Using the e-learning course “Analytic Geometry” in the process of training students majoring in Computer Science and Information Technology

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Abstract. As a result of literature analysis the expediency of free access of bachelors majoring in Computer Sciences and Information Technologies to modern information educational resources, in particular, e-learning courses in the process of studying mathematical disciplines is substantiated. It was established that the e-learning course is a complex of teaching materials and educational services created for the organization of individual and group training using information and communication technologies. Based on the outlined possibilities of applying the e-learning course, as well as its didactic functions, the structure of the certified e-learning course “Analytic Geometry” based on the Moodle platform was developed and described. Features of application of cloud-oriented resources are considered: Desmos, Geogebra, Wolfram|Alpha, Sage in the study of the discipline “Analytic Geometry”.

The results of the pedagogical experiment on the basis of Borys Grinchenko Kyiv University and A. S. Makarenko Sumy State Pedagogical University are presented. The experiment was conducted to verify the effectiveness of the implementation of the e-learning course “Analytic Geometry”. Using the Pearson criterion it is proved that there are significant differences in the level of mathematical preparation of experimental and control group of students.

The prospect of further scientific research is outlined through the effectiveness of the use of e-learning courses for the improvement of additional professional competences of students majoring in Computer Sciences and Information Technologies (specialization “Programming”, “Internet of Things”).

Keywords: e-learning course, computer sciences, information technologies, analytic geometry, professional training.

1 Introduction

In conditions of modernization of higher education in accordance with the requirements of the information society development, an important problem remains the free access of individuals of education to modern information educational resources. A number of scientific studies which disclose the tendencies of the development and reformation of modern professional education in the context of the building of an information society have been recently implemented [18; 20]. The influence of information and communication technologies on the improvement of content, forms and methods of teaching has been revealed (Yurii O. Doroshenko [3], Svitlana H. Lytvynova [7], Oleksandr V. Merzlykin [8], Nataliia V. Morze [9], Zarema S. Seidametova [15], Serhiy O. Semerikov [19], and etc.).

Mentioning the undeniable value of the research carried out, another important problem of using electronic educational resources should be outlined, in particular, e-learning courses in the process of studying mathematical disciplines at the university. It should be noted that the issue of extremely low mathematical training of university students worries not only the authors of this scientific work. In recent years, a series of studies aimed at improving the mathematical training of students through ICT has been implemented. Yurii V. Horoshko [5] has developed a system of information modeling in training of future teachers of mathematics and informatics, Yurii S. Ramskyi [12] has developed a methodical system for the information culture formation by future teachers of mathematics. Besides the method of using mobile mathematical environments (Kateryna I. Slovak [17]) and the system of computer mathematics Sage during independent work of high school students (Svitlana V. Shokaliuk [16]), systems of computer mathematics (Oksana I. Tiutiunnyk [21]) are developed. The implemented studies are aimed at improving professional training, mainly students of Engineering and Economic specialties. The problem of improving the professional training of bachelors majoring in Computer Science and Information Technologies through ICT requires further careful consideration.

2 The objective of research

The purpose of our research paper is to prove the effectiveness of using the e-learning course "Analytic Geometry" in order to improve the mathematical training of bachelors majoring in Computer Science and Information Technology.

3 Research methodology

The purpose of research has made us use the complex of the relevant methods: scientific literature analysis in order to establish the state of the problem development, the definition of the categorical and conceptual apparatus of investigation; synthesis, generalization, systematization for theoretical substantiation and practical development of e-learning course; empirical: diagnostic (conversation, content analysis, testing) for monitoring the dynamics of the mathematical training level of students; a pedagogical experiment in order to prove the effectiveness of using the e-learning course; mathematical methods (Pearson criterion) to assess the significance of positive changes in experimental work results.

The research was carried out within the framework of the complex scientific theme of the Department of Computer Science and Mathematics of Borys Grinchenko Kyiv University "Theoretical and practical aspects of the use of mathematical methods and information technologies in education and science", SR No 0116U004625.

Experimental research base: Borys Grinchenko Kyiv University and A. S. Makarenko Sumy State Pedagogical University.

