Cloud-based Service GeoGebra and Its Use in the Educational Process: the BYOD-approach

Elena Semenikhina, Marina Drushlyak, Yuliia Bondarenko,
Svitlana Kondratiuk, Nelia Dehtiarova

Makarenko Sumy State Pedagogical University, Romenska Str., 87, Sumy, Ukraine

Abstract **– The authors propose one of the possible ways to solve the problem of insufficient number of computers in public educational institutions and limited access to computer classes in Ukraine. Such a way is the introduction of the BYOD-approach (Bring Your Own Device) in the learning process. The authors specify the content and correlation of the concepts of "information technologies", "computer technologies", "cloud technologies" to determine the type of *GeoGebra* service. The authors propose different ways of using the *GeoGebra* service. They are studied to prepare future math teachers for the use of modern information (digital) technologies in professional activities.**

Keywords **– *GeoGebra* service; cloud-based technologies; BYOD-approach; Information and digital competence of the future math teacher.**

1. Introduction

Among many problems teachers of natural and mathematical disciplines face while using information technologies in the professional activity, not the last place is occupied by the problems of insufficient number of computers in public educational institutions and limited access to computer classes. Because of this, attraction towards information technologies often occurs sparingly (or only by the teacher) or is realized only during independent work [1]. At the same time, young people often use their own mobile devices not only to communicate on networks, but also to maintain their own educational activities through organization of the search for the necessary information materials, creation of their own projects, group communication for developing joint solutions etc.

The solution of the problem is seen in different ways, among which we will highlight the active implementation of the BYOD-approach (Bring your own device), which allows you to attract to the educational process more powerful mobile devices with the 3G-connection, than those offered by the educational institution, as well as the use of cloud services of the subject area.

Application of the BYOD-approach is not understood yet by the teachers and the pedagogical Universities, as it is stated in [2], have not yet prepared specialists who will allow students – future teachers – to use fully this technology for educational purposes. Training of a teacher, who can implement such approaches is still an urgent pedagogical problem.

In the pedagogical literature, the problem of implementation of cloud-based [3], [4], [5] and mobile [6], [7], [8], under which we understand the combination of mobile hardware and software, as well as a system of methods and forms of such means in the educational process with the purpose of obtaining, saving, processing and reproduction of audio, video, text, graphics and multimedia data in terms of operational communication with global and local resources, learning technologies, the BYOD technology in the framework of mobile learning (M. A. Zilberman,R. I. Ostapenko, T. V. Aliekseieva, A. H. Dubynskyi, N. V. Dolmatova, P. H. Matuhin) is actively discussed.

According to the analysis of the scientific research, we have found out that there are ways offered to solve physiological, social, pedagogical, technical problems that may arise while using the BYOD

DOI: 10.18421/TEM81-08
https://dx.doi.org/10.18421/TEM81-08

Corresponding author: Marina Drushlyak,
Makarenko Sumy State Pedagogical University, Sumy, Ukraine
Email: marydru@fizmatsspu.sumy.ua

Received: 19 October 2018.
Accepted: 24 December 2018.
Published: 27 February 2019.

approach in [9], [10], advantages and disadvantages of using the BYOD model in the educational process are described in [11], experience of using the services *presentain.com*, *preso.tv* to broadcast presentations and lectures on students' mobile devices in [12], expediency of using file hosting service MS OneDrive to view the content of files such as web pages, chat *Messenger, Skype*, which are integrated into the environment MS OneDrive in [13], experience in the use of pupils' personal mobile devices in primary schools during the control of knowledge with the help of the service *Plickers* as mobile app to read *QR* codes from the pupils' cards in [14], technologies of questionnaire of college students using *Plickers* service in [15].

At the same time, we have determined a lack of scientific research in the direction of using specialized cloud-based services. Among such services for physics/ biology/ chemistry/ geography are resources *VirtuLab* (http://www.virtulab.net), *PhET* (https://phet.colorado.edu/uk/), *Wolfram Demonstrations Project* (https://demonstrations.wolfram.com), Open Source *Physics* (https://www.compadre.org/osp), virtual chemistry lab *Virtual Lab* (http://chemcollective.org/),*Maps* (http://www.edu.ru/maps/). In the context of training support of natural and mathematical disciplines we have identified the resource *GeoGebra* [16].

