cloud computing systems will allow implementing innovative technologies in the university learning environment and will stimulate the creation of a coherent educational infrastructure and provide access to the best examples of electronic resources, in particular, environment design, application virtualization, infrastructure unification, service integration, extension of electronic resource use, extension of cooperation forms. Following scientists' conclusions, we see that the use of such an approach for developing an online course on Operations Research will be efficient during training higher school mathematics teachers.

2 Method

The authors the paper used the Deductive Approach to Content Analysis manuals [19, 20, 21, 22], which provide recommendations for developing syllabuses for online courses. The analysis of the recommendations, developed by the experts (Table 1), made a contribution to the development of the syllabus sections: Summary of the Course, Course Objective, Requirements to the Course Users, and Arrangement of the Learning Process.

Table 1. Recommendations for developing syllabuses for online courses

The syllabus sections	The recommendations
Summary of the Course	Analyze the content of existing courses, identifying their features, shortcomings Determine what are the expectations of future course users
Course Objective	Determine the essence of the problems that arise during the study of the discipline, identify what skills students want to acquire
Requirements to the Course Users	When choosing learning tools, including cloud environments, determine and indicate the minimum requirements for their engagement in the course
Arrangement of the Learning Process	Indicate the topic list of the course, by getting to know the other teachers' opinion of this list, specify the rules, assessment principles, remembering about the incentives

To be able to take into account the recommendations of the above-mentioned guidelines, the authors of this study analyzed online resources [23-32] that share the experience of teaching Operations Research. The content of these resources helps to practically train how to set problems and solve them with the help of computers, but does not give enough attention to the mathematical methods themselves. The tutor of these courses note that it is the job of the specialist to set the task correctly, choose the right computer mathematics system, enter data into the computer and correctly interpret the results. We can also add that some of the resources [27] partly replace the content of the Operations Research course with the content of the Mathematical Programming course. That can be explained by the fact that most Operations Research topics require the methods studied in the Mathematical Programming course. But in this case, students acquire only some idea of the range of issues that should be studied in detail during the Operations Research course. In addition, the analysis of the forums of these resources demonstrates a low level of students' interest in such educational material.

Following expert recommendations concerning the need to communicate with future users of the course, the authors of this paper also developed a questionnaire for the students (the qualification code of the program "014.04. Secondary Education.

Mathematics") and mathematical disciplines teachers working at higher educational institutions. In this way, the course developers determined the essence of the problems that arise when teaching topics related to optimization tasks, and identified methods by which these problems can be solved. 112 respondents participated in the survey on the Higher School Mathematics Teachers platform [33].

The analysis of the survey results helped to discover that while learning Operations Research, in particular, Linear Optimization, there are certain difficulties connected with the complexity of mathematical tools which are used and the necessity to have skills of computer work using modern systems of computer mathematics, in particular, CoCalc.

As students' survey showed, for the purpose of getting them interested in the discipline, the resources should cite examples of using Operations Research methods, in particular, linear optimization, for specific processes and in the activities of really existing enterprises. Surveyed mathematics teachers recommended using the general modeling methodology so that the content corresponds to the students' expectations. Moreover, respondents indicated the relevance of considering the following topics:

- place of mathematical modeling in different situations;
- special features of using models in different situations;
- types of mathematical models;
- computer mathematics systems that can be used;
- means of analyzing the situation that requires optimization and problem formulation;
- modeling process organization;
- relevant modeling method selection and mathematical model building;
- ways of getting data for modeling and requirements that are needed from them;
- verification of the built model adequacy to the real situation and the trust level to this model;
- modeling results interpretation (as the model is a simplified abstract image of the reality and a lot of things are not taken into consideration);
- determining the ways of the most efficient use of modeling results after their interpretation.

All the respondents also pointed out that the class should be given using computer mathematics systems. The respondents ask to pay special attention not only to the task setting but to their mathematical formulation (which is the most complicated and creative part of modeling). So, while forming an online-course syllabus, we took into account the respondents' ideas expressed in the survey and the carried out analysis of resource characteristics that offer to learn Operations Research.

The online course that will be posted on the platform "Higher School Mathematics Teachers" [33], got the name "Operations Research Oriented to Cloud Computing in the CoCalc System" [7]. The course is designed for students who study the course Operations Research, or those who want to learn the methods of Operations Research independently. The course learning, consulting will be carried out by platform tutors. While preparing the syllabus we followed the recommendations developed by Eberly Center in Carnegie Mellon University [32].