4 Results and discussion

According to the provision on the certification of an e-learning course at the higher education institution level the e-learning course (ELC) is a system of teaching materials and educational services created for the organization of individual and group learning using information and communication technologies [10].

Following the provisions of the ELC, the procedure for the creation, certification and use in the e-learning system at Borys Grinchenko Kyiv University, we note that the main difference between ELCs from the electronic version of the training manual is the following: a clear structuring of educational and methodological materials; the system of interaction between the teacher and the student, students among themselves, organized using the resources of the ELC throughout the time of studying the discipline; system for monitoring the implementation of various types of educational activities [11].

The position of Nataliia V. Morze and Oleksandr V. Ihnatenko is very close to us. They point out that by introducing in the educational process of an e-learning course the educational institution has the opportunity:

- to accumulate and analyse the statistics of students' academic achievements – real-time statistics can be passed on to the teacher, supervisor, and curator, which will enable students majoring in Computer Science and Information Technology to evaluate the results of their own activities;
- to standardize educational content – one e-learning course can be accompanied by several teachers while its content does not change, only the teaching method changes;
- promptly administer – the training administrator can promptly grant or cancel the student's access to the required content;
- to provide interactive cooperation between the teacher and students, students with each other at all stages of the educational process – during the study of theoretical material, its consolidation in the process of performing practical tasks, discussing problem situations and issues, joint implementation of educational projects and their public defence, control the results of educational activities, reflection and self-assessment of students' academic achievements, etc. [9].

The literature analysis confirms that the study of mathematical disciplines by means of ELC implements the following didactic functions:

1. Creation of favourable organizational and methodical conditions for training of future specialists in Computer Sciences and Information Technologies:
   - implementation of the visibility principle: demonstration of the dynamics of the studied processes, graphical interpretation of the studied patterns, conditional

graphic means (tables, diagrams, flowcharts, charts, diagrams, organizational charts, maps, etc.), modern multimedia (audio and video fragments, animation));
- simulation and imitation of processes that are studied and researched, phenomena with the transition to "reality-model" and vice versa;
- providing access to educational materials;
- creation of a stable cognitive motive aimed at the need for obtaining, processing and transmitting information, the use of ICTs at the stage of training and future professional activities;
- the principle of differentiation and individualization of education.

2. Improvement of psychological and pedagogical conditions of educational activity:

- creating interest;
- ensuring an adequate emotional state of students.

3. Implementation of the education content in the conditions of informatization of education.
4. Management of educational activity and formation of the structure of philosophical, behavioural and creative qualities [3].

The teaching experience of the authors of the research paper shows that in order to improve the quality of mathematical training for bachelors majoring in Computer Science and Information Technologies it is worth using an e-learning course as a system of electronic teaching materials designed for the organization of individual, frontal and group training. E-learning courses are posted on the server of e-learning courses at Borys Grinchenko Kyiv University at the address: http://elearning.kubg.edu.ua/. The portal's work is organized on the basis of the use of a Moodle platform.

The Moodle-based platform allows teacher to create and edit text, graphical, animated, multimedia blocks in the body of the course using the built-in courseware, create and edit test tasks, view course-tracking statistics by registered students, and discuss topics in the forum.

Bachelors in Computer Science and Information Technology based on the Moodle platform can study the material in a given teacher sequence, perform tasks, ask questions at the forum for the teacher of the course, use the teaching materials posted by the teacher. All course progress statistics are kept, accessible to both the student and the teacher.

The structure of the certified e-learning course "Analytic Geometry" on the basis of the Moodle platform consists of the following blocks:

1. General information about the course: a work program, a thematic plan, evaluation criteria, printed sources and Internet sources, a glossary, a course guide (presentation of the course, a course card, information about the authors, methodical recommendations for the course work);
2. Each of the modules is represented by the following components:

- *Module guide* which includes methodological recommendations for the content module, mental map of the module and a forum for discussing issues that arise during the study;
- *Theoretical educational material* in the form of structured lecture material, which is provided by means of "book", multimedia presentations, audio and video teaching materials; practical work, which includes a list of main tasks;
- *Tasks for independent work* which include a description and a list of individual tasks for independent study; the deadlines for their implementation and the form of submission, as well as the criteria for evaluation;
- *Modular control* which includes a list of typical tasks for modular control work;

3. The final certification, which includes the list of questions for the exam on the discipline "Analytic Geometry", as well as the example of the examination card (Fig. 1).

