CoCalc Tools as a Means of Open Science and Its Didactic Potential in the Educational Process

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Abstract: The article covers the questions of expedient CoCalc environment use as an integrator of services that can be used during different kinds of learning activities. Research goal is to identify the structural elements of the CoCalc environment, which are suitable for informatics and mathematical disciplines learning within the context of open science. Research objectives: a) consider the structure of the CoCalc environment kernel; b) highlight the structural elements that may be used in informatics and mathematical disciplines learning, and c) explore the prospects of their use. The object of research is the computer-oriented study of informatics and mathematical disciplines. The subject of research is the use structural elements of the CoCalc environment in informatics and mathematical disciplines learning. Research methods used: CoCalc environment analysis, comparison of its structural elements and their generalization according to informatics and mathematical disciplines. In the work analyzed, generalization and systematization of the major structural elements of the cluster CoCalc, reviewed the characteristics of items that can be used in the informatics and mathematical disciplines study. Results of the research will be used to improve methods of computer-based informatics and mathematical disciplines learning.

1 INTRODUCTION

Even before Computer Science disciplines studying, the programming basics may be taught directly within other courses. This is particularly true in the case of practically used methods and concepts. It may be considered as one of the ways to integrate practical programming exercises into other courses. We mean focused on the conceptual level rather than pure programming exercises, so that students learn more about specific computational methods and concepts. It is desirable that in the process of computer science learning one of the leading places was given to students' cooperative problem solving that will allow students to learn from each other and all together. As for collective structure, universal access is a key principle for learning in a modern higher education institution (HEI). After all, universal access is one of the principles of open education and open science, which is now being widely implemented in higher education in Ukraine. Solving together the same problem creates an atmosphere in which joint learning is an integral part of everyday practice in the learning environment.

Also, students, researchers, and teachers are subjects of the same information environment; they are equal community members (users) without a certain hierarchical structure. However, in reality there is a strict formal hierarchy in modern universities. Therefore, the question of the relationship between information environment users is quite topical. Because the difference between teachers and students is in fact quite clear, management in the digital environment is related to a structural hierarchy. Lecturers have not only to teach the content of their courses. Their task is also to maintain the existing configuration of the information environment (at least in terms of content) as well as to advise students in case of technical problems. However, it should be noted that in the digital environment, relationships unite all users: students, teachers, and researchers (Klaßmann et al., 2020).

There are another two problems in interdisciplinary relationships. First, social sciences and nat-

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ural sciences students have to put in a great deal of effort while perceiving information literacy material and have some difficulties in performing computational tasks. Humanities students often demonstrate a certain distance in the perception of computational approaches in general. Second, the variety of computing systems, methods, and concepts complicates the transparency, comparison, reproducibility, and transmission of results. Moreover, taking into account such a variety of calculation services, it is almost impossible to develop uniform methodological teaching standards. Therefore, not only information and communication technologies (ICT) courses are needed, but also it is necessary to integrate educational computer systems and research support systems (specialized, for scientists). This approach will help to strengthen the scientific component of students training not only in the humanities but also in technical specialties. In addition, such an integrative mechanism should promote the development of the students and researchers community within a single information space. The single digital environment meets the objectives and offers such integrating tools.

Science is a joint activity by definition. Research is usually conducted by several scientists working together, and this idea has been constantly confirmed in recent years. Moreover, experiments are increasingly being conducted in cloud services or with the use of cloud platforms, which involves the use of appropriate tools to support experimental activities. Workflow management systems and scenario-based tools are popular ways to conduct experiments, but these tools do not always support the idea of collaboration between a group of scientists. Even solutions aimed at collaborative experiments do not always meet the needs of users. Cloud service tools often focus on computing, but collaborating within a single environment is usually underestimated. Even if a certain cloud-oriented environment supports a work or learning management function, the group work is not considered enough in the framework of solving a specific pedagogical problem. Our research therefore was aimed primarily at the study of available tools for students' group tasks performing, joint research, and open access to research results. An experimental research carried out by a group of students, scientists and teachers is rather a challenge of today. There is an urgent need to identify every aspect of the collaboration between a group of students, faculty, and researchers. The analysis should be based on the study of current problems in the area from this aspect. In particular, the evidence in the following paragraphs suggests that the solution to some outlined problems is possible through the use of cloud service tools as a means of open science.

