The use of the cloud services to support the math teachers training

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Abstract. The development of the information society and technological progress are significantly influenced by the learning tools. Therefore, to the variety of tools that could be used to support the study of any discipline new ones emerging lately are continuously being added. Along with the great deal of systems of computer mathematics (SCM), web-oriented versions of SCM mathematical applications and other math learning tools the cloud-based versions of mathematical software such as MapleNet, MATLAB web-server, WebMathematica and others are now being used. These tools accomplishment becomes the essential part of training mathematics teachers. Domestic and foreign experiences of using cloud services for forming professional competences of mathematics teachers are analyzed. The place of the CoCalc within the system of mathematical disciplines learning tools is investigated. The task of improving the math teachers' ICT competence by means of cloud services use in the process of training is considered. Among the new forms of learning rising along with the cloud services dissemination are such as collaborative learning, inquiry-based learning, person-oriented learning. At the same time, the use of the appropriate cloud service in the study of some mathematical discipline improves the assimilation of the learning material and improves the knowledge acquisition process on most topics. The analysis of current research of Ukrainian scientists on the problem in question shows that the progress is underway as for further elaboration and implementation of new learning methods and techniques of using cloud services in the higher education institutions.

Keywords: cloud services; mathematics teachers; mathematical software; learning tools.

1 Introduction

The study of mathematical disciplines, as a rule, combines deep understanding of theory and practice. Within the framework of the Bologna Process and in the context of a single educational space, it would be advisable to use the best experience of the educational practice of European countries in combination with the domestic achievements to raise math education to a new level. In this context, there are a number of unresolved issues.

Analysis of recent research and publications. Some experience of using cloud services and cloud technologies in Ukrainian higher education already has been accumulated [5]. For example, the cloud infrastructure is reported to be used at the Kryvyi Rih State Pedagogical University [12], Google Apps cloud services are integrated into the educational environment of the Faculty of Physics and Mathematics of the Ternopil Volodymyr Hnatiuk National Pedagogical University [17]. Most studies are focused on the principles, approaches, and design of a higher education environment including cloud services [9].

Volodymyr P. Serhiienko and Igor S. Voitovich [23] consider the experience of integrating Moodle training courses with one or more cloud services. Particular attention is paid to the use of the cloud services in the process of distance learning of higher mathematics, which was studied by Oksana M. Markova [10], Natalya V. Rashevska [21], Svitlana V. Shokaliuk [11], Kateryna V. Vlasenko [33], Tetiana I. Zhylenko [35].

Usually, cloud services can be used to visualize data and calculations [3], in particular to solve problems and organize individual [18] or team work [25], to control students' knowledge [24]. According to Kateryna I. Slovak research [30], the role of cloud-based math software in particular CoCalc [8] is growing significantly.

Keith J. O'Hara, Douglas S. Blank and James Marshall explored four ways to use cloud services in the learning process: within the lectures (discussions); seminars; homework (individual) tasks; exams [16].

In Spain, the project "New Free Software Tools for the Automatic Correction of Complex Exercises" was carried out at the University of Madrid of Complutense, with the use of CoCalc service [1; 2]. In particular, it has been found that CoCalc is chosen by more students than other cloud services. This is due to the fact that, in most cases, that this tool is widely used for learning support, in particular math disciplines. Still students also do not have significant difficulties taking up other cloud services.

David I. Ketcheson [4] described the experience of teaching school subjects (ranging from short to 2-3 classes and ending with several semesters) using the CoCalc service. Due to this research CoCalc may be used as a complement to the basic manuals of the subject discipline.

The purpose of the article is to consider the advisable ways of using cloud services to support mathematics teachers training.

2 Research results

The problem of training skilled education management staff as well as ICT-skilled teachers can hardly be considered today separately from the processes of innovative development of the educational space created in a school, region and in the educational system of a country or a world. In this regard, there is a need for basic research with a focus on advisable ways to develop the learning environment of educational institutions. Trends in the improvement of ICT tools searching for new technological solutions and new pedagogical and organizational models should be taken into account [15]. The main focus is on the transition from the mass deployment of individual software products to a complex and integrative environment that supports distributed network services and cross-platform solutions.