Online-Course Syllabus "Operations Research Oriented to Cloud Computing in the System CoCalc"

Summary of the Course. Operations Research refers to the disciplines that provide insight into the systematic approach to the problem raised. The essence of the approach is that any task should be considered in terms of its influence on the criteria of system functioning as a whole. An important feature of Operations Research is its focus on seeking an optimal solution to the raised task (principle of "optimality"). During the course learning the emphasis is put not on routine calculating procedures but on the process of building mathematical models that are connected with designing technical and technological processes, distribution of limited resources and planning enterprise work, the solution to the problems that arise in a person's everyday life. Solving a range of various relative optimization problems with the help of a cloud environment CoCalc is included in the course.

Objective of the course. The students have an opportunity to acquire the following competencies:

- readiness to use the knowledge on Information technology, fundamental and applied Mathematics for the analysis and synthesis of the systems and processes;
- capability to use mathematical tools, programming methodology and modern computer technologies for the optimization of practical tasks for information getting, storing, processing and transferring;
- possession of modern formalized mathematical, information and logical – semantic models and methods of information providing, collecting and processing;
- readiness to provide computer and technological process support to solve the tasks of Operations Research in computer mathematics system of CoCalc;
- capability to use modern information and communication technologies to create, form and represent the received modeling results.

Requirements to course users. Students need to have an account in the environment CoCalc [6] (previous name SageMathCloud). Since the environment supports the technology of web-cloud computing (SaaS), it is necessary to set up a random browser on the computer. For convenient group work while doing the course, it could be recommended to arrange a prepayment (prices start from $14 per month). This will provide more resources to store, calculate and increase the quotes on one project which is used for several accounts.

The organization of learning course modules is directed at students' acquiring certain competencies.

During the course, students review models of operations research, methods of their construction and analysis and learn to work in the CoCalc environment. When mastering the elements of the resource allocation and inventory management theory, course users apply the concept of a definite integral. When studying waiting-line problems, students use Markov chains with discrete and continuous time to solve systems of equations, find their exact and stationary solutions. Performing such activities contributes to the development of students' readiness to apply knowledge of computer science, fundamental and applied mathematics for the analysis and synthesis of systems and processes.

The ability to use mathematical tools, programming methods and modern computer technology to optimize the practical tasks of obtaining, storing, processing and transmitting information is improved when working with ready-made templates in CoCalc. The participants in the course have to modify the given templates according to the model they have built. They should save the template to their folder in the system and then work with it. Also for each fragment they are given a brief theoretical information on the functions included in the templates and algorithms for working in the system. Such activities contribute to forming the course users' readiness to provide computer and technological support for the process of solving the operations research tasks in the CoCalc computer mathematics system.

At the end of each course module, its participants have to perform a certain part of a comprehensive research work on stock planning for the chosen enterprise. The students will need to determine for themselves what data they need and then collect it. Execution of projects by students helps to increase their mastery level of modern formalized mathematical, informational and logical-semantic models and methods of presentation, collection and processing of information. Upon completion of the course, the students are to perform research work and present the results. The implementation of such activities contributes to the formation of the ability to use modern information and communication technologies to create, form and present the results of modeling.

The student can choose his/her own learning pace while doing the modules. Checking the level of acquired competencies is planned to be carried out through expert assessment of the projects completed by students. We also plan to use peer assessment with results discussion on the platform forum "Higher School Mathematics Teachers" [33]. Students will be offered the evaluation criteria in order to implement this part of the task. When the course is finished the students get a certificate about their results.

3 Results

While creating the online-course syllabus "Operations Research Oriented on Cloud Computing in the system CoCalc" [7], we followed the concept that using computer mathematics systems allows focusing teachers' attention on the modeling process during teaching a course. Thus, while designing a survey for teachers and students the authors of this paper aimed at studying the views on improving the course through engaging computer mathematics systems. Respondents' answers to the survey questions helped us to get a sense of it. The survey for Operations Research course teachers included 10 questions and for students – 8 questions and it was designed using an open online service Google Forms, posted on the platform "Higher School Mathematics Teacher" [33].

We got the responses of 71 higher school mathematics teachers, among them 57,3% teach Operations Research course in higher schools, and 15,4% – use methods of Operations Research in practice. This demonstrates that the answers to survey questions also include practitioners' opinions. Also, 41 students joined the problem

research, among them, 62,5% studied/study Operations Research course in higher schools and 37,5% – studied/study Operations Research course independently. Thus, the majority of students (53, 5%) studied most course topics at a sufficient or deep level. At the same time, there are some topics (Markov chains with continuous-time, Johnson's issues, etc.), that in students' opinions are important, but they were not considered during the course. Also, teachers (34,3%) marked an insufficient methodical development of these topics. Regarding the offered themes most respondents (students and teachers) agreed that the course should consist of:

Module 1. Methods of economic-mathematical modeling – 82,3%;

Module 2. Tasks and models of the optimal resources distribution and stock management – 71,7%;

Module 3. Mass service tasks – 69,1%;

Module 4. Ordering and coordination tasks – 54,3%.