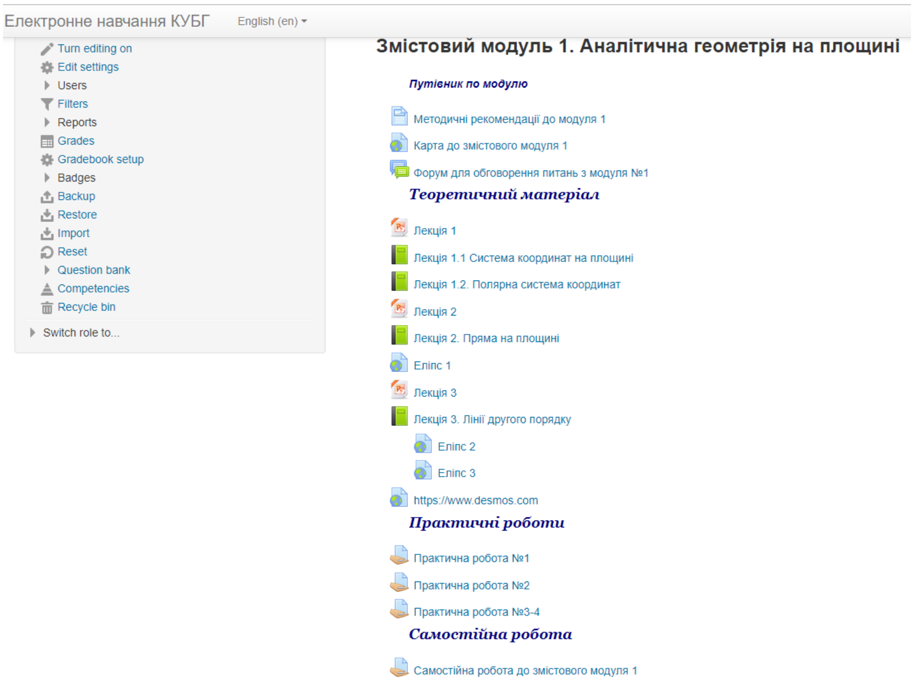

Fig. 1. Content module of ELC "Analytic Geometry"

In addition, the ELC has links to cloud-based resources for the study of higher mathematics.

We have a deep conviction that this kind of ELC structure is convenient for students. This contributes to the realization of their activity within the framework of educational activities (lectures, consultations, practical and individual classes). As practice shows, students also use the developed ELC in the implementation of individual study and research tasks, writing coursework and master's work.

Our selected cloud-oriented technology application in the study of geometry is related to the SaaS model [4]. We share the scientific views of Tatiana V. Batura, Fedor A. Murzin and Dmitrii F. Semich that the main advantages of implementing such a model are the reduction of capital stock in hardware and work resources; reducing the risk of investment loss; a smooth update, and the lack displays as the need for reliable safety features [1].

Let's also turn to the scientific position of Svitlana H. Lytvynova, who points out that cloud-oriented resources for educational institutions have significant advantages, that is: inexpensive computers for users; increased productivity of computer users; reduce costs and increase the efficiency of IT infrastructure; less maintenance problems; less software costs; constant updating of programs; increasing available computing power; unlimited amount of data storage; compatibility with most operating systems; improved document format compatibility; ease of teamwork of user groups; access to documents anywhere and anytime; always the latest version of services; availability of different devices; ecologization and economical spending of natural resources; the stability of the data to the loss or theft of equipment [7, p. 38].

Here are examples of cloud-oriented resources: Desmos, Geogebra, Wolfram|Alpha, Sage, etc [6]. Let's consider the peculiarities of the application of the indicated services in the study of the discipline "Analytic Geometry".

The Desmos Graphic Calculator is an online Internet service that is available at the link https://www.desmos.com/calculator, which builds function graphs using the formulas in the Cartesian and Polar coordinate systems, the graph of the function with the parameters, binding inequalities and contains a set of mathematical patterns and etc. In studying the discipline "Analytic Geometry" it is expedient, in our opinion, to apply this resource within the topic "Analytical geometry on the plane". The resource allows students to demonstrate different types of equations of direct on the plane, as well as equations of curves of the second order on the plane (ellipse, hyperbola, and parabola).

