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Approaches to Teaching Geometry in Kazakhstan Schools Using Information Computer Resources for Educational Purposes

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Abstract

In the context of rapid technological changes and modernization of society, the issue of ensuring adequacy of content in secondary education based on the use of advanced information technologies (ICT) is being updated. The necessity of an appropriate level of primary intellectual activity development in a person in terms of the current trends in society has been determined. In this regard, the goal of the article is to argue advantages of using software products in geometry lessons in the secondary education system of the Republic of Kazakhstan (RK). By the method of expert assessments, criteria for effectiveness of using ICT in geometry lessons have been developed to form applied geometric competencies in students. Functional advantages of certain software product types in the process of teaching geometry in secondary education have been substantiated. A set of practical tasks with the use of ICT for the academic discipline of geometry has been developed. Based on a pedagogical experiment, the effectiveness of using such ICTs in geometry lessons as Microsoft PowerPoint, Microsoft Excel and AutoCAD ensuring applied orientation of the academic discipline has been substantiated and proved. The main problems of introducing ICT in the educational process in the current context have been identified. A set of practical measures has been presented that would contribute to effective and extensive ICT absorption in the process of teaching geometry in secondary education. The presented scientific research findings will contribute to implementation of the advanced education concept and its computerization under the conditions of information society development.

Keywords: secondary education system, geometry, geometric competencies, computer information technologies, learning process technology.

1. Introduction

The quality of education is assessed by the level of knowledge gained, by formation of creative personal qualities and practical competencies aimed at performing social and professional

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functions (Herppich et al., 2017). What should rank first in general scholarship of an intellectual is their geometric education and formed geometric competencies (Pervushkina, Efimovich, 2015). This owes to the fact that people live in a substantial world that is structurally geometric. However, in the course of time, new areas of spatial perception are formed (virtual spaces, multidimensional spaces, digital technologies, etc.), production and industrial technologies change as well (Suh, Prophet, 2018). With all these changes, the main provisions of the very discipline "Geometry" are not only preserved without losing their relevance, but are also developing (Mammarella et al., 2017). Pursuant thereto, geometry leaning goals and technologies and, accordingly, geometric education in the secondary education system of the Republic of Kazakhstan based on the use of information and computer technologies should change (Nazarbayev, 2012; Almaty Education Department, 2013).

Any teaching technology is information technology, as the basis of technological learning process is formed by acquisition and transformation of information (Heitink et al., 2016). Formation of new information technologies within subject geometry lessons enhances the need for creation of new courseware aimed at qualitative improvement of lesson effectiveness (Heitink et al., 2016). Therefore, for successful and purposeful use of information technology in the educational process, secondary education teachers should know a general description of operation principles and didactic scope of software applications and then, based on their experience and recommendations, use them in the educational process. Such an approach contributes to formation of practical geometric competencies in students by means of learning process individualization, students' independent work intensification and training differentiation (Rambousek et al., 2015; Gastelú et al., 2015).

In this regard, the goal of the research is to substantiate the effectiveness of introducing ICT in the geometry teaching process using the example of eleven graders in Lyceum No. 9 named after O. Zholdasbekov in Shymkent with advanced study of mathematics and physics. Within the framework of the research, the following tasks of scientific cognition have been solved: the main problems in the geometry teaching process in secondary education of Kazakhstan have been identified; the most effective ICTs for formation of applied geometric competencies in students in the process of teaching geometry have been determined and the advantages of their use in the educational process based on the pedagogical experiment have been argued; a set of practical measures to increase the effectiveness of ICT use in geometry lessons has been substantiated.

2. Materials and methods

The methodological basis of the research is the following scientific cognition methods.

A pedagogical experiment is a set of logically arranged research operations aimed at a purposeful observation of the educational process in the context of regulated changes in certain characteristics of its progress conditions (Massyrova et al., 2015).

The pedagogical experiment implementation in this study involves the following successive steps:

1. Justification of criteria for comparing software products. Proof of the criteria system representativeness (equations 1, 2);
2. Comparative analysis of software products applicable for geometry studies in school, selection of the most effective ones in terms of feasibility of mathematical operations;
3. Determination of the selected programs use indicating didactic goals and objectives that are to be solved by means of these programs and examples of the software use;
4. Formation of a control and experimental group of students to assess the effectiveness of ICT use;
5. Teaching a class according to a Geometry Training Program using ICTs by areas of activity to the experimental group and the same class without using ICTs to the control group;
6. Development of assignments to diagnose the students' level of knowledge following the classes given. Evaluation of an assignment quality: reliability (equation 3) and validity (equation 4);
7. Assessment of the students' knowledge in the control and experimental groups. A test of statistical significance of differences in the students' level of knowledge obtained in the control and experimental groups (equation 5);
8. Calculating the ICT use effectiveness index in geometry lessons (equation 4), proof of ICT feasibility for geometry studies.