SageMath is an open-source computer algebra system. It has been used in most research on issues related to algebra and geometry. However, open-source cloud service has improved in recent years, and now it supports collaboration, the use of Python, R, Jupyter, LaTeX etc. Moreover, the CoCalc cloud service allows teachers to customize the LMS environment. Programming, the use of LaTeX, simulation – these are new skills in mathematics, and such environments contribute to their development (Martines, 2020).

2 ANALYSIS OF RECENT RESEARCH AND PUBLICATIONS

Klaßmann et al. (Klaßmann et al., 2020) presents a separate case study on the evolution of the digital learning environment and research at the Department of Musicology, University of Cologne. It covers 14 seminars from 2016 to 2020. In particular, the study examines the development of technological configuration as a digital environment and a curriculum development, which consists of educational practice in digital literacy and contains interdisciplinary links (Klaßmann et al., 2020).

de Assis Zampirolli et al. (de Assis Zampirolli et al., 2019) studied MEGUA (Mathematics Exercise Generator, Universidadede Aveiro) 2 – open source software that allows one to create data banks of parameterized questions with their corresponding answers in LaTeX. It works with the mathematical software CoCalc, which uses the Python programming language (de Assis Zampirolli et al., 2019). Data banks of questions are called "Books" and are built with PDFLatex (for printing) or HTML and MathJAX (for web publications) (de Assis Zampirolli et al., 2019). The development of the issue, in fact, takes place directly using the CoCalc toolkit. This process consists of three steps:

1) on a new sheet, a cell is created to import the entire MEGUA library and open / create a database to store questions;
2) the question code is being typed into another cell, which consists of LaTeX text and Python code. The LaTeX block is divided into sections (cataloging and description of the exercise), "% of the problem" (name and question) and "% of the answer" (its solution);
3) CoCalc complements the part of the computation that contains two functions: it generates random

values for the operator, calculates the correct solution and generates other multiple choices.

This cell yields two files: one in PDF format and another in text format (de Assis Zampirolli et al., 2019; Jandre et al., 2020).

There is also a resource for adding parameterized graphs to tasks, but MEGUA is not equipped with automatic correction of printable copies of questions, a function for rating hundreds of users.

The problem of developing a curriculum for courses in the study of operations has been carried out by Vlasenko et al. (Vlasenko et al., 2020). The research focuses on the implementation of cloud computing for solving optimization problems. The study (Vlasenko et al., 2020) confirms the appropriateness of using the CoCalc cloud environment in student teaching.

Bobyliev and Vihrova (Bobyliev and Vihrova, 2021) analyzed the experience of implementing courses in Calculus and History of Mathematics for future mathematics teachers in the learning management system of Kryvyi Rih State Pedagogical University. There is a block-modular approach to creating courses, which allows not only to structure the process of online fundamental mathematical subjects studying, but also to control the students' speed of content mastering and the depth of knowledge. There are examples of laboratory classes on the Calculus taken by by students independently in the CoCalc system of computer mathematics.

Gavrilyuk (Gavrilyuk, 2020) outlines the problems of using cloud services under the quarantine conditions. The scientist considered the possibilities of using cloud technologies for distance learning under precautionary measures, in particular, a key place among cloud services is occupied by CoCalc. An overview of cloud services that may be used to study Mathematics and Statistics related disciplines as well as their brief characteristics is offered.

The aim of the study is to identify the structural elements of the CoCalc environment, that it is appropriate to use in the educational process in the context of open science.

3 RESULTS

CoCalc (**Co**llaborative **Calc**ulation and Data Science; cocalc.com) is a virtual online workspace (cloud-based environment) for calculations, research, authoring documents in collaboration mode.

The learning and scientific activities in the CoCalc environment involve working on a project. The elements of a project are folders and files in different formats.

It is through the project files that the student and/or scientist accesses the main components of CoCalc explicitly (figure 1) or through an "intermediary" (file type "X11 desktop", figure 2).

According to CoCalc's statistics over the last month, the most popular environment instrumental and applied components are Jupyter Notebooks, Sage Worksheets, LaTeX Documents and R Markdown Documents.

