Selecting cloud-based learning technologies for developing professional competencies of bachelors majoring in statistics

Tetiana A. Vakaliuk[1,2,3,4], Olga D. Gavryliuk[2] and Valerii V. Kontsedailo[5]

[1]*Zhytomyr Polytechnic State University, 103 Chudnivsyka Str., Zhytomyr, 10005, Ukraine*
[2]*Institute for Digitalisation of Education of the NAES of Ukraine, 9 M. Berlynskoho Str., Kyiv, 04060, Ukraine*
[3]*Kryvyi Rih State Pedagogical University, 54 Universytetskyi Ave., Kryvyi Rih, 50086, Ukraine*
[4]*Academy of Cognitive and Natural Sciences, 54 Universytetskyi Ave., Kryvyi Rih, 50086, Ukraine*
[5]*Inner Circle, Nieuwendijk 40, 1012 MB Amsterdam, Netherlands*

Abstract

Cloud-based learning technologies (CBLTs) are emerging as a promising way to facilitate the development of professional competencies of bachelors majoring in statistics. However, selecting the most suitable CBLTs for this purpose is not a trivial task, as it requires considering various criteria and evaluating the available options. In this article, we propose a systematic approach to select CBLTs for the formation of professional competencies of bachelors majoring in statistics, based on three main criteria: information-didactic, functional, and technological. We apply the method of expert evaluation to assess the existing CBLTs according to these criteria and identify the most appropriate ones for the educational process. We also describe the general structure of the methodology of using CBLTs for the formation of professional competencies of future bachelors of statistics. The results of our study show that CoCalc and Wolfram|Alpha are the most convenient and effective CBLTs for this purpose, as they exhibit high performance on all criteria.

Keywords

cloud-based learning technologies, professional competencies, statistics education, expert evaluation

1. Introduction

The rapid development of information and communication technologies (ICTs) has brought significant changes to various spheres of human activity, including education. In particular, the emergence of cloud computing and cloud-based learning technologies (CBLTs) has opened new opportunities for enhancing the quality and effectiveness of education, as well as for facilitating the development of professional competencies of future specialists [1, 2, 3, 4, 5, 6, 7, 8]. However, selecting and applying CBLTs for specific educational purposes is not a straightforward task, as it requires taking into account various criteria and evaluating the available options. In this paper, we focus on the problem of selecting CBLTs for the formation of professional competencies of bachelors majoring in statistics, which is an important and relevant field of study in the context of European integration and data-driven society.

Statistics is a branch of mathematics that deals with the collection, analysis, interpretation, and presentation of data. Statistics is widely used in various domains, such as science, engineering, business, economics, social sciences, health, and education. Statistics helps to understand the patterns and trends in data, to test hypotheses and make predictions, to support decision making and problem solving, and to communicate findings and conclusions. Therefore, statistics education is essential for preparing future specialists who can effectively use data in their professional activities.

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tetianavakaliuk@gmail.com (T. A. Vakaliuk); ol.gavryliuk@gmail.com (O. D. Gavryliuk); valerakontsedailo@gmail.com (V. V. Kontsedailo)
https://acnsci.org/vakaliuk/ (T. A. Vakaliuk); https://scholar.google.com.ua/citations?user=MktBlGQAAAAJ (O. D. Gavryliuk); https://www.linkedin.com/in/kontsedaylo/ (V. V. Kontsedailo)
0000-0001-6825-4697 (T. A. Vakaliuk); 0000-0001-9761-6511 (O. D. Gavryliuk); 0000-0002-6463-370X (V. V. Kontsedailo)

The formation of professional competencies of bachelors majoring in statistics involves acquiring both theoretical knowledge and practical skills in statistics, as well as developing critical thinking, creativity, communication, collaboration, and self-regulation abilities. To achieve these learning outcomes, it is necessary to use appropriate learning technologies that can support the learners' engagement, motivation, feedback, reflection, and collaboration. Moreover, it is desirable to use learning technologies that can provide access to various statistical tools and resources, such as software packages, databases, datasets, online calculators, simulators, visualizers, etc.

