

1. Introduction

In the modern information-educational environment there are new models of the learning activity organization, based on innovative technological decisions of environment infrastructure organization including the cloud oriented.

The question of adjusting the information-technological infrastructure of the educational institution to the necessities of users, and organization of facilities and services of this environment in order to realize as much as possible the pedagogical potential of modern ICT, to attain the increase of learning results and also the improvement of the process of research activity of the students the innovative approaches are in demand. These approaches are to provide the most advisable ways of organizing access to systems of computer mathematics, that are among the leading types of learning tools of mathematics and informatics.

The teaching "Operations research" in the system of specialists of informatics training in the pedagogical university plays the special important role as it combines both the fundamental concepts and principles of different mathematics and informatics disciplines and applied models and algorithms of their implementation. There are the basic research approaches to the processes of mathematical modeling, decisions making, and mathematical description of the basic concepts and principles of data processing that are the subjects of computer modeling in informatics.

The use of SCM in the process of "Operations research" studies allows:

- to change the accents in the selection of theoretical material;
- to increase the fraction of tasks on mathematical models construction of the real optimization tasks and their research by means of SCM;
- to introduce the tasks on comparison of the results, obtained by means of the numeral methods of optimization, described by one of programming languages and built-in SCM tools, and their analysis at different input data, as well as the tasks on programming in the environments of mathematical packages of numerical methods of optimization and their research [1, 2].

The analysis of the domestic and international experience of the use of ICT in the process of informatics disciplines learning testifies that such class of ICT-based learning tools as the systems of computer mathematics (SCM) constantly attracts attention of researchers [3, 4]. These systems, that are

INVESTIGATIVE APPROACH IN OPERATIONS RESEARCH LEARNING USING MAXIMA SYSTEM

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Abstract: In the article the problems of using the systems of computer mathematics (SCM) as a tool to support the teaching and research activities in the field of informatics and mathematics disciplines training are investigated. The role of SCM in the process of bachelors of informatics training and special aspects of pedagogical applications of these systems in the "Operations research" study is defined. The main characteristics of SCM MAXIMA and the ways of organizing access to it both in local and the cloud-oriented implementation are considered. The results of the pedagogical experiment on MAXIMA application to support the investigative approach to operation research study and the analysis of its conclusions are reported. The use of SCM Maxima in the process of "Operations research" teaching aims at the forming students' ICT-competences, including in a cloud-based environment due to: the acquaintance with functional characteristics of SCM Maxima; developing skills of mathematical research of the applied tasks, in particular the construction of mathematical models; mastering programming in the SCM Maxima; obtaining the necessary knowledge base for studying other disciplines; increasing the level of informatics acquirement by means of the extensive use of SCM and cloud oriented systems in the educational process and research work. The aim of the research is justification of Maxima system use of in the process "Operations research" teaching in the pedagogical university as enclashing the investigative approach to learning and determination of the perspective ways of its introduction.

Keywords: "Operations research", MAXIMA, learning tools, investigative approach.

complex, multifunctional, powerful enough and at the same time simple in use, become irreplaceable in maintenance of various processes of numerical accounts, patterns visualization, realization of symbol operations, algorithms and procedures [4, 5]. SCM is the environment for projecting and use of programming tools of the maintenance of informatics disciplines teaching, forming innovative pedagogical technologies.

In recent years, informatics disciplines learning tools and technologies have obtained a further development, in particular based on the concept of cloud computing. This conception significantly changes the existing views on the organization of access and integration of applications, so there is a possibility to manage larger ICT infrastructures, that allow to create and to use both individual and collective "clouds" in a cloud-oriented educational space [5, 6].

Localization of such tools for educational purposes as SCM "in the cloud" is a perspective direction of their development, when there are more possibilities of adapting the teaching environment to academic achievement, individual needs and goals of the learners. There is expansion of a "spectrum" of research activities due to both fundamentalization of informatics disciplines teaching content and expansion of access to research activities tools. In this regard, we must pay attention to issues of grounding theoretical and methodical bases of formation and use of SCM, the definition of advantages and disadvantages of different approaches to deployment, research and analysis of the experience of their implementation.