The popularity of Jupyter Notebooks is obvious. Because it is on Jupyter Notebooks that you can modeling (calculate, programming, etc.), with the functionality of SageMath or Python or R or Julia.

Before talking about the already popular tools (SageMath, Python, R, LaTeX), let's focus on the latter mentioned, Julia.

Julia is a high-level, high-performance programming language with dynamic typing for mathematical calculations. The syntax is similar to the matlab family, the language is written in C, C++ and Scheme, it is possible to call C libraries.

Julia was designed from the beginning for high performance. Julia programs compile for efficient native code for multiple platforms via LLVM.

Julia plays dynamically, is a scripting language and has good support for interactive use.

Playable environments make it possible to play the same Julia environment every time, on different platforms, with pre-built binaries.

Julia uses multiple sending as a paradigm that facilitates the expression of many object-oriented and functional programming patterns. Provides asynchronous I/O, metaprogramming, debugging, logging, profiling, package manager, and more. You can create entire programs and microservices in Julia.

Julia is an open source project with more than 1,000 authors. It is provided under MIT.

But first of the stages in the development of the CoCalc is a web Computer Mathematical System (web-CMS) *SageMath*.

SageMath is a free open-source mathematics software system based on many existing open-source mathematical packages – FLINT, GAP, Matplotlib, Maxima, NLTK, Numpy, Pandas, Scikit Learn, Scipy, Statsmodels, SymPy, and many others. They can be accessed using a generalised language based on Python, or directly through interfaces or shells.

The available web-CMS tools of SageMath version 4.6 (the latest version before the advent of CoCalc, even earlier than SageMathCloud) were not sufficient to organize all types of learning activities under distance learning or its elements. It was necessary either to organize training or with the involve-

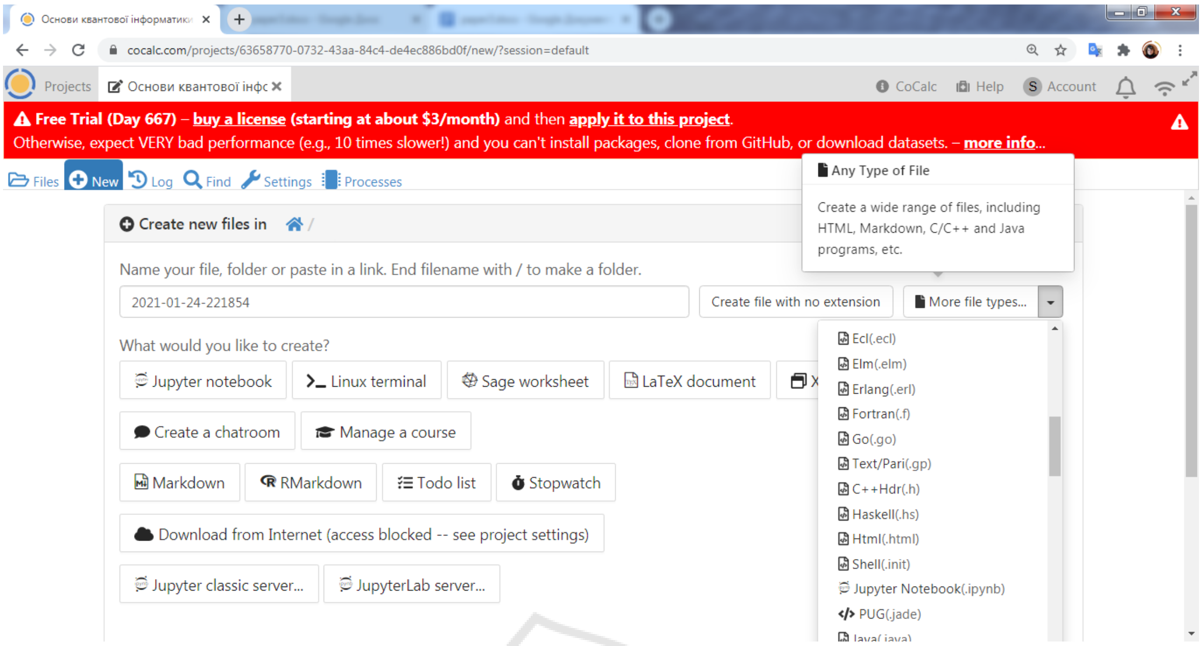

Figure 1: Page to create a new project file.

ment of two systems – web-CMS SageMath and any system to support distance learning, such as Moodle, or to integrate them. The first method proved to be inconvenient for neither teachers nor students, the second method – continues to be widely used (Shokaliuk et al., 2020), but it, with the advent and improvement of CoCalc, may lose relevance.