CBLTs are learning technologies that are based on cloud computing, which is a model of providing on-demand access to a shared pool of configurable computing resources (such as servers, networks, storage, applications, and services) over the Internet [9]. CBLTs offer several benefits for education [10], such as:

- *Scalability*: CBLTs can dynamically adjust the amount of resources according to the demand and load.
- *Availability*: CBLTs can be accessed anytime and anywhere via the Internet using various devices (such as computers, tablets, smartphones, etc.).
- *Cost-effectiveness*: CBLTs can reduce the costs of acquiring, maintaining, and updating hardware and software resources.
- *Collaboration*: CBLTs can facilitate the collaboration among learners and teachers by providing tools for sharing data and documents, communicating via text or voice or video chat, co-editing files or code or formulas or graphs etc.
- *Innovation*: CBLTs can enable the creation and delivery of new types of learning activities and content that are not possible with traditional learning technologies.

However, not all CBLTs are equally suitable for the formation of professional competencies of bachelors majoring in statistics. Therefore, it is important to have a systematic approach to select the most appropriate CBLTs for this purpose. In this paper, we propose such an approach based on three main criteria: information-didactic, functional, and technological. We also apply the method of expert evaluation to assess the existing CBLTs according to these criteria and identify the most appropriate ones for the educational process. We also describe the general structure of the methodology of using CBLTs for the formation of professional competencies of future bachelors of statistics.

2. Methods

An expert evaluation method was used to implement the selection of the CBLT for the formation of the professional competencies of future bachelors of statistics and for effective application in the process of forming the corresponding competencies [11, 12]. According to the purpose and objectives of the method, the corresponding CBLT is numbered in ascending or descending order based on a separate trait, by which further ranking is made. It should be noted that the peer review was carried out in two stages.

In the first stage, experts were asked to evaluate 8 CBLT that could be used in the process of forming the professional competencies of future bachelors of statistics.

In the second phase of the study, another group of specialists was recruited to evaluate the most significant CBLT according to certain criteria.

3. Results

3.1. Selection of cloud-based learning technologies for the formation of professional competencies of future bachelors of statistics

Research on the implementation of cloud-based learning technologies to shape the professional competencies of future professionals is being actively pursued by various researchers. As this research is

aimed at CBLT to shape the professional competencies of future Bachelor of Statistics, it is important to identify, by a certain set of criteria, the most effective, convenient, and relevant cloud-based learning technologies to be used in the educational process of HEI.

To begin with, we will define the term "criteria", since this definition is presented differently by different researchers.

In encyclopedic reference publications, the concept of "criterion" is defined as "a trait, a basis for evaluation, taken as a basis for classification" [13].

In [14] the criterion is called "the criterion for evaluating something, a means of verifying the truth or falsehood of a statement".

Bagrii [15] argues that the criterion is "a standard against which to evaluate, compare a real pedagogical phenomenon, process, or quality by reference".

Torchevsky [16] notes that "in the most general form, the criterion is an important and defining feature that characterizes the various qualitative aspects of a particular phenomenon under study, helps to clarify its essence, helps to specify the main manifestations. In this regard, the indicator is a quantitative characteristic of this phenomenon under study, which makes it possible to conclude on the state of statics and dynamics".

In Dychkivska [17] term "criterion" is defined as "an indicator that characterizes the property (quality) of an object, the evaluation of which is possible using one of the measurement methods or the expert method".

Under the selection criteria of CBLT for the formation of professional competencies of future bachelors of statistics, we will understand such features, qualities, and properties of cloud-based technologies that are required for their effective use in the educational process to form the professional competencies of future bachelors of statistics.

We apply the method of expert evaluation [11, 12]. In the first stage, experts were asked to evaluate 8 CBLT that could be used in the process of forming the professional competencies of future bachelors of statistics.

20 experts of different profiles were invited to the expert evaluation procedure, among them officials of the State Statistical Service of Ukraine and the State Treasury in Zhytomyr, employees of banking institutions, employees of commercial financial institutions.

A point scoring system was used in the study [18]. According to the aforementioned evaluation system, for the number of N CBLT, the maximum possible estimate of N is given to the most significant in the use of CBLT and 1 to the least significant. The results of the assessment are presented in the form of a table, where the columns indicate the hotline number and the fields the expert number. The CBLT name card is presented in alphabetical order (A to Z), to prevent psychological clues that could affect the outcome of the assessment.