The aim of the article is to describe the cloud-based service *GeoGebra* and ways of its use in the training of natural and mathematical disciplines.

The aim of the article has preconditioned solving the following tasks:

1) to clarify the content and correlation of the concepts "information technologies", "computer technologies", "cloud-based technologies" to determine the type of *GeoGebra* service;

2) to describe ways how to use the service *GeoGebra* at math lessons;

3) to confirm the feasibility of the formation skills to use cloud-based services of this type in the training of future teachers of natural and mathematical specialties.

2. Results and Discussion

In the context of the information society development, we often encounter technologies and processes that are associated with the processing of information content and which are called "information technologies", "computer technologies", "Internet technologies", "cloud-based technologies" and "fog technologies". Their interpretation allows identification from the standpoint of the need to use specialized technical devices for the implementation of such technologies (personal computer, smartphone, tablet, etc.). At the same time, they cannot be identified from the perspective of the data processing method.

Information technologies are technologies, which involve the use of different means and methods combination of processing and transmission of primary data about the object (process or phenomenon) to obtain secondary data about it. Such process does not necessarily involve the use of computer technology.

Computer technologies are information technologies which use computer facilities to process and transmit primary data about an object (process or phenomenon) to obtain secondary data about it. In other words, in computer technology, the principle is the use of computer to implement the technology itself.

Internet technologies are computer technologies which are designed to work with the Internet. In other words, it is all that is connected with the Internet and is subject to certain protocols and programs.

Cloud-based technologies are the Internet technologies which provide a way of data processing through online services and provide for the performance of basic functions through centralized Data-centers. In other words, these are the technologies that constantly store user information content on the Internet servers, which are only temporarily cached (stored) on the user side on stationary computer systems. Nowadays, within the framework of cloud-based technologies, "*fog technologies*" are singled out. These are cloud-based technologies that are characterized by the distribution of calculations between devices that are included in the Internet of things (in particular, smartphones, which are used today by almost everyone, have processors that are not actively used). When using cloud/fog technologies, secondary data are created from shared resources and are always transferred to the "cloud" (to a remote server) [17].

Well known services *YouTube* (video-sharing company that provides services for storing, searching and displaying video materials), *Office365* (cloud-based Internet service and software from Microsoft company that expands under "software + services") have such property Analysis of such services found that the *GeoGebra* resource is a cloud-based service, because it offers data processing on-line and provides fulfilment of certain actions: its use involves a view of created by others educational content (Fig.1.), as well as network communication (Fig.2.), and also the development and addition of own training materials (Fig.3.), which confirms its cloud orientation.

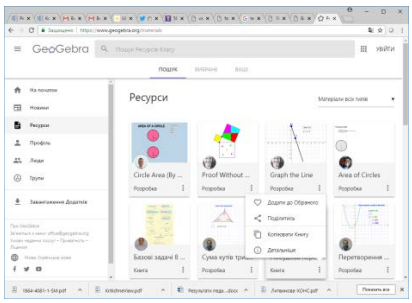

Figure 1. View GeoGebra content

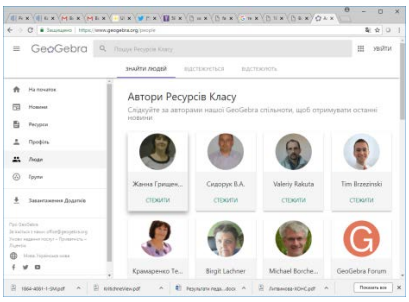

Figure 2. Network communication in GeoGebra

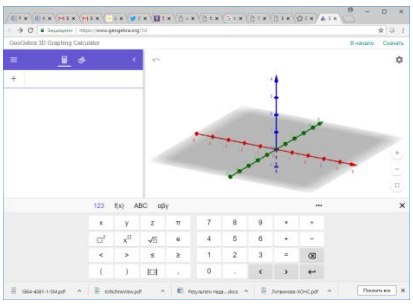

Figure 3. GeoGebra Graphics View to create your own materials

GeoGebra resource can be perceived also as a social community, which unites the ideas of popularization of mathematical ideas, laws, scientists, teachers, and all those interested in mathematics.