2.1 The formation of professional competences of a mathematics teacher

The main feature of the competency approach is that during the training process students are gaining competences necessary for leaving and professional realization in the information society [14]. It would be false to assume that at the beginning the students have no competence at all, since the process of its formation can be quite long and fall under the influence of various factors: training in educational institutions, professional activity, interpersonal communication and so on. Therefore, saying that students acquire certain competencies implies the formation of their competence at the particular level.

Within the Tuning project, the specific competencies for the following subject areas have been considered: Business and Management, European Studies, History, Mathematics, Earth Sciences, Education, Nursing, Physics, Chemistry. In this project there are 42 subject areas: the main 9 are located on the Tuning site, the other 33 can be found on the Internet sites on the pages of the Tuning project [34].

The work was carried out by different groups of scholars, reflecting the specific traditions and development and implementation of educational programs in the field of each subject area. But at the same time, each group took into account the Tuning methodology, with further opportunities to create educational programs. By this way the project was developed using the same language (vocabulary, components), recommendations (learning outcomes and competencies, approaches to both learning and evaluating its results, etc.).

Another source on professional competencies is the UK Quality Assurance Agency for Higher Education (QAA, UK). The Agency has approved Subject benchmark statements for 60 Bachelor’s degree programs with honors (in some approximation – Bachelor’s Degree in Ukraine), 17 Master’s programs and 16 programs for Healthcare professions [32].

As for the classification of professional competences, they are generally divided into three categories: domain knowledge, cognitive and domain skills, subject domain practical skills.

Considering mathematical competence, which is a component of professional competence Ianina G. Stelmakh [31] treats it as a property inherent for a personality, which is ready to use mathematical tools independently and responsibly as confirmation of the theoretical and practical readiness of graduates for further professional activity.

Svitalna O. Skvortsova [29] proposes her own classification of the professional competences of a future mathematics teacher. The basis is the generally accepted separation of competencies into key, special and basic competencies. At the same time, each competency is characterized by separate components: communicative, personal and professional.

The professional component has two competencies:

- information competence (ability to process mathematical facts, work with mathematical data, organize a systematic search and generalize available mathematical material),
- subject (presence of a comprehensive system of complex mathematical knowledge and willingness to use them in their professional activities; ability to solve typical professional problems with the involvement of mathematical apparatus).

The communicative component consists of communicative competence (knowledge of mathematical terminology; willingness to transmit mathematical information; ability to use verbal and non-verbal means of transmitting mathematical data and information).

The personal component contains: reflexive competence (desire to improve the use of mathematical tools in professional activity); creative competence (use of innovative mathematical methods in professional activity).

Sometimes, among professional competencies consider: general professional [13] and specially professional. In this case, the specially professional competencies include:

- ability to use professionally profiled knowledge in the field of mathematics (mathematical statistics), for the statistical processing of experimental data and mathematical modeling of natural phenomena and processes;
- ability to use mathematical apparatus for modeling various processes;
- ability to use professionally profiled knowledge and practical skills in algebra and number theory;
- ability to use professionally profiled knowledge and practical skills to master the basics of theory and methods of theoretical research;
- ability to use professionally profiled knowledge and practical skills in mathematical analysis;
- ability to use knowledge and skills in analytical and differential geometry;
- ability to use professionally profiled knowledge in discrete mathematics;
- ability to use knowledge and skills in the theory of probabilities;
- ability to use professionally profiled knowledge and skills in mathematical logic and theory of algorithms;
- ability to use knowledge and skills in differential equations;
- professionally profiled knowledge and skills in the theoretical foundations of computer science and practical use of computer technologies;
- ability to use computer and ICT skills;
- ability to use professional knowledge and practical skills in teaching mathematics in primary school.