To determine whether there is an objective agreement between experts, calculated Kendall's Concordance Coefficient W [11, 12] by the appropriate formula specified in [11, 12].

The results of the peer review are presented in table 1.

Four CBLT 4 were selected: CoCalc, Scilab, WebMathematica, Wolfram|Alpha.

After calculating based on the experimental data presented (table 1), obtained a coefficient of concordance $W = 0.71$. Since the value obtained is non-zero, there is an objective agreement between experts.

In the second phase of the study, another group of specialists was recruited to evaluate the most significant CBLT according to certain criteria. It is worth noting that the second stage involved 15 specialists of different profiles, namely: teachers, heads of departments and deans of faculties of higher education institutions of Ukraine, having experience and related to the professional training of future bachelors of statistics, employers (Main Department of Statistics in Zhytomyr region, Department of the State Treasury Service of Ukraine in Zhytomyr, Main Department of State Tax Service in Zhytomyr region, heads of state and commercial banks, managers financial companies), which worked directly with the selected CBLT and could objectively evaluate them according to the degree of manifestation of each criterion.

Table 1
Ranking cloud-based learning technologies for the formation of the professional competencies of future bachelor of statistics.

Expert number	CBLT							
	CoCalc	Excel Online	GeoGebra	Google Sheets	Maple Cloud	Scilab	Web Mathematica	Wolfram|Alpha
1	6	4	2	1	3	5	7	8
2	6	5	1	2	3	4	8	7
3	8	1	2	3	4	5	7	6
4	5	3	2	1	4	8	7	6
5	5	2	1	4	3	6	7	8
6	6	1	5	2	3	4	8	7
7	8	2	3	1	5	4	7	6
8	5	3	1	2	4	6	7	8
9	6	1	4	3	2	5	8	7
10	7	1	2	3	4	8	5	6
11	7	3	2	4	1	6	5	8
12	5	2	3	6	1	4	8	7
13	8	1	2	3	4	5	6	7
14	6	4	1	3	2	5	8	7
15	7	4	1	3	2	5	6	8
16	5	3	2	4	1	6	8	7
17	8	2	1	3	5	4	7	6
18	7	1	2	3	4	8	5	6
19	4	3	2	1	8	7	5	6
20	7	4	1	2	3	6	5	8
S	126	50	40	54	66	111	134	139
d	36	-40	-50	-36	-24	21	44	49

The manifestation of each of the presented criteria was evaluated for each of CBLT. To this end, experts have been asked to evaluate its performance using the scale shown in table 2.

Table 2
Scale bar for evaluation of the relevant criteria.

Scores	Evaluation of the indicator
0	the indicator is missing
1	the indicator is partially available (not available more than available)
2	the indicator is more available than not available
3	the indicator is completely available

The indicator will be considered positive if the arithmetic mean of these points is at least 1.5. If more than half (50%) of the indicators of the relevant criterion are negative, then the criterion is defined as insufficiently developed. In the case of:

- when 50–55% of the indicators of the criterion are positive, the criterion is characterized as critically manifested;
- if 56–75% of the indicators of the criterion are positive, then the criterion is characterized as sufficiently manifested;
- if 76–100% of the criterion indicators are positive, then the criterion is characterized as highly manifested [18].

An analysis of existing cloud-based learning technologies to shape the professional competencies of future bachelors of statistics has made it possible to identify the criteria and relevant indicators of these cloud-based learning technologies:

- information-didactic: information support; coverage of various sections of mathematics and statistics; graphical presentation of results; teamwork on the project; ability to apply programming knowledge;
- functional: user-friendly interface; free of charge; accessibility; multilingualism;
- technological: cross-platform; integration with other cloud services; adaptability.

The results of the peer review of each of the selected criteria and relevant indicators will be discussed in more detail.