If you perceive the *GeoGebra* resource as a network, there should be distinguished two types [18]: the first is characterized by the use of profiles such as *Facebook* (Fig.4.), the second is characterized by the use of interactive applets such as *YouTube* (Fig.5.). The second type of social network provides the ability to leave "likes" to the applets that you liked the most, to combine applets by themes, to embed applets in other objects using automatically generated HTML-code.

In order to use the *GeoGebra* resource in professional activities, you need to register on the website *geogebra.org* (you can use existing *Google, Office365, Microsoft, Facebook, Twitter* accounts) and create your own profile (*Profile Creation*).

To download the author's applets, click the button *+New* and select the item *Create Worksheet*. Then you need to enter the title of the applet, add the text of the task, instructions for its implementation, add the *GeoGebra* file in the format **.ggb*. For registered users there is a possibility to edit the added content (*Edit Worksheet*): adding information, for example, various explanations, comments or restrictions on access to files.

The authors outlined the following ways of using the *GeoGebra* service:

1) as a cloud environment for hosting visualising content or as a means of visualization of mathematical knowledge;
2) as a cloud environment for the organization of empirical rather than analytical search of the answer while determining some characteristics of objects;
3) as a cloud environment for conducting home computer experiment.

Let us consider them in details.

1. *GeoGebra* as a cloud environment for hosting visualising content or as a means of visualization of mathematical knowledge;

As the terminological analysis shows the concept "visualization" is identified with the perception of some object through visual image. We understand visualization as the process of demonstrating something that requires not only the reproduction of the visual image, but also its creation. For this purpose, the means of computer visualization of mathematical knowledge are used. They are computer environments, where developers provide opportunities for mathematical modelling of processes, creating images of objects and interactive operation of them [19].

This is especially important in the field of mathematical education, since Mathematics often operates with abstract forms that are difficult to explore without visual support [20], [21], [22]. The properties of geometric shapes (the sum of the angles of a triangle, the location of the centres of the circumscribed and inscribed circles, locus, sections of solids), graphs of functions (in particular, their transformation, dependence on parameters), solutions of equations, inequalities and their systems (analytical and graphical solution), random variables and their properties (the probability of the event, statistical characteristics of the sample) can be visualized at the level of school mathematics.

For example, before studying the topic of "Body of rotation", the teacher can place interactive applets in the cloud, after working with which students will be already prepared to perceive the cone (the applet "Cylinder", available: https://www.geogebra.org/m/dgbu2kvq, Fig.4.) as body of rotation.

2. *GeoGebra* objects as a means of organization of empirical rather than analytical search of the answer while determining individual characteristics of objects.

In this case, we see the possibility to use the resource for implementing a constructive approach to solve, for example, geometric extremum problems.

Problem. The sum of the lengths of the cone base radius and its height is constant and equal to 10. At what ratio of the radius and the height volume of the cone will be the biggest? (the applet "Extremum problem", available: https://www.geogebra.org/m/befv4ye7, Fig.5).

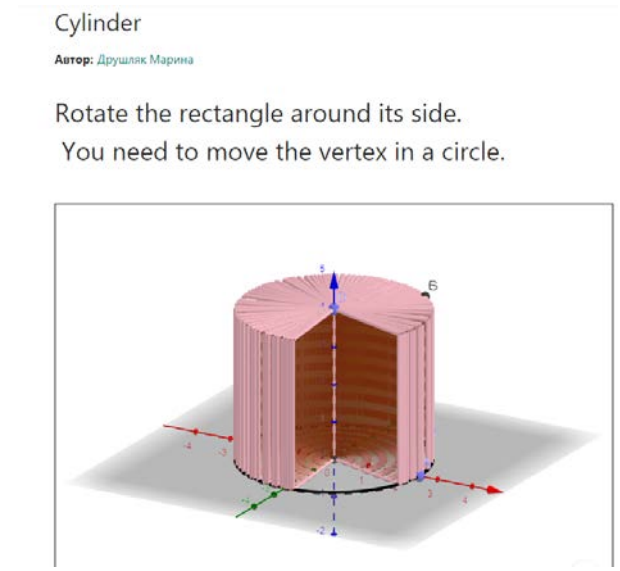

Figure 4. Applet "Cylinder"