The Wolfram|Alpha [22] computer mathematics system is useful in solving tasks on geometry: construct a vector on a plane and in space, find a vector module, angle with axes, polar coordinates of a vector, calculate the sum and difference of vectors (on a plane and in space), to calculate the scalar product of vectors (on a plane and in space), calculate the vector product in space, find the angle between two vectors (in degrees, radians), the point of intersection of two straight lines on a plane, find the point of a symmetric given relative to the line, the coordinate of the middle of a segment, etc.

Let's consider the use of computer mathematics systems on an example of accomplishing a task: find a point on a plane symmetrical to a point (5, 7) relative to the straight line

$$-x + y + 1 = 0.$$

To do this, you have to offer students the following algorithm:

1. Go to https://www.wolframalpha.com/.
2. Enter the command:

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reflect (5,7) across -x+y+1=0
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3. Get the result (Fig. 2).

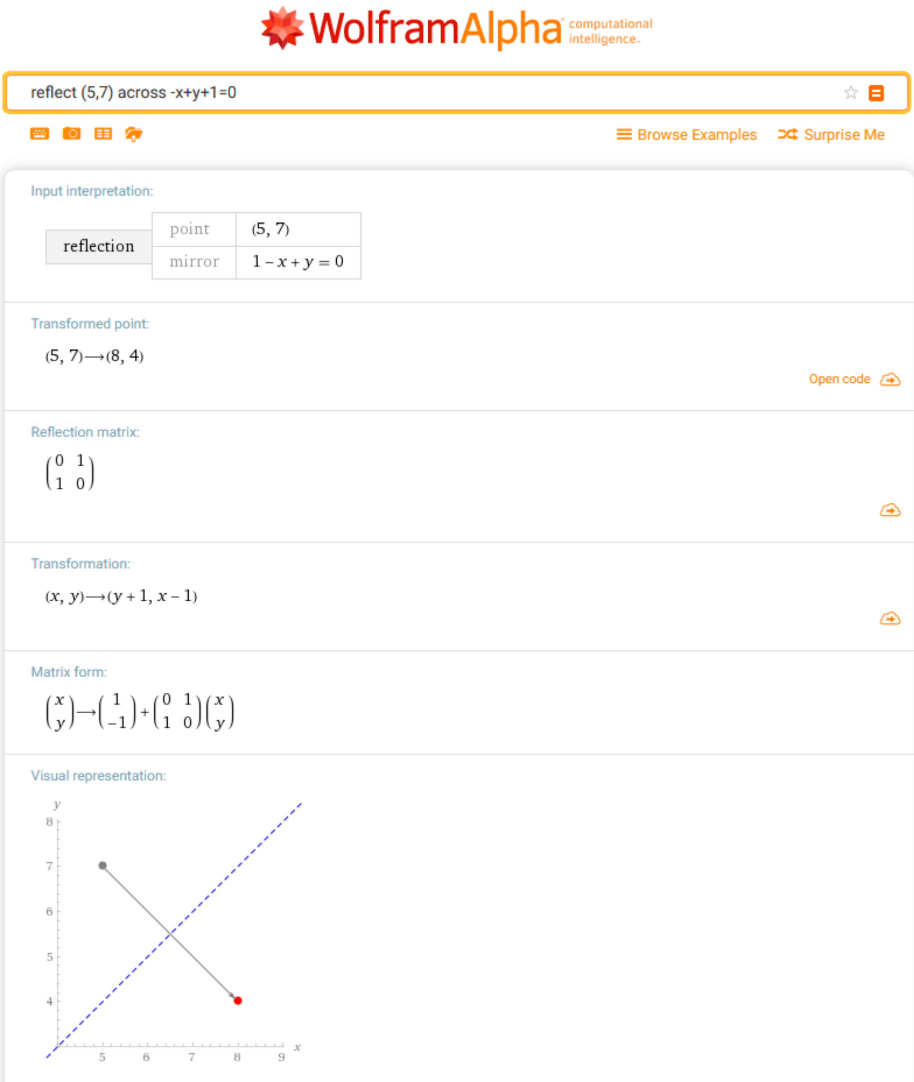

Fig. 2. An example of solving a task in wolframalpha.com

One of the powerful tool for learning mathematics is the GeoGebra Dynamic Geometry System. We agree with the scholars that the functionality of the program and the web-support of GeoGebra users provide an opportunity to use it effectively when studying the vast majority of the topics of the mathematics course. It is important that the program has a wide set of tools for creating dynamic computer models of mathematical objects, which makes it possible to use it not only for solving mathematical problems, but also for organizing heuristic learning, forming skills and abilities of research activity, development of creative abilities of students, creation of dynamic visual manuals, etc. [13].

Let's look at software for algebraic and geometric studies Sage (Software for algebra and geometry experiments). It is an open source distributed mathematical computing environment for performing numerical calculations and symbolic transformations as well as visualization of data [1]. In particular, in the course of geometry it is expedient to use a graphical environment for the demonstration of the operation on vectors, a vector, vector length determination, vector construction, arithmetic operations on vectors, calculations of scalar product vectors, etc.

During 2017-2018 an experimental study was carried out to verify the effectiveness of the implementation of e-learning course "Analytic Geometry". Its goal was to determine the level of mathematical training for students majoring in Computer Science and Information Technology. The experimental research base was Borys Grinchenko Kyiv University (experimental group (EG) in the number of 37 students), A. S Makarenko Sumy State Pedagogical University (control group (CG) in the number of 28 students). An analysis was made of the academic discipline "Analytic Geometry" which is compulsory for students to study both in experimental and control groups. Students of the experimental group were offered an e-learning course. Students in the control group studied higher mathematics traditionally, using a teaching methodology that does not involve the use of e-learning courses and digital resources.