The above competences allow solving the typical problems that the graduates are facing at the pedagogical university, in particular the teachers of mathematics, in the performance of their professional functions.

Analyzing professional functions, typical tasks of activity and content part of skills, it is expedient to distinguish a certain group of professional functions (Table 1) taking into account the properties and qualities (specialized professional competences) of graduates of pedagogical high school, namely teachers of mathematics of school mathematics.

Table 1. Professional functions, typical tasks of the activity, which should be possessed by mathematics teachers

Content of function	The name of a typical activity task	Content of the skill
Conducting all forms of classes in secondary schools	Class planning	Draw up a plan and a synopsis of lessons using educational and methodical documents and educational and methodical literature
	Conducting classes	Use special knowledge in conducting classes
	To control the knowledge acquired by the students	Obtain and use scientific and technical professional information for conducting classes
		Use a computer to perform control measures
Educational activity	Provision of independent methodological level of knowledge	Use mathematics and informatics teaching methods to conduct different forms of classes
	Methodical support of independent work of students	To draw up and prepare for printing methodical instructions, manuals for mathematics and informatics with the use of educational literature, educational-methodical and other instructive documents

As shown in Table 1, specially professional competences do not relate only to such professional function as educational and public education of students. In these professional functions, due to specialized professional competencies, it is possible to solve all typical tasks of the activity, which are disclosed in the cells that characterize the content of the skill.

If we consider specialized professional competences in terms of the system of skills that reflect them, we obtain the following correspondence (Table 2) between the specialized professional competences and the content of skills.

In the Guidelines for the Development of Higher Education Standards, specific (professional, subject) competencies are defined as subject-area competencies and are important for successful professional activity in a particular specialty.

2.2 CoCalc in the system of teaching mathematical disciplines

New technologies, information and communication networks create the basis for the implementation of a holistic approach to education and training [26]. The holistic approach focuses on the integration of science and practice, training and production, fundamental and applied knowledge and technological competences. First and foremost, it aims to develop management skills in education that should be based on a unified approach to learning, design and management. This is a promising area for developing the staff potential of the education system. Therefore, new approaches and models are needed to organize and develop the learning and training environment for qualified teaching staff.

Table 2. Specialized professional competencies and a system of skills that reflects them

Competence in solving problems and problems of social activity, instrumental, general scientific and professional problems	Content of the skill
Use of modern information technologies	Be able to use existing and learn new information technologies
Search for new data	In professional activity, using keywords in a specific industry based on professionally oriented (print and electronic) sources, with the help of appropriate methods, to search for new textual data (work with sources of educational, scientific and reference data); search for new graphic, audio and video data
To apply the laws of formal logic in the process of intellectual activity	Use formal logical procedures to analyze the available data for their compliance with the conditions of necessity and sufficiency to ensure efficient operation
	Use formal logical procedures analyze existing data for compliance with internal consistency requirements
	Use formal logic procedures to structure the data
	According to the results of structural and logical processing of the work data, the conclusion about their suitability for the implementation of the given functions
	Based on the results of the activities carried out using certain criteria to determine the quality of the previously performed logical operations
	In case of negative result of activity to find errors in structure of logical operations

There is a problem of accessibility and ways of learning and supplying resources for better pedagogical effect of their use. This problem can be partially solved by using cloud computing tools. The main benefit of this technology is to improve access to qualitative resources (and sometimes the only way to access the resources you need). The idea is to identify approaches to modeling and evaluating cloud components and computing capacity using the knowledge about the design of the learning environment and its different tools.

Thus, Mariia A. Kyslova, Serhiy O. Semerikov and Kateryna I. Slovak includes in the mobile educational environment of higher mathematics:

- mobile tools of supporting educational and, in particular, mathematical activities,
- mobile tools of educational communication,
- mobile tools of supporting the process of teaching higher mathematics, to support interaction between students and the teacher [6].