Since 2014, more than 80 students have completed the courses "Computer Technologies in Research" and "Computer Mathematics" for future computer science teachers with the additional qualification "applied programmer". The SageMath toolkit in CoCalc became especially popular with the advent of the ability to work on interactive Jupyter Notebooks instead of Sage Worksheets (Markova et al., 2018). While the latter has the advantage of being able to work simultaneously (within one sheet) with different mathematical applications.

In addition, future teachers of mathematics and computer science were offered to master the tools of SageMath in CoCalc within the optional course "Using SageMathCloud in learning mathematics" (by Maiia V. Marienko), the course "Numerical Methods / Methods of Computing / Computational Mathematics", "Discrete Mathematics", "Operations Research", "Mathematical Programming", as well as to perform independent work on the courses "Linear Algebra and Numerical Systems", "Analytical and Differential Geometry", "Calculus", "Probability Theory and Mathematical Statistics".

The mathematical packages FLINT, GAP, Matplotlib, Maxima, NLTK, Numpy, Pandas, Scikit Learn, R, Scipy, Statsmodels, SymPy, TensorFlow are known as members of the *Python Scientific Computing Ecosystem* or more simply *Scientific Python* because they provides data processing (modeling, experiment control) and visualize results for quick analysis with high-quality metrics for reports or publications.

Among the tools mentioned, the packages *TensorFlow* and *R* are of particular note.

TensorFlow is a comprehensive open source platform for machine learning. It has a comprehensive flexible ecosystem of community tools, libraries, and resources that allows researchers to advance the latest advances in machine learning, and developers can easily create and deploy machine-based applications.

R is an integrated suite of software facilities for data manipulation, calculation and graphical display. Among other things it has

- an effective data handling and storage facility;
- a suite of operators for calculations on arrays, in particular matrices;
- a large, coherent, integrated collection of intermediate tools for data analysis;
- graphical facilities for data analysis and display either directly at the computer or on hardcopy;
- a well developed, simple and effective programming language (called 'S') which includes conditionals, loops, user defined recursive functions and input and output facilities. (Indeed most