The information-didactic criterion characterizes the information and didactic component of cloud-based learning technology and is based on the laws of assimilation of knowledge, skills, and competences, namely:

- the indicator "information support" characterizes the presence of a description of the use of the tool, examples, or the presence of a section of assistance;
- the indicator "coverage of various sections of mathematics and statistics" characterizes the possibility of using CBLT in the process of studying certain sections of mathematics and statistics;
- the indicator "graphical presentation of results" characterizes the ability to interpret the results in the form of graphs, histograms, or a three-dimensional model;
- the indicator "teamwork on the project" characterizes the ability to work with multiple users at the same time;
- the indicator "ability to apply programming knowledge" characterizes the ability to take individual actions to perform calculations using different programming languages.

Basic data on indicators of information-didactic criteria for each of the selected CBLT are shown in table 3.

Table 3
The information-didactic criterion for selection of cloud-based learning technologies and the value of its indicators.

CBLT	The indicators						
	Information support	Coverage of various sections of mathematics and statistics	Graphical presentation of results	Teamwork on the project	Ability to apply programming knowledge	The manifestation of the criterion	The level of manifestation
CoCalc	1.93	2.67	2.07	1.80	2.00	100%	highly
Scilab	2.13	2.20	0.80	0.80	2.33	60%	sufficiently
WebMathematica	1.47	2.00	1.33	1.53	2.13	80%	highly
Wolfram|Alpha	2.33	2.27	2.33	1.53	2.33	100%	highly

The functional criterion characterizes the functional component of cloud-based learning technologies and assumes the following indicators:

- the indicator "user-friendly interface" describes the convenience and comprehensibility of the interface and the computational component of the software system;
- the indicator "accessibility" characterizes the provision of cloud-based learning technology to different categories of users;
- the indicator "free of charge" characterizes the possibility of free or full use of cloud-based learning technologies;
- the indicator "multilingualism" characterizes the support of multiple languages (localization) of the interface.

Table 4
The functional criterion for the selection of cloud-based learning technologies and the value of its indicators.

CBLT	The indicators					
	User-friendly interface	Free of charge	Accessibility	Multilingualism	The manifestation of the criterion	The level of manifestation
CoCalc	1.80	2.00	2.20	1.80	100%	highly
Scilab	2.00	1.87	2.13	1.53	100%	highly
WebMathematica	1.73	1.87	1.73	1.93	100%	highly
Wolfram Alpha	2.13	2.53	2.20	1.60	100%	highly

The basic data on the indicators of the functional criterion for each of the selected CBLT are shown in table 4.

The technological criterion is characterized as follows:

- "cross-platform" indicates the possibility of using cloud-based learning technologies in different operating systems;
- the indicator "integration with other cloud services" implies the possibility of supporting the work with calculations in different cloud services, and the possibility of further integration with other services;
- "adaptability" indicates the possibility of full use of cloud-based learning technologies on different devices (desktop computer, notebook, tablet, smartphone, etc.).

The basic data on the indicators of the technological criterion for each of the selected CBLT presented in table 5.

Table 5
The technological criterion for the selection of cloud-based learning technologies and the value of its indicators.

CBLT	The indicators				
	Cross-platform	Integration with other cloud services	Adaptability	The manifestation of the criterion	The level of manifestation
CoCalc	1.53	1.53	1.93	100%	highly
Scilab	1.53	1.53	1.53	100%	highly
WebMathematica	1.73	1.73	1.93	100%	highly
Wolfram Alpha	2.60	2.33	2.93	100%	highly

Let's summarize the results of the study in table 6.

Table 6
Generalized results of the selection of cloud-based learning technologies by the manifestation of all criteria

CBLT	Criterion		
	Information-didactic	Functional	Technological
CoCalc	100%	100%	100%
Scilab	60%	100%	100%
WebMathematica	80%	100%	100%
Wolfram Alpha	100%	100%	100%

3.2. The general structure of the methodology of using cloud-based learning technologies for the formation of professional competencies of future bachelors of statistics

The formation of professional competencies is a long process that requires, in addition to appropriate teacher training, the use of appropriate methods of its implementation.

The methodology of using cloud-based learning technologies for the formation of professional competencies of future bachelors of statistics includes the purpose of the application, the content of an application, interrelated forms of training, methods, and tools for achieving a predictable result.