Respondents-teachers' idea regarding the use of computer mathematics systems during teaching Operations Research is more conservative. Only 13,5% believe that CMS should be used and 51,3% – that it is rather relevant. These results are confirmed by students' responses, the majority of whom point out that while learning Operations Research course they were not offered the tasks that required the use of computer mathematics systems and their use in the course is very insignificant (82,3%), but all the respondents-students noted that there is need to use such systems in the course.

Meanwhile, most respondents-teachers marked organizational and psychological-pedagogical advantages of implementing computer mathematics systems in Operations Research (see Fig. 1 and Fig. 2). A significant number of respondents (57.9%) note that the advantage of using CMS is the increase in students' interest in learning. A smaller number of respondents (21.1%) bring out as an advantage the development of students' intellectual abilities. The authors of this paper believe that this view is caused by the stereotype about using CMS and want to show the course participants that the removal of a big number of routine calculations will enable them to spend more time in the modeling process, which will undoubtedly contribute to their intellectual abilities. Moreover, 52.6% of respondents chose the possibility of mathematical modeling among the organizational advantages of the course.

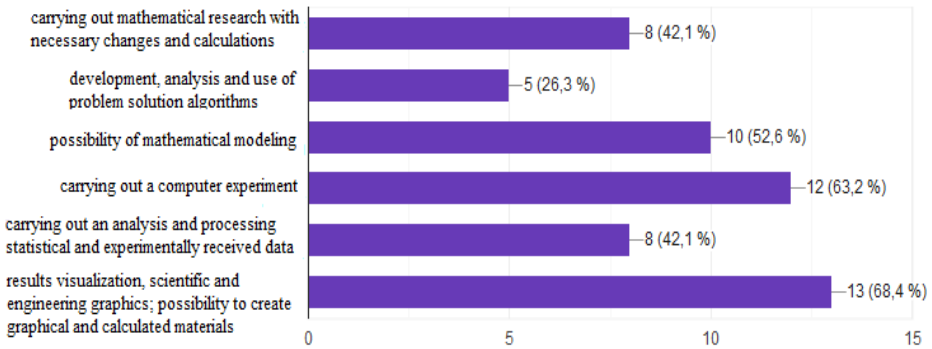

Fig. 1. Organizational advantages of using computer mathematics systems

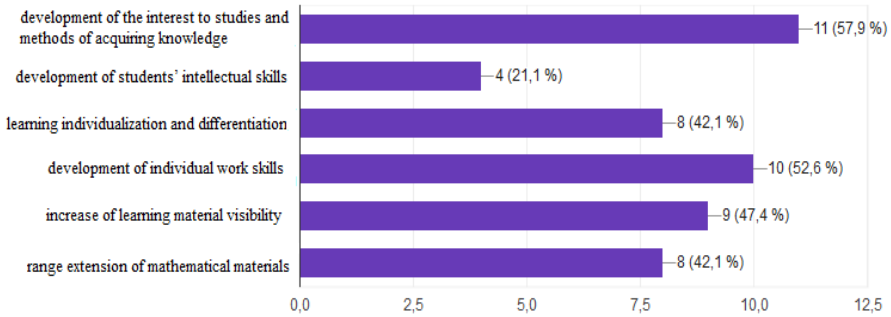

Fig. 2. Psychological-pedagogical advantages of using computer mathematics systems

82.3% of respondents demonstrated that they have a sufficient level of awareness about the capabilities of cloud CMS. At the same time, few teachers and students pointed out that they have a sufficient awareness level concerning the CoCalc system of learning management. 57, 9% of teachers explained it as the lack of scientific-methodical recommendations of using this CMS and the lack of mathematics courses with the orientation on cloud computing in the system. Also, teachers pointed out the necessity to devote additional time to programming while solving tasks. All the respondents stated that they are willing to improve their knowledge in Operations Research and get an experience of implementing CoCalc while solving tasks.