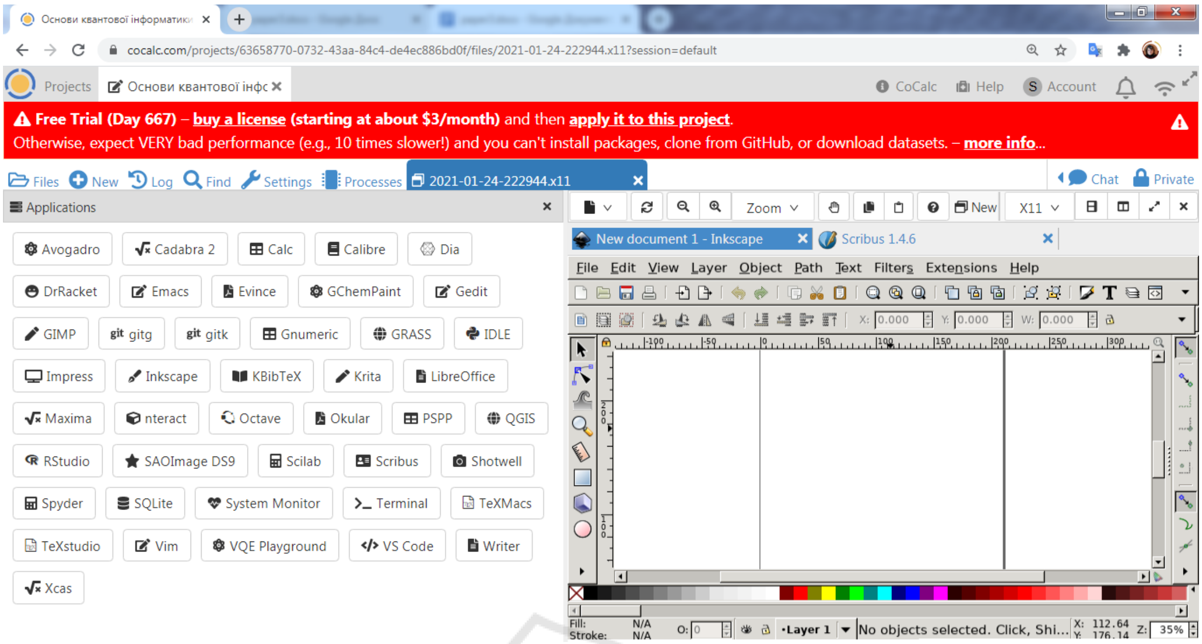

Figure 2: Page of a new file of type "X11 desktop".

Table 1: The main components (components, software) CoCalc: System software.

Type of software	Name of the software
Request and process user account information	accountsservice
FTP client	CFTP
VNC server	X11vnc
Archiver	7-ZIP, gzip, tar
Free command line utility for data compression	bzip2
Garbage collector	The Boehm-Demers-Weiser
Shell for GNU Screen and Tmux (application)	Byobu
Shell for Python GD library	gdmodule
Program for displaying a list of running processes	htop, ps
SageMath Notebook Server	SageMathNB
Operating System	Debian GNU/Linux

of the system supplied functions are themselves written in the S language.)

R is very powerful tool for newly developing methods of interactive data analysis. It has developed rapidly, and has been extended by a large collection of packages.

Since September 2018, almost 50 PhD candidates have been involved with the R toolkit in CoCalc and have successfully completed the Modern Information and Communication Technology in Research course.

To support cumbersome scientific calculations, there is a need to reduce the computational delay. Edge computations adopt a decentralized model that brings cloud computing capabilities closer to the user equipment to reduce computational latency. There are two types of projects in CoCalc: "trial (free) projects" and "participating projects". Trial projects run on computers that share the same node with many other projects and system tasks. These nodes may also stop at any time, causing the current project to interrupt and restart.

Projects accepted by members are transferred to less loaded machines, which are reserved only for users who have purchased one of the proposed licenses (tariff plans). Those servers are not being restarted daily. The cluster is dynamically scaled to accommodate different numbers of member projects.

Work on members projects is much smoother because commands are executed faster with less delay, and heavy operations of the processor, memory and I/O work faster.

By default, free projects stop working after about

30 minutes of inactivity. This makes the calculations quite time-consuming.

There is an advanced license option to completely prevent downtime. Processes can still stop if they use too much memory, crash due to an exception, or or being restarted by the server on which they are running.

That is, for users who have purchased one of the proposed tariff plans, there are more opportunities to use edge calculations.

Also, it is possible to change the free tariff plan (default) Hub server by clicking “Reconnect” (figure 3). To some extent, this setting may also be considered as a practical use of edge computing (Chen et al., 2016).

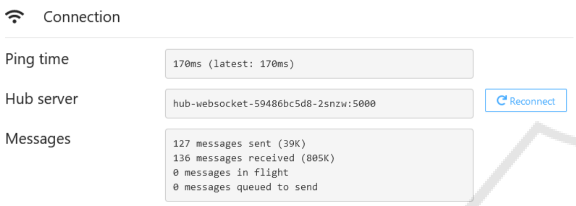

Figure 3: Pop-up settings “Connection”.

In addition, we should mention Big Data. The complexity arises from several aspects of the Big Data lifecycle, such as data collection, storage on cloud servers, data cleaning and integration. But edge computing solves this problem, which is an essential point for working with CoCalc.

CoCalc offers a wide collection of software environments and libraries (see tables 1-4).

A complete list of the current versions of CoCalc (1267 Python packages, 4472 R packages, 447 Julia libraries and more than 243sd files have been installed) can be obtained by using the command `$ sudo dpkg --get-selections`.

Detailed information on the specified in tables 1-4 and other CoCalc components (at the time of publication) can be obtained by direct link https://cocalc.com/help on the official website of the CoCalc project.

Implementation of research projects, term papers with the use of CoCalc involves two ways:

1. Using the individual tools presented in CoCalc.
2. Execution, writing and registration of results of educational and research work in CoCalc without involvement of auxiliary software.

At the same time, teachers and a group of students can be involved in the research project.