In addition to mobile learning tools, researchers in recent publications have taken the cloud services as learning tools. Mariia A. Kyslova and Kateryna I. Slovak [7] analyzed a number of cloud services that they propose to use in the learning process in combination with traditional learning tools: Google Apps for Education, Office 365, ThinkFree Online. In particular, each cloud service is characterized, its characteristics, components and the advantages of its use as a tool for teaching mathematical disciplines are highlighted.

The following selection criteria can be used to select a cloud service [1]:

- compare computing resources (RAM, number of available kernels), the amount of data that can be computed by a cloud service, without affecting these characteristics by the computing power of the user-operated device and provided free of charge;
- the availability of tools for the organization of training and its control (it is necessary to take into account whether there is an existing distribution of exercises at the level, the ability to collect completed tasks and evaluate them);
- the possibility of increasing the computing resources for a small fee, comparing tariff plans;
- openness of the program code, possibility of setting of own settings and applications (special libraries), except for those provided by default (to individualize the work and settings of cloud service for an individual student or teacher);
- possibility of joint editing, simultaneous work on one problem (project) of a group of students, resources of different formats.

The advantages of cloud services include the following items (according to Natalya V. Rashevska and Viktoriia V. Tkachuk) [22]:

- the data are accessible to the user from any device having access to the Internet;
- the user is able to work with all educational material, without installing additional software;
- the ability to work anywhere, not just within the audience;
- the organization of the learning process is of a mixed type.

But Mariia A. Kyslova and Kateryna I. Slovak [7] consider the use of only cloud services as teaching aids to be inadequate. In the process of studying mathematical disciplines, it is appropriate to pay attention to the specialized web-oriented versions of SCM (the principle of operation of which is based on cloud technologies), which are referred to by Sage. In addition to Sage, in [7] considered GeoGebra, MathCAD

Calculation Server, MapleNet, Web-Mathematica. Each software tool is presented as a short feature that can be used as a learning tool.

At the same time, there is a tendency for the development of computer mathematics systems, which were still operating in a network environment (the so-called Web-SCM [20]) with respect to their gradual transformation into cloud-oriented systems. The main differences between Web-SCM and cloud-oriented SCM are covered in more detail in [27]. A variation of this type of system namely the cloud-oriented Web-SCM is CoCalc, the cloud-oriented version of Web-SCM Sage [27].

Modern SCM can be divided into seven main types, but despite the fact that each of these SCM has some differences in its purpose and architecture, it is considered that they have a similar structure [28]:

- the computing core of the system occupies a central place;
- codes for a large number of compiled functions and procedures that need to be performed fairly quickly, so the kernel volume is usually minimized;
- user-friendly interface through which the user can easily access the kernel and get the result directly on the monitor screen;
- powerful graphical toolkit extends the use of SCM not only for mathematical calculations, but also thanks to it can illustrate most non-mathematical processes;
- extension packages that increase SCM capabilities by increasing the number of user-assigned tasks;
- libraries of procedures and functions that allow the use of less commonly used, but equally important, rare procedures that are simply not included in the kernel due to its size limitations;
- a help system through which the user can at any time refer to each section regarding the correct use of a particular function, syntax and examples of use.

SCM has implemented a significant number of special mathematical operations, functions and methods [28]:

- opening of brackets in symbolic expressions;
- calculating the value of a numerical expression;
- schedule of polynomials on factors;
- calculating the value of a symbolic expression, but provided that the values of the variables are known;
- erection of such additions without opening the brackets;
- solving algebraic equations or a system of equations;
- solving transcendental equations, or the approximate value of the roots of the equations;
- performing mathematical analysis operations: calculating integrals, multiple integrals, finding primitives, boundaries of functions and numerical sequences; solving differential equations (analytically);
- plotting functions on a plane and in space, constructing vectors; calculations from the section of linear algebra (multiplication of matrices, calculations of determinants, raising a square matrix to any natural degree) and many others.