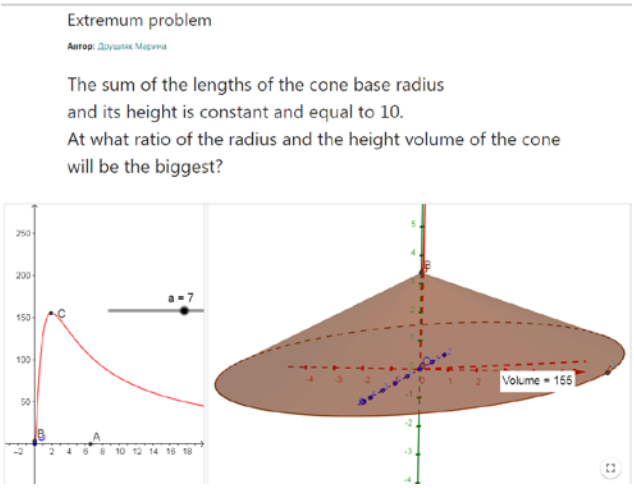

Figure 5. Applet "Extremum problem"

When changing the position of the base point *A*, the proposed table is filled in with the appropriate value sets. We can analyse the dynamics of changes in the volume value – value is growing up to the certain point, and then falling. Critical value 155,1 is achieved at the ratio of 2.

3. *GeoGebr*a objects as a cloud environment for conducting home computer experiment.

A large number of scientists (V. D. Boiev, A. Yu. Ivanova, M. N. Mariukov, I. B. Petrov, R. P. Sypchenko, M. I. Starovyk, D. E. Temnov) consider a computer experiment as a kind of model, where a substitute of a real object/process is a virtual model. Others scientists (A. H. Hein, I. H. Semakin, L. V. Pihalitsyn) believe that the computer experiment is "an experiment with data on the results of observation of the behaviour of the system under consideration, which are stored in electronic tables to predict the behaviour of this or a similar system outside the sphere of observations" [23]. We prefer the definition of a computer experiment, which is given in [24]. Computer experiment is an experiment, which is carried out in dynamic mathematics software (means of computer visualization of mathematical knowledge, which provide the dynamic operation of various mathematical objects and the ability of operation obtaining on-screen information about their properties [19]), where the object of study is a dynamic model of the geometric configuration. This interpretation, in our opinion, is fully consistent with the meaning laid down by different authors in the description of this method of teaching in the school course of geometry.

Before studying the topic "Lengths of segments in a circle", the teacher can place applets on the Internet (in particular on *https://www.geogebra.org* or on their own site), where the possibility of experimental study of metric relations is foreseen (the applet "Lengths of segments in a circle", available: https://www.geogebra.org/m/jhEexqpD, Fig.6.; https://www.geogebra.org/m/sPguGVsV, Fig.7.). The task is to fill in the Tables 1-2.

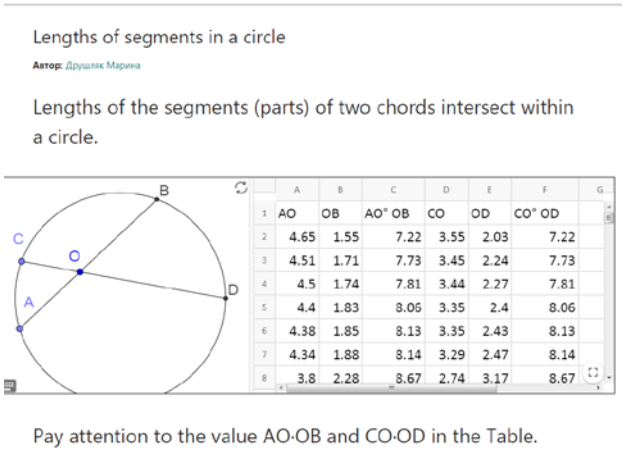

Figure 6. Applet "Lengths of segments in a circle"

Table 1. Lengths of the segments (parts) of two chords intersect within a circle

Lengths of the segments (parts) of two chords intersect within a circle						
№	AO	OB	AO·OB	CO	OD	CO·OD
1						
2						
3						

Note: Pay attention to the values of AO · OB and CO · OD in the Table.