The IPython interpreter in the process of training future mathematics teachers can be used to develop dynamic models with semi-automatic / automatic demonstration modes.

The first way involves creating a model (models) of the phenomenon under study on a worksheet using standard controls, HTML tags, LaTeX commands and using CSS.

The disadvantages of this use are that in the process of registration of the obtained results have to involve other software: text editor, software for creating presentations, video editor (if necessary). As a result, only a certain point of the research work was performed using the CoCalc toolkit. In addition, in the process of presenting scientific findings, the student will have to demonstrate to their colleagues in addition to the presentation of the developed model using a browser (or video editor). This can be avoided by using CoCalc tools not only to perform the research part of a particular job. Therefore, it is better to use the built-in LaTeX editor as a CoCalc tool.

LaTeX is a high-quality text document program.

LaTeX is a TeX-based macrosystem that aims to simplify its use and automate many common formatting tasks. This is the de facto standard for academic journals and books, and it offers one of the best free typography programs it has to offer.

Performing a term paper or a thesis in the LaTeX editor, the student has the opportunity to print it, preformed on the basis of a resource such as tex PDF-document.

That is, at the same time there is a process of registration of the obtained results, calculations, presentation and presentation of the main provisions of the study (using the presentation developed in the LaTeX editor) and demonstration of the created model. The student does not need to include additional software to perform, design or present the results, because all the work is completely unified within one cloud service – CoCalc.

```
\documentclass{article}
\usepackage[a5paper]{geometry}
\usepackage[utf8]{inputenc}
\usepackage[ukrainian]{babel}
\usepackage{sagetex}
\title{Sharing Sage and LaTeX}
\author{M. V. Popel}
\date {13 January 2015 year}
\begin{document}
\maketitle
The easiest way to embed the results of
Sage commands in the tutorials created
in LaTeX is to use the sage and
sageplot tags:"
a) finding the derivative:
$(x^3)'=$$\sage{diff(x^3,x)}$
b) plotting:
\sageplot{plot(sin(x),-pi,pi)}
\end{document}
```

Table 2: CoCalc main components: General purpose application software.

Type of software	Name of the software
Analog screen for graphics programs	Xpra
Database of combinatorial graphs	Graphs
Library for rasterization of fonts and operations on them	FreeType
Library for working with raster graphics in PNG format	Libpng
GNOME tooltip browser	Yelp
File management and collaboration system	Mercurial
Electronic dictionary (thesaurus)	WordNet
Image viewer	GPicView
Interactive editor and macro support	Prerex
Programs for comparing the contents of text files and directories	Meld, diff
Services for reading e-books	Calibre, Evince
Document processing system in HTML, LaTeX or XML document formats	Docutils
Database management systems	RethinkDB, sqlite3
Text editors	GNU Emacs, Vim, nano, mcedit, AbiWord
Utility for finding differences between files	GNU patch
Cloud file storage	Dropbox

You can of course offer an alternative to CoCalc – Jupyterhub and Zoom. However, they do not include the ability to synchronize with other community members in a text file, although Zoom has a basic real-time chat feature. Of course, you can offer to integrate the Markdown hypertext into the configuration by using the Jupyter Notebook, which seemed to be the ideal solution to enable collaboration in a browser-based text document in real time using Zoom, for example in workshops. In addition, HackMD Markdown files will be available to students at any time and will be used for notes during the workshop. In this way, you can create joint documents that implement synchronous and asynchronous discussions. In addition, HackMD will provide tools for documenting group work sessions so that it is easy to share with other users. In this way, you can create templates for courses that will be used later for notes, discussion of seminar topics outside the classroom. Currently, Jupyterlab does not allow real-time collaboration on real-time collaboration due to technical limitations.

CoCalc offers shared computing capabilities to small groups of users. It also includes basic chat and video conferencing features. CoCalc toolkit supports student projects and group assignments that require synchronous collaboration in computer science and math. Because CoCalc is also based on the Jupyter Notebook, integration with individual workspaces will be seamless, as users in the same group can easily transfer individual files between CoCalc to both the shared workspace and their own, private instance of Jupyterlab. Using the advanced configuration with Zoom, HackMD and CoCalc, seminars can be organized completely remotely (Klaßmann et al., 2020).