The first stage of SCM development (60's – 90's of XX century) is characterized by the fact that SCM was distributed locally – it was necessary to install the software on the user's computer and then it could be used in accordance with the license conditions.

The second stage of SCM development (90-ies of XX century – the first decade of XXI century) was marked by the emergence of Web-SCM, in which one of the main characteristics was equipped with Web-interface. Web-SCMs have the following properties:

- no need to install the system computing kernel on the client machine;
- all calculations are performed directly on the Web server;
- query execution and results are calculated using a Web browser.
- In addition, the following features of Web-SCM stand out:
- undemanding to the hardware component of the computer system;
- indifference to the browser used;
- ease of administration;
- mobile access to training resources, programs and data, etc. [28].

Today, the most usual Web-SCMs include MathCAD Application Server (MAS), MapleNet, Matlab Web Server (MWS), webMathematica, wxMaxima and Sage. Web-SCMs are equipped with a user-friendly interface, powerful graphical tools, and they implement a significant amount of mathematical calculations, functions and methods.

Among the specific characteristics of modern SCM there are:

- availability of programming languages inherent in these systems;
- importing data from other software;
- tools for printing mathematical texts.

There are several advantages to using CoCalc Web-SCM. Among them is the largest arsenal of tools for the development and research of various mathematical models within the mathematical disciplines. The first version of Sage (former SAGE) was released in February 2006.

Using Sage in the process of teaching mathematical disciplines provides the opportunity [28]:

1. Perform calculations: both analytical and numerical.
2. Submit calculation results in natural, mathematical language using symbolism.
3. Build two- and three-dimensional graphs of curves and surfaces, histograms and any other images (excluding animations).
4. Combine calculations, text and graphics within a single worksheet, printing, publishing and collaborating on them.
5. Create models using Python's built-in Sage language for practical work, educational research.
6. Create new features and classes in Python.

The third stage of SCM development (since 2009) is related to the emergence of cloud oriented systems. CoCalc is a free service supported by the University of Washington, the National Science Foundation and Google. CoCalc was specifically designed to help you use mathematical computing on the Android platform. CoCalc implements all the features of Sage, but there are some differences [28].

Strictly speaking, Sage is a console program. And all the calculations can be done in the console. Another issue is that this is inconvenient, which is why Sage Notebook and CoCalc were created. Historically, the first was the Sage Notebook. This is a graphical shell with a slightly outdated but user-friendly interface that is more suitable for working with Sage on a local computer. The Sage Notebook comes bundled with Sage and has the ability to perform calculations right in the browser. The Sage Notebook supports virtually every feature of the Sage console (except for code debugging commands), except you can: design sheets, add images, videos, 2d and 3d graphics, and create interactive applications.

By making certain adjustments, you can make it work with the Sage Notebook over the Internet. There are sites that provide access to the Sage Notebook, but they use an older version of Sage. It is recommended to use CoCalc to work with Sage online.

The idea behind the creation of CoCalc belongs to the professor of mathematics at the University of Washington, William Stein. Most servers are located in the US at the University of Washington. There are several servers in Europe. The servers are running the Ubuntu 14.04.1 LTS (Trusty) operating system with the Sage web-SCM kernel. Google App Engine is also used.

For Linux applications, this feature is distinctive: they can clearly distinguish the console part, which contains all the features of the program, and the graphical part of which the user usually works. It’s easy to make the program work on one computer and its graphics part on another.

Currently, various graphical environments are used to work with Sage. The Sage console is typically used for a variety of narrow tasks, such as: building your own mathematical web applications, debugging code, converting files to different formats.

The main source of data and communication resource is the SMC User Forum. A developer forum has recently opened after SMC’s final transition to open projects. Active communication occurs in the Gitter chat; created a FAQ on Github.

The principle of working at CoCalc is to create individual or group projects, fill them with training resources and work with individual resources or a group of resources at the same time. The system also preserves user actions, which are displayed in chronological order. It is possible to display the history of work with a particular learning resource (or project) of both a specific user and a group of users. Making certain changes to each project leads to a backup of the structure of the project itself. All copies are stored in chronological order, indicating the author of the changes.