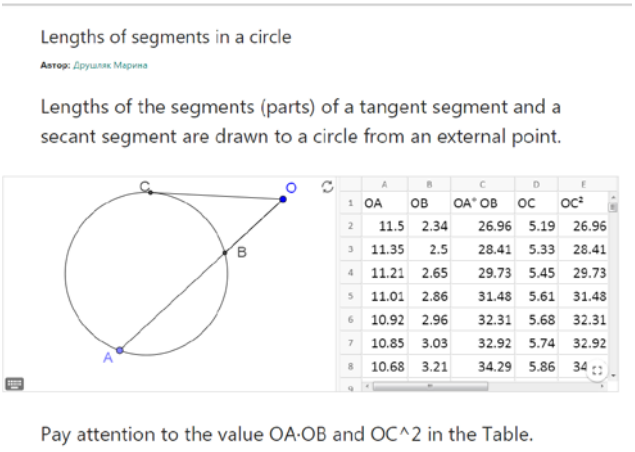

Figure 7. Applet "Lengths of segments in a circle"

Table 2. Lengths of the segments (parts) of a tangent segment and a secant segment are drawn to a circle from an external point

Lengths of the segments (parts) of a tangent segment and a secant segment are drawn to a circle from an external point					
№	OA	OB	OA·OB	OC	OC^2
1					
2					
3					

Note: Pay attention to the values of OA · OB and OC^2 in the Table.

Pupils conduct research at home and fill tables. They are already prepared to formulate hypotheses about the relationship between lengths of the segments (parts) of two chords intersect within a circle and lengths of the segments (parts) of a tangent segment and a secant segment are drawn to a circle from an external point at the next lesson.

Hypothesis 1: if two chords intersect within a circle, then the product of the lengths of the segments (parts) of one chord is equal to the product of the lengths of the segments of the other chord.

Hypothesis 2: if a tangent segment and a secant segment are drawn to a circle from an external point, then the square of the length of the tangent equals the product of the length of the secant with the length of its external segment.

The ideas described by us are studied in the framework of the special course "Digital technologies in education" (topic "Applets and their use in the educational process"). The main aim is to prepare future teachers for the use of modern information (digital) technologies in professional activities. In book [25] in addition to the theoretical material about the applets and features of their development, we offer tasks for independent execution.

Individual task

Pre-reformulate the theorem as a research task and create an interactive applet to demonstrate the theorem using *GeoGebra*.

1. An isosceles triangle has two congruent angles.
2. In an isosceles triangle, the median drawn to the base is both the altitude and the bisector.
3. In a triangle, the sum of the measures of the interior angles is 180°.
4. The diagonals of a parallelogram bisect each other.
5. The diagonals of a rhombus are perpendicular.
6. The length of the median of a trapezoid equals one-half the sum of the lengths of the two bases.
7. If two parallel lines are cut by a transversal, then the alternate interior angles are congruent, the interior angles on the same side of the transversal are supplementary.
8. The measure of an exterior angle of a triangle equals the sum of the measures of the two nonadjacent interior angles.
9. The diagonals of a rectangle are congruent.
10. The segment that joins the midpoints of two sides of a triangle is parallel to the third side and has a length equal to one-half the length of the third side.

The created applets can be directly tested in the classroom on the mobile devices of all students of the academic group.

Our experiment on the formation of future teachers' skills to use cloud-based services in professional activities confirmed the effectiveness of the study by the following method: 0.5 hours of lecture was given to the description of cloud technologies and BYOD-approach in the educational process, then there was a students' questionnaire, then one lesson was devoted to the study of *GeoGebra* applets and their use, and then there was again a questionnaire.

Questionnaire

What do you know about the use of cloud-based services in the teacher's professional activity?