The volume of the educational material of the disciplines "Analytic Geometry" is defined as an independent variable of this study. Assessment of the academic achievements of the experimental and control group students was carried out according to the modular rating system, which is based on the principle of operational reporting, compulsory modular control, accumulation system for assessing the level of knowledge, skills and abilities, expanding the number of final scores to 100. Calculation of rating points by types of current control of load: 18 hours of lectures, 24 hours of practical work and 6 hours of modular control were carried out according to the table 1. The main methods of pedagogical diagnostics which were enabled: methods of verbal verifying of theoretical knowledge, methods of written verification of the learning curve, skills and assumptions – an independent work performed on each practical lesson, and a test work which is given in the form of modular test. Since in the educational process of higher education institutions students receive an official assessment of their academic achievements, which are recorded in the academic class register, the records of the success studies depending on the form of control, therefore the method of studying the products of the activity was used for the study of these data. Analysis of the results of independent work and modular tests allowed to find out the significance of qualitative assessment of academic achievements of students (table 2).

It should be noted that Borys Grinchenko Kyiv University has a unified system for assessing academic achievements of students. The transfer of the final rating grade to the ranking indicators of success in European ECTS assessments is carried out using the algorithm: the transfer coefficient is calculated: $k = \frac{60}{231} = 0,2597$; received during the semester the final rating point of each student is multiplied by the coefficient *k*.

Table 1. Calculation of rating points by types of current (modular) control

No	Type of students activity	Max points number per unit	Module 1		Module 2		Module 3	
			Number of units to be calculated	Max points number per type	Number of units to be calculated	Max points number per type	Number of units to be calculated	Max points number per type
1	Visiting lectures	1	3	3	4	4	2	2
2	Visiting practical classes	1	4	4	4	4	4	4
3	Performing tasks for independent work	5	1	5	1	5	1	5
4	Work on practical (seminar) classes	10	4	40	4	40	4	40
5	Performing of modular tests	25	1	25	1	25	1	25
6	Laboratory classes (admission, performing, protection)	10	–	–	–	–	–	–
	Max number of points by type of current control	–	–	**77**	–	**78**	–	**76**

Table 2. Methodology of calculations of module and semester assessments of the student

No	Student's grade	Max grade	M 1	M 2	M 3
1	Maximum final semester modular grade (MS)	**60**	–	–	–
2	Maximum totals for content modules (MM)		**20**	**20**	**20**
3	The actual number of points received by the student by type of current control (*example*) (AP)		*70*	*70*	*70*
4	Final student's actual grades for content modules M = AP*MM/MS *(example)*		18	18	18
5	Final semester modular student grade $S = M_1+M_2+M_3$ *(example)*		**54**		
6	Examination rating grade of students, (E) *(example)*	**40**	**40**		
7	Final Semester rating student's grade A = S + E *(example)*		**94 / A**		

Thus, during a semester the student can score a maximum of 60 points according to the ECTS system. Other 40 points can be scored on the exam (the theoretical part of the test is presented in the form of tests).