The expected result of the methodology is the formed professional competencies of future bachelors of statistics in the specialty 112 "Statistics".

The purpose of using cloud-based learning technologies is to form in future bachelors' statistics of professional competencies.

The content of the methodology involves improving the learning process of disciplines of general training of the variable part of the free choice of students using cloud-based learning technologies (on the example of the content of the variable discipline of "Computer Statistics").

Note the features of teaching the discipline "Computer Statistics" for the training of future bachelors of statistics using cloud-based learning technologies.

To improve and enhance the discipline "Computer Statistics" carried out:

- selection of cloud-based learning technologies that are appropriate and reasonable to use in the learning process of future bachelors of statistics, to form their professional competencies;
- improving the content of the variable discipline "Computer Statistics" for the use of cloud-based learning technologies during the acquaintance and mastery of relevant topics of the course;
- development of methodical recommendations on the use of cloud-based learning technologies in the educational process of the discipline "Computer Statistics".

The purpose of the discipline is based on the mastery of practical skills of future professional activity in conditions that are as close as possible to the real ones; to form professional competencies in applicants related to a thorough knowledge of the chosen field of statistics, the ability to perform a qualitative analysis of data or calculations, calculations of relevant processes, the ability to work with statistical information, the use of appropriate software and cloud services, able to work both independently and in a team.

The study of the discipline "Computer Statistics" assumes that applicants for the specialty 112 "Statistics" must *know* the:

- basic concepts of mathematical statistics;
- stages of statistical research;
- specialized programming languages, in particular, the statistical programming language R;
- software for working with statistical data;
- specialized cloud services for organizing work with statistical information;
- features of the organization of joint work using cloud services;

be able to:

- perform statistical calculations;
- perform statistical calculations using specialized software;
- perform statistical calculations using appropriate cloud services;
- transmit and receive statistics;
- analyze the obtained data;
- build and edit schedules;
- visualize the received data with the help of specialized cloud services;

- organize joint activities with other specialists of the relevant activity or clients for whom the statistical survey is carried out.

Consider the modules that form the content of the advanced program of the discipline "Computer Statistics":

Module 1. Working with data. Basics of work in R.
Content module 1. Basic concepts, data types, and elementary functions. Arithmetic and logical operations. Basic mathematical functions. Vectors. Matrices. Arrays and data frames.
Content module 2. Export and import of data in R. Export of data, import of data in internal format. Export and import data tables.
Content module 3. Programming in R. Creating your functions. The technique of vectorization of the function. Conditional use (if) and multi-conditional (switch) operations. While and repeat loops. Cycle for.

Module 2. Basic concepts of statistical distribution.
Content module 4. Basic probability distributions. General concepts of distribution. The most commonly used distributions.
Content module 5. Graphic representation of statistical distributions. Points on the plane. Charts. Construction of histograms. Elements of three-dimensional graphics.

Module 3. Statistical evaluation and statistical testing of hypotheses.
Content module 6. Evaluation of unknown parameters. The method of moments. Quantile method. The method of the highest probability. Confidence intervals.
Content module 7. Test of statistical hypotheses. General concepts of the theory of hypothesis testing. Algorithm for testing statistical hypotheses. Pearson's criterion. Kolmogorov's criterion.

The proposed technique involves the use of the following teaching methods of selected cloud-based learning technologies (CoCalc and Wolfram|Alpha, as described above and in [12]):