1. Do you know any specialized cloud-based services?
2. Will you be able to develop a summary of the lesson with the use of cloud-based technologies?
3. Do you know what the BYOD-approach is in education?
4. Do you see any ways to use BYOD-approach in your future professional activity?

5. Will you be able to organize educational process based on BYOD-approach?

The study was carried out during 2016-2017. Statistical evaluation of training results could be carried out on the basis of the nonparametric sign test for dependent samples [26]. At the end of the study of the topic comparative tables were formed. The dynamics of the results of the questionnaire responses was recorded.

The total number of respondents was 146 people. 30 results out of them were chosen arbitrarily (Table 3.).

Table 3. The students' test results

№ of student	First questioning	Second questioning	№ of student	First questioning	Second questioning	№ of student	First questioning	Second questioning
1	2	3	11	2	5	21	1	3
2	1	4	12	2	4	22	2	3
3	2	4	13	3	3	23	2	2
4	1	3	14	3	3	24	3	2
5	1	2	15	3	3	25	3	3
6	2	4	16	1	2	26	3	3
7	3	4	17	2	4	27	3	3
8	3	2	18	2	2	28	2	4
9	2	5	19	2	3	29	2	3
10	3	2	20	3	3	30	3	5

The number of respondents whose total score decreased ("–"), did not change ("0") and increased ("+") was determined according to these scores (Table 4.).

Table 4. Dynamics of scores in the students' test result

Dynamics of scores	Negative, «–»	Without changes, «0»	Positive, «+»	The number of changes, n=«–»+«+»
The number of respondents	4	10	16	20

In accordance with the aims of the experiment, the null hypothesis was formulated: the study of the topic does not contribute to the formation of ideas about the use of cloud-based services in future professional activities. Then the alternative hypothesis in the study of the topic contributes to this formation.

Formulated hypotheses determine the one-way sign test for testing dependent samples. Since $T_{exp}=16$ is not included in the interval of acceptance of the hypothesis H_0 (interval [6],[14] for the significance level of 0.05) [26], the alternative hypothesis was accepted with the conclusion that the study of the topic contributes to the formation of skills to use cloud-based services in future professional activities. Since the value of T_{exp} has gone beyond the segment on the right, the conclusion about the positive dynamics of the number of such students who have formed an idea about the use of cloud-based services in future professional activities, was made.

As practice shows, with successful motivation students are actively involved in this process, realizing the effectiveness of BYOD technology in the modern world. In particular, according to the results of an additional survey of students, the future teachers of mathematics, physics, computer sciences, chemistry (total number of respondents is 146 people), it was found that: the use of this type of cloud-based services in professional activities is

considered to be appropriate by 89% and effective by 76% of respondents; 83% of future teachers will use in their own professional activities (a smaller percentage in the use of such a service showed future teachers of chemistry (53%), who noted the need for additional development of the relevant creative tasks of the chemical direction).

The questioning of working teachers of mathematics and computer sciences (total number of respondents is 74 people) revealed the majority of negative attitudes to such innovation: 46% of respondents believe that cloud-based service is suitable for teaching mathematics, effective – 32% of respondents; 12% of working teachers will use it in their own professional activities.

The additional need for training future teachers to use this technology is provided by the modern unsatisfactory technical condition and the level of computerization of state educational institutions: the use of out-dated computer equipment, its insufficient number, limited access to it by teachers of non-informatics disciplines, insufficient power of stationary Internet networks, etc.

These facts determine the search for ways that would ensure the modern educational process and its compliance with the level of development of modern (digital) technologies. The concept of a new Ukrainian school [27] focuses on the formation of information and digital competence, which "...presupposes confident and at the same time critical application of information and communication technologies for creation, search, processing, exchange of information at work, in public space and private communication". This means the need to form the young generation's digital competence through the cross use of digital technologies in the study of various subjects, personalized and at the same time in the interaction of students with each other, with teachers, experts etc. This need is realized by offered BYOD-approach and the use of specialized cloud-based services, in particular, *GeoGebr*a.