4 Discussion

Numerous examples provided by N. Finlay and M. King [34], prove that optimal solutions increase the efficiency of processes by 10-40% under the condition that the operations research method is applied to the model. The researchers rely on these statistics and conclude that professionals make more effective decisions when using operations research compared to their colleagues who are unaware of this science. C. Keller and J. Kros [35] cover the problem of training Operations Research within Master of Business Administration (MBA) program. The scientists believe that the course is an important part of a training program that concentrates on strong interdisciplinary connections. U. Kohut [14] studies employers' opinion regarding the practical training of graduates. He mentions that their level of readiness for the application of research methods does not meet modern requirements and is not sufficient. According to the scientist, the reason for this is the lack of communication between students and the lack of projects that are related to actual practice. C. Keller and J. Kros [35], U. Kohut [14], N. Ahuja [36] analyze the causes of these problems. The researchers also say that insufficient use of computer mathematics systems in teaching Operations Research is the cause of the shortcomings. The authors of this paper took into account the works of the following scientists: I. Lovianova et al. [16], O. Markova et al. [17], V.N. Kozhukhova et al. [37] and selected the virtual online computer lab CoCalc to be used while teaching Operations Research. The choice of this learning management system is based on its advantages, including the ability to write and compile program

code inside, with support for different programming languages. The authors of this study also took into account the opinion of A.M. Geoffrion [38], who pointed at the theorizing of this course in most universities and noted that advances in computer technology would greatly simplify the process of solving the developed mathematical model.

While searching for factors that influence the effectiveness and satisfaction with learning mathematical modeling, the authors of this paper analyzed the study of H. Kauffman [39], K. Vlasenko et al. [40], L. Panchenko [41], K. Vlasenko et al. [42], I. Lovyanova [43]. The researchers singled out online learning as one of the effective ways of non-formal education. The authors of this study share the opinion of H.A. Henson et al. [44], who called Syllabi as a coursemap of any online course. To prepare the complete syllabus for Operations Research Oriented to Cloud Computing in the System CoCalc, the course developers collected and evaluated all the information (results, assessments, actions and content).

While pointing out the learning outcomes, the course tutors relied on the conclusions made by C. Campbell et al. [45]. According to these scientists, checking learning efficiency through the level competencies formation is the most adequate strategy of lifelong learning. To prepare learning material for presenting a short description of the modules the authors of this research oriented at the recommendations given by M. King [46], K. Vlasenko et al. [47] and selected such course tasks that do not require formalization in the form of mathematical symbolism. The course developers believe that students will only need to select and correctly interpret the data to enter them into the CoCalc system. This approach, according to W.J. Erikson and E. Turban [48], should lead to a significant increase in interest in the operations research, reduce fear of mathematics and computers, and improve problem-solving ability. In order to show the course participants the details of using the CoCalc system and the correct interpretation of the results, the course developers focus on where exactly the necessary information is in the results of the system work and how to use them in practice.

The discussion of Syllabus and course materials on the platform [33] will help the course developers to improve it in accordance with the participants' needs. Students' engagement in course development through discussions at the forum will encourage their desire to work in the course.

5 Conclusions and Future Studies

The survey of the resources and scientific research confirmed the conclusion about the necessity of developing a course in which the issues of implementing cloud computing for solving optimization tasks will be considered. The review of the features of the Operations Research course showed that it contributes to the formation of students' ability to develop mathematical models on which most interdisciplinary mathematics courses are built. This explains the choice of subject for course development. The analysis of the capabilities of cloud-based environments confirmed the feasibility of using the CoCalc system, the components of which will help the course developers

to prepare quality teaching materials and dynamic models. It is substantiated that the placement of the "Operations Research Oriented to Cloud Computing in the CoCalc system" [7] online course on the Higher School Mathematics Teachers platform [33] should begin with the creation of the syllabus.

The analysis of the recommendations, developed by the experts on working out online courses, contributed to working out the syllabus sections: Summary of the Course, Course Objective, Requirements to the Course Users, and Arrangement of the Learning Process. A review of online resources sharing the experience of teaching Operations Research helped to identify a methodology for providing the content for these sections. While developing the summary of the course and the course objective, its developers clarified the expectations of future course users, who consisted of both mathematics students and teachers. In selecting the topic for the course, its authors took into account the desire of the respondents to master the models of operations research, their construction and analysis methods, as well as gain experience in engaging CoCalc in solving optimization problems. In formulating the requirements to the course users, the developers of the online syllabus found out the minimum requirements for engaging the CoCalc system for the convenient organization of students' independent and group work during the course. Arrangement of the Learning Process aims to attract students to the learning environment, which promotes positive motivation through a clear message of high expectations and confidence in the implementation of projects that will be encountered during hard work.

Uploading materials of the Operations Research Orientated to Cloud Computing in the CoCalc System on-line course [7] to the Higher School Mathematics Teacher online educational platform [33] is our focus of further research. The direction for further research implies describing the implementation of the on-line course into practical training of the students majoring in Mathematics in teacher training universities.

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