- *Explanatory and illustrative.* Statistics as a science is quite complex and contains many sections that contain a significant amount of theoretical material, theorems and proofs, formulas, and graphical constructions of relevant processes. The explanatory-illustrative method as the most appropriate to use because students receive accurate theoretical material from the teacher, or independently from the textbook or textbook with subsequent discussion in class or online, and receive a visual presentation of the material using selected cloud-based learning technologies, demonstration of practical application cloud-based learning technologies CoCalc and Wolfram|Alpha (figure 1). Explaining the theoretical aspects of statistics is a basic factor influencing students' further understanding of the following related topics in the course, the use of cloud-based learning technologies to effectively perform professional tasks and the formation of professional competencies of future bachelors of statistics.
- *Reproductive.* Given the accuracy and complexity of the theoretical material, the course of the discipline "Computer Statistics" provides for laboratory and practical work, which is planned to practice tasks of varying complexity according to the specified algorithm according to the relevant educational topic, as well as a demonstration of their cloud-based learning technologies. CoCalc and Wolfram|Alpha followed by a repetition of the action scenario by the students. It is planned to present ready-made solved exercises and perform exercises in a similar way (two or three exercises or tasks). Also, it can be pre-prepared by the teacher sets of statistics provided to students as a separate file in the cloud storage or ready-presented statistical sets presented on the MEI page (Mathematics Education Innovation, http://mei.org.uk/data-sets), or on Google Public Data, Google Dataset Search services.
- The method of *problem statement* can be effectively used during practical or independent work, during which students do not receive samples of problem-solving or ready-made algorithms for working with cloud-based learning technologies. The teacher describes the problems or asks the