We believe that our vision of using cloud-based services correlates with the state document "On the digital agenda of Ukraine» [28], which today is proposed for discussion to the Ukrainian society. It is based on the idea of digitalization of all spheres of activity, and, above all, digitalization of education. Its adoption will allow to achieve the goals defined in the Conceptual framework of the project "Digital agenda of Ukraine – 2020" [29], which points to the urgent need to revise "the curricula of higher education institutions, the accelerated introduction of new courses that meet the requirements of Industry 4.0." We believe that the described approach to the training of future teachers of natural and mathematical specialties to use cloud-based services in professional activities is a step towards the formation of the younger generation's digital competencies.

3. Conclusion

1. Modern education should take into account not only the development of information/digital technologies and actively use them, starting from the lower level of education, but also the current state of computerization of public educational institutions. This leads to the use of the potential of private mobile devices in training sessions and cloud services that they support. Now this use is the basis for the implementation of BYOD-approach in the educational process and specialized cloud-based services.

2. *GeoGebra* resource is a cloud-based service of mathematical direction, because it provides tools for creating mathematical models of various mathematical objects or processes, offers data processing online and performing of certain actions regarding communication with adherents without the need to involve stationary computer equipment. Among the ways of using *GeoGebra* service we found: the location of author's visualised content, the possibility of empirical numerical study organization and organization of local computer experiment.

Their implementation will contribute to the formation of a cross-digital competence of the younger generation.

3. Developed topic "Applets and their use in the educational process" within the special course "Digital technologies in education", which is focused on the formation of ideas about the use of cloud-based services in future professional activities, confirmed its effectiveness by the sign test at the significance level of 0.05.

References

[1]. Semenikhina, O. V. & Drushlyak, M. G. (2015). Dynamic mathematic software in the context of the work of a modern teacher: the results of a pedagogical experiment, *Informatsiini tekhnolohii v osviti*, *22*, 109-119.

[2]. Sweeney, J. (2012). BYOD in Education (A report for Australia and New Zealand). Intelligent Business Research Services.

[3]. Spirin, O. & Eremeev, V. (2017). The usage of cloud services in the process of professional training of programmers at higher educational institutions, *Informatsiini tekhnolohii v osviti*, *32*, 7-20.

[4]. Shyshkina, M. P. & Popel, M. V. (2013). Cloud based learning environment of educational institutions: the current state and research prospects, *Information Technologies and Learning Tools*, *5*(37), 66-80.

[5]. Sejdametova, Z. S., Abljalimova, Je. I., Medzhitova, L. M., Sejtvelieva, S. N. & Temnenko, V. A. (2012). *Cloud technologies and education*. Simferopol': "DIAJPI".

[6]. Semerikov, S., Teplytskyi, I. & Shokaliuk, S. (2008). Mobile learning: history, theory, methodology, *Informatyka ta informatsiini tekhnolohii v navchalnykh zakladakh*, *6*, 72–82.

[7]. Rashevska, N. V. (2011). *Mobile information and communication technologies of learning calculus (higher mathematics) students' in higher technical institutions, thesis for the degree of candidate of pedagogical sciences*, Institute of Information Technologies and Learning Tools NAPS, Kyiv.

[8]. Slovak, K. I. (2011). *Methodic of using mobile mathematical environments in the process of education higher mathematics of student of economic specialties, thesis for the degree of candidate of pedagogical sciences*, Institute of Information Technologies and Learning Tools NAPS, Kyiv.

[9]. Zil'berman, M. A. (2014). The use of mobile technologies (BYOD technology) in the educational process. Retrieved from: http://didaktika.org/2014/p/ispolzovanie-mobilnyh-tehnologij-v-obrazovatelnomprocesse/. [Accessed on: Jul. 20, 2018.]

[10]. Alekseeva, T. V. (2015). Byod Technologies in Education", in *V international scientific conference*, Prague, 177.

[11]. Telezhinskaja, E. L. & Dudareva, O. B. (2016). Mobile education is a tool of the modern teacher, *Nauchnoe obespechenie sistemy povyshenija kvalifikacii kadrov*, *2*(27), 88-94.