The experiment was carried out on eleven graders in Lyceum No. 9 named after O. Zholdasbekov in Shymkent with advanced study of mathematics and physics, with a total of 188 students (96.4 % of all the eleven graders in the school).

Expert assessment method. This statistical method was used to define effectiveness criteria certain software products use in geometry lessons in terms of their feasibility in the educational process in the form of a generalized opinion of professionals (experts).

To substantiate representativeness of the criteria for comparing software products and assessing feasibility of their introduction in the educational process for geometry studies, an expert group was formed. It included: Deputy Director for Studies and Educational work, four math teachers of Lyceum No. 9 in Shymkent, through the example of which the feasibility of ICT introduction in the educational process in geometry studies is assessed, and two computer science teachers.

The competence of the expert group on ICT introduction in teaching geometry is confirmed by higher teacher education of the experts, the teaching of mathematics and computer science, and over 10 years' work experience in the teaching profession.

The method of individual scoring was applied, whereby the experts were asked to assess the representativeness of each criteria separately (the applicability of each criterion in evaluation) and the entire proposed criteria system on a scale from one to ten (how much the proposed system is able to characterize the feasibility of ICT introduction in geometry teaching process). Score 0 indicates the lack of representativeness in a criterion, 10 stands for the maximum representativeness and the possibility to assess ICT feasibility by this criterion.

The representativeness coefficient is calculated by the formula (Astfalck et al., 2018):

$$R = \frac{\sum_{i=1}^{n} a_i}{\sum_{i=1}^{n} \acute{a}_i} \cdot 100\%, \qquad (1)$$

where R is the representativeness coefficient of a criterion (criteria system), as %;

a_i is the estimate of representativeness by an expert;

$\acute{a}_i$ is the maximum possible estimate by an expert (10 points);

n is the number of experts.

The use of individual expert assessment makes it possible to level out the influence of other experts, thereby ensuring unbiased opinions.

Consistency of expert opinions is indicated by the value of variation coefficient (<10 %) (equation 1) (Rousseau et al., 2018):

$$v = \frac{\sigma}{\bar{x}} * 100\ \%, \qquad (2)$$

where v is the variation coefficient of the expert estimates, as %;

σ is a standard deviation of the experts' estimates;

$\bar{x}$ is the arithmetic mean deviation of the expert estimates.

Interpretation of the results is as follows:

$v \leq 10$ % indicates that the expert estimates are characterized by low variability and a high degree of consistency;

10 $< v \leq 20$ % indicates that the expert estimates are characterized by an average degree of variability;

$v > 20$ % indicates that that expert estimates are characterized by a high variability and the degree of expert consistency is low.

The quality of test assignments (stereotyped level), their feasibility for assessing students' knowledge has been evaluated by reliability (3) and validity (4) indices (Ryabinova, Bulanova, 2016).

$$K_r = \frac{n}{n-1} \cdot \left(1 - \frac{\sum_{i=1}^{n} p_i q_i}{S^2}\right), \qquad (3)$$

where n is the number of test assignments;

p_i is the ratio of correct answers to the –th assignment;

q_i is the ratio of incorrect answers to the –th assignment;

S^2 is the variability of the scores obtained.

$$K_v = \frac{(\overline{X_1})_i - (\overline{X_0})_i}{S} \cdot \sqrt{\frac{(N_1)_i \cdot (N_0)_i}{N(N-1)}}, \qquad (4)$$

where $(\overline{X_1})_i$ is the average value of individual scores of the students (the average grade in geometry in the past year) who completed the task correctly;

$(\overline{X_0})_i$ is the average value of individual scores of the students(the average grade in geometry in the past year) who did not complete the task correctly;

S is a standard deviation of individual points;

$(N_1)_i$ is the number of students who completed the task correctly;

$(N_0)_i$ is the number of students who did not complete the task correctly;

N is the number of students tested.

The reliability indicator characterizes the invariance of the test under the effect of random variables. The test is feasible at $K_r \geq 0.7$.

Validity is a test applicability index showing the possibility to use it for a specific purpose (in this case, to assess the level of geometry knowledge). The validity index in the range [-1; +1] is measured, where -1 means there is no correlation between students' performance level in geometry and the test results; +1 means all students with a high performance level gave the correct answers to tests, while incorrect answers were given by those with a low level of academic achievement. If the validity coefficient value is < 0.3, the test has low validity and is not applicable for knowledge assessment; if over the range [0.3; 0.6), it has the average validity; if [0.6; 1], it has high validity (Ryabinova, Bulanova, 2016).