The use of SCM Maxima in the process of "Operations research" teaching aims at forming students' ICT-competences, including in a cloud-based environment due to:

- the acquaintance with functional characteristics of SCM Maxima;
- developing skills of mathematical research of the applied tasks, in particular the construction of mathematical models;
- mastering programming in the SCM Maxima;
- obtaining the necessary knowledge base for studying other disciplines;
- increasing the level of informatics acquirement by means of the extensive use of SCM and cloud oriented systems in the educational process and research work.

Methodical peculiarities of teaching optimization methods and "Operations research" using WEB-SCM are analyzed in the work [7]. The graphical interface of SCM Maxima for modeling animations is described in detail in the work [8] and

examples of creating the animation evidences models and their use are made for development of educational-research abilities.

2. Research methods

The study is based on the methods of theoretical analysis, generalization and systematization of scientific facts about the pedagogical processes and phenomena, methods of system analysis and modeling, pedagogical observations and generalization of pedagogical experience, as well as the results of the pedagogical experiment. The study was carried out in the framework of the implementation of the planned research undertaken in the Institute of Information Technologies and Learning Tools of NAES of Ukraine and the Department of Informatics and Computing Mathematics of the Drohobych Ivan Franko State Pedagogical University. In the process of research the scientific-methodical principles of using the cloud based component on the basis of Maxima system in the process of informatics disciplines teaching for computer specialists have been grounded and analyzed.

Such interdisciplinary methods and procedures are used in informatics as analysis and synthesis, induction and deduction, visualization and formalization, algorithmization and programming, informative-logical, mathematical and computer modeling, program management, expert evaluation, identification and others. It is necessary to acquire them in complex, otherwise there is not a sufficient level of mastering the material of informatics disciplines.

3. Research results

3. 1. The features of using Maxima system in the process of informatics disciplines study

In the conditions of informative society formation it is very important to prepare highly skilled specialists, capable to undertake productive work in this society. Therefore it is necessary to search for new methodological approaches to organization of learning that would assist the deep mastering and understanding of basic concepts, rules, principles and methods of disciplines studies, their relationship to contiguous disciplines, and ways of their use in practice. The perspective direction is the integration of the systems of computer mathematics in the process of "Operations research" teaching. These systems may help, on the one hand, to automate some routine actions, focusing students on mastering the concepts and principles that are studied, and on the other hand, to identify the interdisciplinary links of various disciplines, examining how certain fundamental concepts are implemented in applications.

The use of the cloud-based tools of SCM design is a significant factor in the expansion of access to them in the process of teaching and research activities in the field of informatics and mathematics. If research activity happened only in specially created situations in the case of application of a local version of the tool, more attention can be paid to the independent work with using a cloud-oriented version, and research activity is extended outside the classroom time [5].

The use of mathematical packages to solve practical problems involves:

- understanding the problems of the educational discipline for proper use of SCM;
- understanding the methodology of developing the algorithm from the mathematical ideas to the formulation and the ability to apply this methodology;

– the ability to carry out grounding and estimation of the algorithm complexity at run-time and memory requirements [4, p. 138].

Special attention should be paid to Maxima system, as it is easy in learning, does not yield to such systems as Maple and Mathematica in solving the problems and is freely distributable. It is equipped with a menu system that allows to perform symbol con-versions, to solve equations, to compute limits, derivatives, integrals and the like, not knowing the language for description of the commands to perform these actions. Therefore Maxima system can be used for informatics and mathematics disciplines learning even on the first course of pedagogical university [4]. Maxima system application will not cause any difficulties for students in solving tasks of mathematical analysis and linear algebra – the students are required only to select a menu item and enter the expression. However, for programming in Maxima system one needs knowledge of language and syntax, as well as certain commands [4, p. 138].

"Operations research" teaching of pre-service specialists requires special attention as it combines both the fundamental concepts and principles of different mathematics and informatics disciplines and applied models and algorithms for their application.

The goal of SCM using in the process of pre-service specialists training in Informatics is the formation of the ability for successful using the information technologies in their professional activities, creative approach to solving non-standard problems, deep mastering the fundamentals of the disciplines. For this purpose the methodology of SCM using in the process of "Operations research" teaching was developed, aimed at:

- the formation of the professional competences of future specialists in Informatics that will give an opportunity in the future to adapt oneself to the requirements of informative society;
- the development of the creative approach to solving non-standard tasks;
- the formation of mathematical skills needed for analyzing, modeling and solving theoretical and practical problems with application of SCM [5].