[12]. Dubinskij, A. G. (2014). Informatization of the educational process: several simple solutions", in *Conference "Perspective innovations in science, education, production and transport»*. Retrieved from: http://www.sworld.com.ua/konfer37/784.pdf. [Accessed on: Jul. 20, 2018]. (in Russian).

[13]. Matuhin, P. G., Gracheva, O. A., Jel'sgol'c, S. L. & Pevnickaja, E. V. (2016). Tabular organization of educational content as the basis of the BYOD complex for supporting and controlling the training of foreign students in physics and the Russian language of physics on the basis of the cloud resource MS ONEDRIVE. Retrieved from: http://inforino2016.mpei.ru/transfer2pub. [Accessed on: Jul. 20, 2018]. (in Russian).

[14]. Dolmatova, N. V. (2016). Use of personal mobile devices in the educational process, in All-Russian Scientific and Methodological Conference "The Modern Lesson in the Conditions of the Implementation of the GEF: Experience, Problems, Prospects", Orenburg, 82-86.

[15]. Ostapenko, R. I. (2017). Teaching of information cycle disciplines with the help of BYOD, *Perspektivy Nauki i Obrazovanija*, *5*(29), 66-73.

[16]. GeoGebra., (2018). Retrieved from: https://www.geogebra.org. [Accessed on: Jul. 20, 2018.]

[17]. Kleyman, B. (2013). Welcome to Fog Computing: Extending the Cloud to the Edge. Retrieved from: https://xcluesiv.com/welcome-to-fog-computing-extending-the-cloud-to-the-edge/. [Accessed on: Aug. 11, 2018.]

[18]. Alferov, M. Ju., Fedorova, Ju. V., Nevskaja, O. V., Paromova, S. Ja. & Kalinin, A. A. (2015). Dynamic geometry software *GeoGebra* as a tool for creating social objects of networked pedagogical communities, in *XXVI International Conference "Application of Innovative Technologies in Education»*, Troitsk, Moscow, 178-179.

[19]. Semenikhina, O. V. (2016). *Professional readiness of the future math teacher to use the dynamic mathematics software: theoretical and methodical aspects*, Sumy, Ukraine: «Mriya».

[20]. Dalinger, V. A. (1999). *Formation of visual thinking among students in the process of teaching mathematics: Textbook*, Omsk, Rossija: Izd-vo OmGPU.

[21]. Reznik, N. A. (1997). *Methodical foundations of teaching mathematics in secondary school using the means of developing visual thinking, thesis for the degree of doctor of pedagogical sciences*, Institute of Productive Education of the Russian Academy of Education, Moscow.

[22]. Sergeev, S. I. (2012). Computer visualization in mathematical education as a practical pedagogical task, *Problems of Education in the 21st Century*, *49*, 95-103.

[23]. Gejn, A. G., Senokosov, A. I. & Yunerman, N. A. (2002). *Informatics: textbook*, 10-11, Moskva,: Prosveshhenie.

[24]. Shabanova, M. V. & Shirikova, T. S. (2013). Computer experiment in the system of methods of working with the theorem, *Sovremennye problemy nauki i obrazovanija*, 2. Retrieved from: http://www.science-education.ru/108-9005. [Accessed on: Jul. 20, 2018].

[25]. Semenikhina, O. V. & Drushliak, M. H. (2017). *Computer-oriented systems of teaching mathematics. Tutorial*, Sumy: SumDPU im.A.S.Makarenka.

[26]. Grabar, M. I. & Krasnjanskaja, K. A. (1977). *Application of mathematical statistics in pedagogical researches*. Nonparametric methods. Moscow: Pedagogika.

[27]. New Ukrainian school. Retrieved from: https://mon.gov.ua/ua/tag/nova-ukrainska-shkola. [Accessed on: Jul. 20, 2018].

[28]. On the Digital Agenda of Ukraine. Retrieved from: http://www.rada.gov.ua/uploads/documents/40009.pdf. [Accessed on: Jul. 20, 2018].

[29]. Digital Agenda of Ukraine – 2020. Conceptual foundations. Retrieved from: https://ucci.org.ua/uploads/files/58e78ee3c3922.pdf. [Accessed on: Jul. 20, 2018].