To test the statistical significance of differences in the level of knowledge in the control and experimental sample of students, Pearson's chi-square test is used (χ^2-test). χ^2-test is calculated by the formula (Nabiulina, 2015):

$$\chi^2{}_{\text{расч}} = \frac{N\cdot(|n_{1k}\cdot n_{0e} - n_{0k}\cdot n_{1e}| - \frac{N}{2})^2}{N_k\cdot N_e\cdot(n_{1k}+n_{1e})\cdot(n_{0k}+n_{0e})}, \qquad (5)$$

where N is the number of students tested;

N_k is the number of students in the control group;

N_e is the number of students in the experimental group;

n_{1k} is the number of correct answers to tests among the control group students;

n_{1e} is the number of correct answers to tests among the experimental group students;

n_{0k} is number of incorrect answers to tests among the control group students;

n_{0e} is the number of incorrect answers to tests among the experimental group students.

When $\chi^2{}_{\text{calc}} > \chi^2{}_{\text{tab}}$, the null hypothesis of no difference between the values of sample characteristics is rejected, whereas at $\chi^2{}_{\text{calc}} < \chi^2{}_{\text{tab}}$ it is accepted.

The effectiveness of ICT use in geometry lessons is calculated by the formula (Massyrova et al., 2015):

$$\eta = \frac{AS_e}{AS_k}, \qquad (6)$$

where AS_e is the average score of test results for the experimental group;

AS_k is the average score of test results for the control group.

The value of $\eta > 1$ indicates the feasibility of ICT, whereas $\eta \leq 1$ indicates its unfeasibility.

3. Findings

Learning goals should be consistent with public demands, that is, with those problems that society poses for education. Under the current conditions in Russian schools, geometry syllabus is covered from the perspective of two subdisciplines: plane geometry dealing with planar figures and their properties; solid geometry dealing with solid figures and their properties. Application of plane geometry is essential to the development of such disciplines as physics, chemistry, geography, and others based on understanding the connection between solid figures and the three-dimensional world around. However, given the fact that the geometry course contents are too simplistic, they do not adequately reflect the relationship of geometry with the surrounding world. Internal and logical connection between plane and solid geometry is terminologically and practically substantiated for math teaching method (Pervushkina, Efimovich, 2015), yet, a scientifically grounded methodical technology to implement this relationship with due regard to achievement age and cognitive abilities of students, as well as teaching principles (scietificity, comprehensibility, etc.) remains in progress.

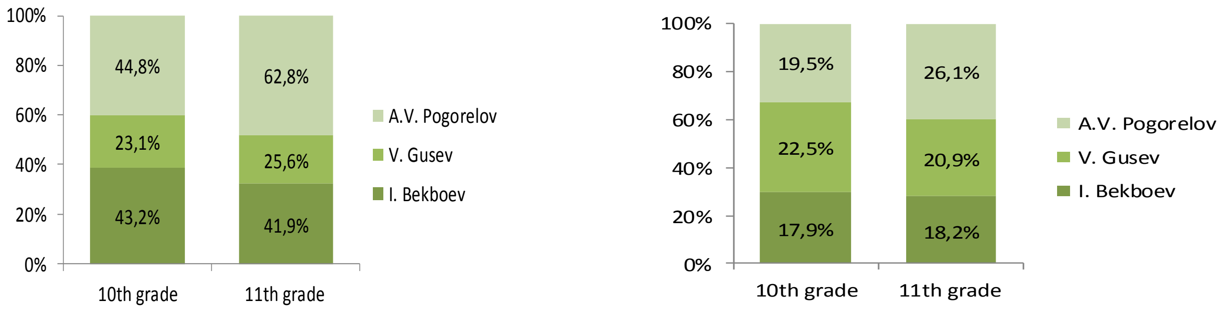
In addition, a destructive factor in the learning process is a distribution of periods when studying geometry areas. Solid geometry studies begin only in the 10thgrade, whereas many students can interrupt their training after the 9thgrade. In other words, students leave school without studying solid geometry.

At the math curricula level in general education school, this problem has found a certain partial solution only as the following changes in the programs:

an increased scope of instruction material in geometry studied at the propaedeutic level in the 5th-6thgrades;

the geometry teaching in the middle school is completed with the area "Solid Geometry Elements", whereas only the first solid geometry lessons in the 10th grade provide an insight into polyhedra, solids of revolution and their plane in the sections (Ministry of Education…, 2017).