Educational results of the students are recorded in the ELC evaluation register "Analytic Geometry". In the e-register assessments the teacher sets the categories for the assessment of all types of educational activities and their extent (in percentages) relative to the final assessment from the discipline is determined. Each student has a personal register, which shows all categories of evaluation and the results of their own educational achievements (Fig. 3). Within each evaluation module, a 100-point scale is performed. Moodle provides the automatic transfer of points in accordance with the volume of the module in the final assessment of the discipline and representation of the letter mark. In our opinion, such a tool contributes to tracking their own educational activities by each student and analyzing the results of the student's progress with a teacher.

Grade item	Calculated weight	Grade	Range	Percentage	Feedback	Contribution to course total
Вища математика: Геометрія (1 курс, ІНФ, денна)						
Поточний контроль						
M1						
Присутність	23.08 %	21.00	0–21	100.00 %		9.09 %
Практична робота №1	10.99 %	9.00	0–10	90.00 %		3.90 %
Практична робота №2	10.99 %	4.00	0–10	40.00 %		1.73 %
Практична робота №3-4	21.98 %	5.00	0–20	25.00 %		2.16 %
Самостійна робота до змістового модуля 1	5.50 %	5.00	0–5	100.00 %		2.16 %
Модульна контрольна робота №1	27.47 %	21.00	0–25	84.00 %		9.09 %
Σ M1 total	**39.39 %**	**65.00**	**0–91**	**71.43 %**		-
M2						
Практична робота №5	14.29 %	10.00	0–10	100.00 %		4.33 %
Практична робота №6	14.29 %	10.00	0–10	100.00 %		4.33 %
Практична робота №7-8	28.57 %	9.00	0–20	45.00 %		3.90 %
Самостійна робота до змістового модуля 2	7.14 %	5.00	0–5	100.00 %		2.16 %
Модульна контрольна робота №2	35.71 %	23.00	0–25	92.00 %		9.96 %
Σ M2 total	**30.30 %**	**57.00**	**0–70**	**81.43 %**		-
M3						
Практична робота №9-10	28.57 %	14.00	0–20	70.00 %		6.06 %
Практична робота №11-12	28.57 %	19.00	0–20	95.00 %		8.22 %

Fig. 3. User report

The experiment was conducted in two stages: the recording and forming. At the recording stage (May 2017 – September 2017), a set of diagnostic procedures (questionnaires, knowledge sections and conversations of students with teachers) was developed to identify the level of knowledge, skills and abilities of students in discipline. Matching levels are defined for the level of success: the initial level – the grade on the ECTS scale E and D, the average – C, the sufficient – B, and the high – A.

The experimental group was the object of scientific research. During the forming stage of the experiment (October 2017 – July 2018) a complex of methodological materials was offered at the Moodle system on the basis of the e-learning course. At the end of the discipline the educational results were checked in the form of final control.

As a result of the experiment the obtained results indicate the effectiveness of using the e-learning course. Thus, the number of students with a high level of knowledge, skills and abilities in the EG – 26.67%, in the CG – 11.11%; 39.33% for the students of the EG and 42.74% for CG on the sufficient level; 17.3% of EG of respondents and 21.37% of CG is on average level; the initial level is 16.67% of students of EG and 24.79% of CG.

To verify the truth of the hypothesis H_0, H_1 the Pearson statistical criterion χ^2 was used:

H_0 – argues that there are no significant differences in the level of mathematical training of experimental and control students' groups;

H_1 – argues that there are significant differences in the level of mathematical training of experimental and control students' groups.