Overall, this configuration is a good starting point for the further evolution of the digital environment and the management of a group of students to increase digital literacy in interdisciplinary research and the teaching of computer science and mathematics. To assess the cloud environment, it is necessary to take into account both the student's opportunities and interaction with them, as well as the success in achieving interdisciplinary learning goals and the level of discussion of the content achieved in seminars. CoCalc cloud service can be recommended to groups of students of all academic levels, from bachelor to doctoral and teachers of various fields of science. The use of a single cloud platform has certain advantages: it will help to form and hold regular meetings to discuss modern computational approaches in interdisciplinary research. This creates a digital environment for developing students and researchers that goes beyond weekly seminars. From the point of view of teaching, seminars conducted in one case study will confirm the potential of a common information environment for teaching computational interdisciplinary research. Thus, students with limited programming experience or no previous programming experience during distance learning workshops will be able to fully learn the basics of Python programming and gain skills in discussing and implementing high-level computational models (Klaßmann et al., 2020).

The evolution of the configuration of the digital environment demonstrates clear progress, which is closely linked to the requirements of pedagogical and methodological practices within the developing free

Table 3: CoCalc main components: Special purpose application software.

Type of software	Name of the software
Automatic grid generator for geometric constructions	Gmsh
Software package for algebraic, geometric and combinatorial problems on linear spaces	4ti2
Library for performing problems in number theory	FLINT
Library for dynamic work with images	GD Graphics Library (GD)
Library for processing video and audio files	Ffmpeg
Library for working with graphs and other network structures	NetworkX
Library for solving linear programming problems	GLPK
Library for solving convex programming problems	CVXOPT
Library designed for applied and scientific mathematical calculations	GNU Scientific Library (GSL)
Libraries for determining and calculating elliptic curves defined over a field of rational numbers	eclib
Vector graphic editor	Inkscape
Sage versions	Sage.7, Sage.8, Sage.9, Sage.10
Client for Git repository	SparkleShare
Mathematical library	Cephes
Mathematical library for performing actions on complex numbers	GNU MPC
A set of libraries that extend the functionality of C++	Boost
SageTeX package extension	SageMathTeX
Software package for generating three-dimensional models	GenModel
Software package for scientific calculations	Scilab
Software packages for building phylogenetic trees	Phylip
System for mathematical calculations	GNU Octave
Computer algebra systems	Gias/Xcas, Axiom, GAP
Computer mathematics system	Maxima

economic system, students and researchers. Thus, the resulting configuration for the introduction of computational thinking and digital literacy consists of the following tools that support the necessary functions in a single digital environment:

- Jupyter Notebook, which is serviced through Jupyterhub, will provide a basic environment for notes, programming and working with computational methods and concepts without the need for local installation and maintenance.
- GitHub, GitHub Pages, and GitHub Classroom will be used to track file versions, create a course website as an alternative communication channel, and support the logistics of issuing and submitting course assignments.
- Zoom will provide a tool for interactive synchronous social communication in distance and face-to-face learning.
- HackMD is used for synchronous co-writing of hypertext documents.
- CoCalc provides collaborative real-time programming based on the Jupyter Notebook.

4 DISCUSSION

The roadmap for Ukraine's integration into the European Research Area (ERA-UA) has been approved by the decision of the Ministry of Education and Science of Ukraine No. 3/1-7 on March 22, 2018. Priority 5 contains a sub-item, which indicates the further directions of open science development in Ukraine. Open science means revealing a research process by publishing all its results as well as details on how they have been achieved and making them publicly available on the Internet.

The practical use of the open science paradigm is (Shyshkina, 2018): presentation of educational materials in open access (data, program of the event, abstracts, minutes of meetings, didactic materials, data analysis files); open access materials publication; free distribution and dissemination of educational and scientific materials and data (for example, uploading content to an open repository).

If we consider the principles of open science, then, according to Shyshkina (Shyshkina, 2018), it means (Shokaliuk et al., 2020):

Table 4: CoCalc main components: Software tools.