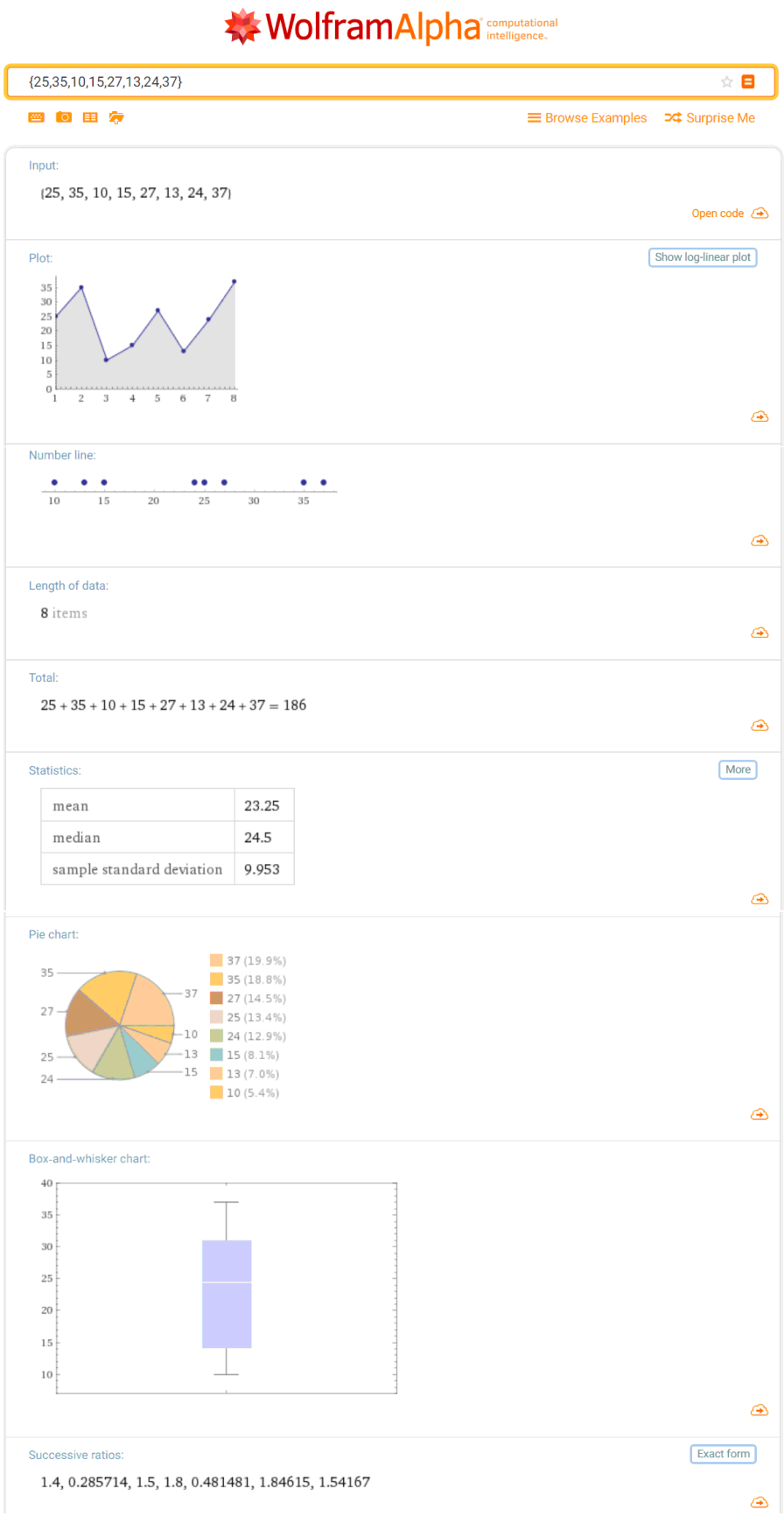

Figure 1: The result of sampling calculations in the Wolfram|Alpha service.

formed problem question (one or more), describes the ways to solve the problem, acts as a mentor who guides the work of students. Working in such circumstances promotes the development of students' critical thinking, solving atypical situations, and forms professional competencies, in particular, to develop research and analyze the data obtained; ability to present the results to the target audience; ability to work in a team.

- *Partial search.* The study material is presented by the teacher in part (a certain part of the topic), and the rest of the students work independently. However, the teacher directs the work of applicants with questions or pre-selected tasks to prevent errors in their activities or found the wrong solution.
- *Research.* The method is quite difficult to use because it requires additional training from the teacher and is quite time-consuming. Provides independence of students in the study of a particular topic or theoretical aspect, its practical implementation in cloud-based learning technologies CoCalc, Wolfram|Alpha, or the study of additional topics related to the topic of the course, but not considered due to time constraints on learning discipline. Researching the problem develops the ability to conduct research, the ability to use hardware and specialized cloud services, obtain additional data and interpret them, the ability to work independently, all together are components of professional competencies formed at the appropriate level of a successful future statistician.

The means of forming the professional competencies of future bachelors of statistics, which are specified in the presented methodology using cloud-based learning technologies, include CoCalc and Wolfram|Alpha, textbooks or teaching materials, as well as computers (laptops, tablets, smartphones) with an active connection to the Internet.

The result of the proposed methodology is the formed professional competencies of future bachelors of statistics at a high level, as well as the successful application of skills to use CoCalc and Wolfram|Alpha to perform practical work in the professional field.

4. Conclusions

In this paper, we have proposed a systematic approach to select cloud-based learning technologies (CBLTs) for the formation of professional competencies of bachelors majoring in statistics. We have defined three main criteria for selecting CBLTs: information-didactic, functional, and technological. We have applied the method of expert evaluation to assess the existing CBLTs according to these criteria and identify the most appropriate ones for the educational process. We have also outlined the general structure of the methodology of using CBLTs for the formation of professional competencies of future bachelors of statistics.

The results of our study show that CoCalc and Wolfram|Alpha are the most convenient and effective CBLTs for the formation of professional competencies of bachelors majoring in statistics, as they exhibit high performance on all criteria. CoCalc is a cloud-based platform that provides access to various open-source software packages for mathematics, science, and engineering, such as SageMath, Python, R, Julia, etc. Wolfram|Alpha is a cloud-based computational knowledge engine that can answer factual queries, perform calculations, generate plots, and provide step-by-step solutions. Both CBLTs can support the learners' engagement, motivation, feedback, reflection, and collaboration, as well as provide them with various statistical tools and resources.

The general structure of the methodology of using CBLTs for the formation of professional competencies of future bachelors of statistics consists of four main components: objectives, content, forms, and methods. The objectives define the expected learning outcomes and competencies that the learners should acquire by using CBLTs. The content specifies the topics and tasks that the learners should cover and complete by using CBLTs. The forms describe the ways of organizing the educational process by using CBLTs, such as individual work, group work, project work, etc. The methods describe the techniques and strategies that the learners and teachers should use to facilitate the learning process by using CBLTs, such as problem-based learning, inquiry-based learning, collaborative learning, etc.

As a direction for future work, we plan to elaborate on each component of the methodology of using CBLTs for the formation of professional competencies of future bachelors of statistics. We also intend to conduct an empirical study to evaluate the effectiveness and efficiency of our proposed approach and methodology.

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