Determination of criteria statistics χ^2 is carried out according to the formula:

$$\chi^2 = \frac{1}{n_1 \cdot n_2} \sum_{i=1}^{k} \frac{(n_1 Q_{1i} - n_1 Q_{2i})^2}{Q_{1i} + Q_{2i}},$$

n_1, n_2 – volume of samples; Q_{1i}, Q_{2i} – the number of elements of the corresponding samples related to the i-th level; k – number of levels.

The substitution of the values for the formula made it possible to obtain the size of the criteria statistics for the levels of success of the students of the EG and CG groups $\chi^2 = 10.9$.

At the level of significance α=0.05 the critical value for the four levels is 9.49. Determined statistic data $\chi^2 = 10.9$ exceeds the critical value of 9.49. Consequently, in accordance with the rules of decision making the values obtained refute the hypothesis H_0 and give reasons for the hypothesis H_1.

Comparison of the generalized results of the students' success levels before and after the formative stage of the experiment is presented in the table 3.

Table 3. Results of evaluation of students' level of success before and after the formative stage of the experiment

Levels	EG_1, %	EG_2, %	CG_1, %	CG_2, %
Initial	20.67	16.7	25.64	24.79
Average	17.33	17.3	28.21	21.37
Sufficient	43.33	39.3	34.19	42.74
High	18.67	26.7	11.97	11.11

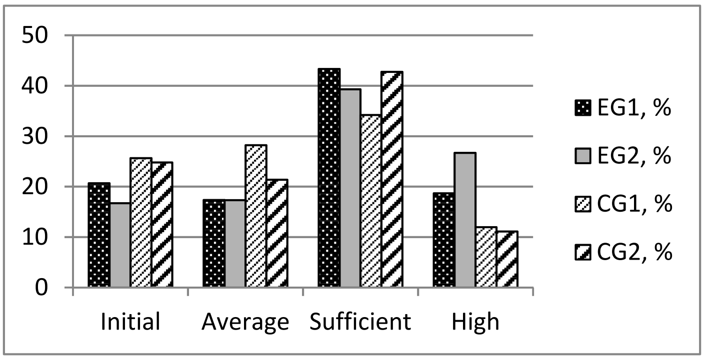

Fig. 4. Comparative data of success styles levels before and after the formative stage of the experiment

Table 3 shows the designation: EG_1 – experimental group (before experiment), EG_2 – experimental group (after experiment), CG_1 – control group (before experiment), CG_2 – control group (after experiment). As can be seen from Table 3 the number of students with a high level of knowledge in discipline in the experimental group increased by 8.03%, in CG – decreased by 0.86%; at a sufficient level the indicator dropped by 4.03% in the EG, but increased by 8.55% in CG; on average, the indicators decreased in both the EG and the CG, respectively, by 0.03% and 6.84% and at the initial level, the indicators decreased by 3.97% in the EG and by only 0.85% in the CG. The graphic representation of the results is reproduced in Fig. 4.

5 Conclusions

1. The importance of free access of bachelors majoring in Computer Science and Information Technologies to modern information educational resources, in particular e-learning courses, in the process of studying mathematical disciplines is substantiated. It was found out that the e-learning course is a complex of teaching materials and educational services created for the organization of individual and group training using information and communication technologies. The possibilities of applying the e-learning course, its didactic functions (creation of favourable organizational and methodical conditions for educational activity, improvement of psychological and pedagogical conditions of educational activity, implementation of the content of education in the conditions of informatization, the management of educational activities and the formation of the structure of ideological, behavioural and creative qualities) are outlined.
2. The structure of the certified e-learning course “Analytic Geometry” based on the Moodle platform has been developed and described. Features of application of cloud-oriented resources are considered: Desmos, Geogebra, Wolfram|Alpha, Sage in the study of the discipline “Analytic Geometry”.
3. In order to verify the effectiveness of the implementation of the e-learning course “Analytic Geometry” on the basis of Borys Grinchenko Kyiv University and A. S. Makarenko Sumy State Pedagogical University an experimental study was carried out. Using Pearson’s criterion, it was found that there are significant differences in the level of mathematical training of experimental and control groups of students.

The prospect of further research is to demonstrate the effectiveness of using e-learning courses in order to improve the additional professional competences of students majoring in Computer Science and Information Technologies (specialization “Programming”, “Internet of Things”).

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