Considering the aforementioned advantages of cloud services in teaching mathematical disciplines, as well as the prospects of introducing into the learning process of the free-running CoCalc cloud service, unlike most varieties of mathematical software of other manufacturers, at the same time, it is powerful enough to provide these processes, the application of this system was selected as the subject of experimental study.

2.3 Organization and results of the experimental research

The control and experimental groups of the experimental study were formed as follows: the control groups (CG) included the students trained according to the traditional method of mathematics teachers' professional competencies formation; the experimental groups (EG) included students trained according to the author's technique for using CoCalc as a training tool for mathematics teachers' pre-service training [19].

The following components of the subject, technological and professional-practical competencies were examined: subject-pedagogical, informational-technological and mathematical competencies [19]. Each component was considered separately, and the values were calculated according to the levels: high, sufficient, average and low. For data analysis, matches (at the initial stage of the experiment) and differences (after the forming stage of the experiment) of the experimental and control group characteristics were determined according to Fisher's criterion. For this purpose, statistical hypotheses were formulated: the absence of differences between the levels of formation of the individual components of the system of professional competencies and the significance of differences between the levels of formation of selected components.

Analyzing the obtained results at the summarising stage of the experiment, it can be concluded that the levels of formation of professional competences of mathematics trainee teachers in control and experimental groups [19] coincide with the level of significance $\alpha=0,05$.

Comparing the levels of the formation of professional competencies in the control and experimental groups at the beginning of the formative stage and at the end of the experiment, one can observe an increase in the proportion of students with high and average levels of professional competence.

The analysis of the results of the forming stage of the pedagogical experiment showed that the distribution of the levels of the formation of professional competencies in the experimental and control groups of mathematics trainee teachers has statistically significant differences due to the implementation of the developed method of using the cloud service CoCalc, which confirms the hypothesis of the study.

3 Conclusions and prospects of further research

1. In the study, the key concept is substantiated: the professional competence of a mathematics teacher is the ability of a person to perform professional activities in teaching mathematics of students and to achieve certain results on the basis of knowledge, skills and personal attitude.
2. According to the results of the research, special professional competencies were identified, the formation of which is expedient with the use of cloud services, namely: ability to use professionally profiled knowledge in the field of mathematics, for the statistical processing of experimental data and mathematical modeling of natural phenomena and processes; ability to use mathematical apparatus for modeling various processes; ability to work with a computer at the level of the user and the expert in the field of ICT.

3. During the study of domestic and foreign experience, the following advantages of using cloud services of mathematical purpose were revealed: saving resources (reducing the burden on the auditor's fund, the environment, the cost of acquiring and upgrading computer hardware, software, staff salaries); mobility of access (employment as the assimilation of material at a convenient time and in a convenient place); elasticity (provision of additional computing resources at the user's request). Given the aforementioned advantages of cloud-oriented learning tools in mathematical disciplines, as well as the prospects of implementing a CoCalc cloud service in the learning process, which is freely distributed and yet powerful enough to deliver the learning goals, it is advisable to use it to support mathematics teacher competencies formation.
4. The use of cloud services leads to the emergence and development of innovative forms of learning organization focused on collaborative learning activities on the Internet. It is shown that cloud services in teaching future mathematics teachers should be used as a tools for: communication (synchronous – chats, voice and video and asynchronous – mail, forums); collaboration (accessing, sharing, and collaborating with other users); data storage and processing.
5. The areas of use of CoCalc in training math teachers are: organization of educational communication; support of individual and group forms of organization of educational activities (classroom and extra-classroom); supporting learning management; providing clarity by constructing different interpretations of mathematical models, visualization of mathematical abstractions, etc.; providing accessibility through the use of a shared interface for access to environmental assets and reliable open source software; increasing temporal and spatial mobility; formation of a unified learning environment, the content of which is developed in the learning process.

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