Type of software	Name of the software
Interactive shell for programming	Jupyter Notebook
Python programming language interpreters	Python 2.x, Python 3.x, Python (Anaconda)
C ++ programming language compilers	C++
Interpreters	CPython, Java, Perl, bash
Compilers	Mono, Embeddable Common Lisp
Functional programming environments	DrRacket, MIT/GNU Scheme
Environment for statistical calculations, analysis and presentation of data in graphical form	R

- open access to scientific sources;
- open access to electronic resources used during the study;
- free access to data arrays obtained during a pedagogical experiment;
- open e-infrastructures.

A common example of open source is the large number of open source virtual learning environments used in the academic environment. The most striking example is Moodle due to its widespread use in educational institutions (Mintii et al., 2019; Polhun et al., 2021).

As a consequence, the introduction of open science norms in Ukraine should lead to greater exchange, accountability, reproducibility and reliability of scientific materials and affect the learning process as a whole. In the process of studying domestic and foreign experience, the following advantages of using cloud services for mathematical purposes were identified: resource savings; access mobility; flexibility.

Cloud platforms and services engaging with the educational process leads to the emergence and development of education and research organization forms focused on joint educational activities, creating more opportunities for educational and research projects (Merzlykin et al., 2017; Popel et al., 2017; Lovianova et al., 2019). Methods and approaches of open science have a significant impact on the educational process. Given the above advantages of cloud-based tools in the mathematical disciplines teaching, as well as the prospects of the CoCalc cloud service implementation in the educational process, the study considers this service to be a potential cloud component of open science.

CoCalc is a cloud service, a virtual workspace for computing, research, collaboration and document creation (Jandre et al., 2020), which contains a cloud storage where scientists may share files with their colleagues. These include Jupyter sheets, where multiple scientists may edit scripts in real time.

CoCalc (Jandre et al., 2020) supports query, detection and visualization subphases. This allows scientists to query the results of the experiment and its history, among other data. Users may also visualize results using Jupyter sheets and libraries, such as matplotlib. They may also use chats to discuss an experiment and its stages.

In this cloud service (Jandre et al., 2020) the whole experimental environment is based on the principle of cloud operation. All changes are made directly in the cloud and synchronized with the user's browser via the Internet, that is to say, no blocking occurs.

CoCalc (Jandre et al., 2020) allows one to share a wide variety of files, including scripts in different programming languages. The cloud service toolkit allows you to share documentation that can help scientists understand what has been done in the experiment and help them make better use of shared data and scenarios.

The cloud service (Jandre et al., 2020) makes it possible to store performed by scientists interaction in a journal (chronology), but it resembles more unstructured information that is difficult to reproduce.

Although the cloud service is absolutely ready for use in research (Jandre et al., 2020), it requires a stable Internet connection to work. Working with the service is possible directly through the browser, which may cause some difficulties when replacing the workspace, tools and development environments to which the scientist is accustomed. You may run code from the CoCalc environment, but this method is different from running files from a scientist's device. There are some restrictions on using a free cloud service account. Another problem worth mentioning is that CoCalc does not properly capture all stages of the experiment. It provides features such as “time travel” and “log” that allow users to see the history of file changes and activity of project participants. But these data cannot be fully detailed so will be insufficient to guarantee the reproducibility of the experiment.

It may be concluded that CoCalc meets all the principles of open science. And CoCalc tools may be considered to be open science tools that have didactic potential in the learning process.

5 CONCLUSIONS

The given chronology clearly demonstrates creation and adaptation of the digital environment on the basis of particular needs and practical tasks of group of students, teachers and researchers in interdisciplinary researches and educational process. As the digital environment is constantly evolving, research cannot be considered exhaustive. We intend to integrate the configuration of CoCalc and the curricula of individual disciplines for a deeper training material understanding and to expand the means of professional competencies forming of future specialists in various fields of education and science. CoCalc tools enhance students' ability to organize and perform teamwork by implementing a joint project task. Thus, if the cloud service is used, the indicators of scientific research improve, the educational process becomes more open, appropriate to human needs and content relevant.

Given the growing popularity of free software and a wide range of CoCalc applications and services, it should be noted that there is need to develop teaching materials for Computer Science and Mathematics.

The use of cloud services leads to the emergence and development of learning forms, focused on joint learning activities on the Internet. Cloud services should be used in Mathematics teachers training as a means of: communication; cooperation; data storage and processing, which should be the subject of further research. It is advisable to focus further research on the dissemination of open science approaches to Mathematics teachers training process.

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