The use of this technique was a subject of the present experimental studies with application of both local and cloud oriented implementation of SCM Maxima.

One of the important use of SCM Maxima in scientific investigations and at the mathematics and informatics disciplines learning at higher school is the solution and study of the optimization problems arising in various fields of human activities [9, 10].

Due to the introduction of SCM Maxima into the "Operations research" teaching process the opportunity is occurred to focus students on key concepts, principles, approaches, releasing time and efforts that are spent on the software establishment, maintenance, and even greatly to mitigate the real spatial and temporal boundaries of the implementation of access to necessary electronic resources. This approach develops interdisciplinary links, assists the deep study of material, and extends possibilities of independent research, combination of theory and practice, knowledge integration concerning the various departments and levels of computer education [4, 5].

For this purpose the technology of "virtual desktop" may be applied, where the data storage and processing are happened in the data center. Also, for a user, the work with cloud supplements, appealed via the Internet browser, does not differ from the work with software installed on a desktop of the user's personal computer [5].

The use of software that is installed on the student's virtual desktop:

- does not require spending educational time on installing and updating;
- the conditions for more differentiated approach to learning are created;
- provides the opportunity to focus on the basic material study [5].

A large number of practical problems are studied within the discipline "Operations research", which are easy to be interpreted as optimization problems on graphs. The examples of such tasks are:

- searching for the shortest route between two settlements;
- determination of the maximal admission characteristics of the oil pipeline;
- scheduling the execution of the project works etc.

When solving optimization problems on graphs the interdisciplinary relationships of informatics, mathematics, economics and other disciplines are realized that contributes to the intellectual development of students on the basis of forming ideas about the integrity of vision of the world, ensures the formation of skills not only declarative but also procedural knowledge. The use of graph theory for the problems solution by students develops their ability to represent the conditions of the problem in the language of graph theory, and then to interpret the solution in terms of the original problem.

The possibilities of using Maxima system to solve optimization problems on graphs are wide enough. A student, using SCM Maxima, solves the problem set before him, and thus he doesn't have the psychological barrier in application of mathematical apparatus, and besides he realizes also, what material is necessary to be repeated (or to be learnt). The solution of problems of applied nature (including, in particular, optimization problems on graphs) using a SCM provides the possibility of formation of the professional competences. The interest is also the research of optimization theory problems, in particular the implementation of the numerical methods, both conditional and unconditional optimization using SCM Maxima.

The main stages of the solution of such problems are the problem setting (providing of the objective function, optimality criterion, limitations, and accuracy of the solution) and analysis of the obtained results. The students obtain the system approach basis in solving problems, and they see the relationship of the content of various academic disciplines studies [11].

Summarizing the consideration of the course "Operations research", it should be noted that a wide set of tools for computer support of analytical, computing and graphical operations make the system of computer mathematics one of the main tools in the professional activities of mathematicians and programmers. The studies using Maxima system combine algebraic and computing methods. In this sense, SCM is the combining link between mathematics and computer science, where the research focus both on the development of algorithms for symbolic computation and data processing using computer and the creation of the programs to implement these algorithms.

3. 2. The results of the pedagogical experiment on the use of Maxima system in the process of "Operations research" teaching

In the joint research experiment held at Drohobych State Pedagogical University, named after I. Franko, 240 students participated. The aim was to test the specially designed learning environment for training the operations research skills on the

basis of Maxima system. During the study, the formation of students' professional competence by means of a special training method was examined. The experiment confirmed the rise of the student competence, which was shown using the χ^2 -Pearson criterion [12]. This result was achieved through a deepening of the research component of training. The experiment was designed using a local version of the Maxima system installed on a student's desktop.

The special aspect of the study was the expansion of these results using the cloud version of the Maxima system that was posted on a virtual desktop. In the first case study (with the local version), this tool was applied only in special training situations. In the second case study (the cloud version), the students' research activity with the system was extended beyond the classroom time. This, in turn, was used to improve the learning outcomes.

Summarizing, we conclude that the pedagogical experiment confirmed the hypothesis of the study. Analysis of the results indicates the increase in the level of formation of individual components of professional competence using the developed methodical system and, consequently, its effectiveness.

4. Discussion

Results of the study indicate certain movement in the development of new ways to create and use the software for educational purposes based on the concept of cloud computing, which very much changes the tools and approaches to educational activities.

Methodological guidelines on the organization of a cloud-based learning of environment, informational or mathematical disciplines of computer-based math models cover a range of delivery services and software applications to be available for use. Choosing a SaaS model in this respect could be justified by the fact that these services are the most affordable to use, regarding the restriction in the choice of software application to those offered by the supplier. When choosing a PaaS or IaaS model one must take into account a number of technological and organizational factors forming the environment, and quality characteristics of software selection which need to be installed in the structure of the medium.

SCM implementation in the process of training of pre-service professionals in computer science provides an opportunity to intensify the educational-cognitive activity of students, assists to development of their creative abilities, mathematical intuition and skills of research activities realization. SCM systematic using contributes to students' attitude toward a computer as to the means of solving professional problems. Such students gain more knowledge not only in mathematical disciplines but also in computer science. As a rule, they have no psychological barrier to using sophisticated software tools. On the contrary, they are attracted by the programs created at high professional level, and they notice the unique application possibilities of such systems.

SCM is an environment for learning tools projecting and, consequently, can be used for creation of innovative pedagogical technologies. The perspective direction is using the tools of this type "in the cloud", when there are more possibilities of adaptation of the learning environment to the learning needs of the user.

The prospect of further research is to expand the range of research tasks that can be solved using the proposed cloud-based component, further testing and comparison with other cloud-centric software products on the basis of the certain system of indicators.

References

1. Kobylnyk, T. P. (2008). Systems of computer mathematics: Maple, Mathematica, Maxima. Drohobych: Redaktsiino-vydavnychiy viddil DDPU imeni Ivana Franka, 316.
2. Slovak, K. I., Semerikov, S. O., Tryus, Yu. V. (2012). Mobile mathematical environment: current state and development prospects. *Naukovyi Chasopys M. P. Dragomanov. Series 2: Computer Oriented Learning Systems*, 19 (12), 102–109.
3. Tryus, Yu. V. (2005). Computer-oriented methodological training system of mathematical disciplines in higher education. Cherkasy, 649.
4. Shyshkina, M. P., Kohut, U. P., Bezverbnyi, I. A. (2014). Formation of Professional Competence of Computer Science Bachelors in the Cloud Based Environment of the Pedagogical University. *Problems of Modern Teacher Preparation*, 9 (2), 136–146.
5. Shyshkina, M. P., Kohut, U. P. (2014). Guidelines on the use of the cloud-based component with the Maxima system in the process of computer science courses learning. Drohobych: Red.-vyd. viddil DDPU im. I. Franka, 57.
6. Bykov, V. (2011). Cloud Computing Technologies, ICT Outsourcing, and New Functions of ICT Departments of Educational and Research Institutions. *Information Technologies in Education*, 10, 8–23.
7. Tryus, Yu. V. (2012). Using WEB-SCM in optimization and operations research methods training of students of mathematics and computer science disciplines. *Innovative computer technologies in higher education*. Lviv, 110–115.
8. Bugayets, N. O. (2015). Modeling of animated simulations by maxima program tools. *Information Technologies and Learning Tools*, 47 (3), 67–79. Available at: <https://journal.iitta.gov.ua/index.php/itlt/article/view/1244>
9. Smith, A., Bhogal, J., Sharma, M. (2014). Cloud Computing: Adoption Considerations for Business and Education. 2014 International Conference on Future Internet of Things and Cloud. doi: 10.1109/ficloud.2014.54
10. Turner, M., Budgen, D., Brereton, P. (2003). Turning software into a service. *Computer*, 36 (10), 38–44. doi: 10.1109/mc.2003.1236470
11. Vaquero, L. M. (2011). EduCloud: PaaS versus IaaS Cloud Usage for an Advanced Computer Science Course. *IEEE Transactions on Education*, 54 (4), 590–598. doi: 10.1109/te.2010.2100097
12. Vouk, M. A., Rindos, A., Averitt, S. F., Bass, J., Bugaev, M., Kurth, A. (2009). Using VCL technology to implement distributed reconfigurable data centers and computational services for educational institutions. *IBM Journal of Research and Development*, 53 (4), 1–18. doi: 10.1147/jrd.2009.5429056