Another important problem in geometry studies in the secondary education system is applied orientation of the training course inextricably linked with the problem of geometric competency formation in students. Thus, analysis of the most commonly used geometry textbooks in Kazakhstan schools for the 10th-11thgrades has shown that the ratio of learning activities in textbooks for the 10th grade ranges from 23.1 % to 44.8 %, and for the 11th grade it ranges from 25.6 % to 62.8 % (Figure 1), whereas there are 2 % to 7 % of applied problems therein out of the total task material, with the volume of illustrative material not exceeding 22.5 % for the 10th grade and 26.1 % for the 11thgrade (Figure 1). The current situation indicates an insufficient level of applied nature of procedural guidelines for geometry lessons in the secondary education system.



Correlation of tasks

Correlation of visual information

Fig. 1. Correlation of tasks and visual information in geometry textbooks for the 10th-11th grades by the most commonly used authors in the system of secondary education of the Republic of Kazakhstan

Applied orientation of a geometry course is implemented in ways to apply school geometry knowledge in everyday life, in industries and in science. The applied orientation techniques of solid geometry course are focused on formation of students' ability to study the surrounding phenomena in mathematical terms, to analyze, to create mathematical models, that is, they equip students with knowledge and skills that are indispensable in solving problems practically. In this regard, given the shortcomings existing in the process of forming geometric competence in school students, it seems expedient and necessary to mainstream information computer technologies (ICT) in the educational process.

In Kazakhstan, continuous efforts are also taken to digitalize training to fit the times. Within the framework of e-learning, 41 metropolitan educational institutions were included in the experiment, including 32 schools and 9 vocational educational institutions. Project "School of the Future Today" has been implemented in 17 schools of the city. In an interactive studio of the Department of Education, online lessons and educational events were held (Ministry of Education…, 2015). At the same time, in 2015, Astana Innovations JSC launched new pilot project "Smart School", with its performance specifications being almost identical to those of the "School of the Future Today" system (Electronic Office Systems, 2015). Within the government program "Digital Kazakhstan" for 3rd-4th grades, the subject "Information and Communication Technologies", which forms general basic skill to operate modern information technologies for their effective use in learning and everyday life, has been introduced. 372 groups on robotics have been founded to teach the general basics of programming within the robotics framework. The aim of the project is to organize joint project activities of students and teachers by means of modern and emerging technologies (The Prime Minister…, 2017).

It is planned to set up a specially equipped BilimBook room in schools of three Kazakhstan regions. Bilimbook contains four educational resources in Kazakh, Russian, and English languages – universal educational platform BilimLand, virtual training simulator for UNT (Unified National Testing) and CTA (Complex Testing of Applicants) iTest, full elementary school curriculum in the Kazakh language iMektep, a kit of more than 1,500 absorbing educational films Twig-Bilim. Within the framework of this project, the schools will be equipped with a newly modified room – an interactive whiteboard with a projector and a safe box with 18 touch-screen laptops-transformers. BilimBook is designed for individual use by a student in order to enhance the learning motivation and to stimulate their cognitive activity (Bilim Media Group, 2017).

In addition, specialized package Geometre's Sketchpad, version 3.1, developed by Key Curriculum Press, has been created to study basic geometrical figures and their characteristics (Mukminova, 2016). The program ensures student activity in the field of analysis, problem solving, theorem proving, allows them to reveal trends in geometric phenomena, to formulate theorems for subsequent proving and to develop skills to comprehend them. The package is recommended for use in math lessons in the 6^{th}-9^{th} grades and is widely used in schools of the Republic of Kazakhstan.

ICTs have quite a diverse range of uses in educational process, of which the main ones are: the use of ICT as a computing device and multimedia tools, to simulate various phenomena and processes, as a means for reinforcing the competences developed by students (Olmedo-Torre et al., 2017; Rambousek et al., 2015; Gastelú et al., 2015). Therefore, within the framework of the research, a pedagogical experiment was conducted to determine priority ICTs when studying geometry in schools, as well as the effectiveness of their use.

The pedagogical experiment advantage in this study is the possibility to actively influence the formation of geometric competencies in students by providing new conditions. In this study, new conditions are the use of appropriate ICTs in geometry lessons.

Within the framework of the research, analysis of those main software products has been carried out that are feasible in geometry studies, are of applied nature and contribute to the geometric competence formation.

The results of evaluating the criteria informativeness based on the expert assessment results according to equations 1 and 2 are presented in Table 1.

Table 1. Representativeness indices of the criteria for assessing the feasibility of ICT introduction in the learning process when studying geometry

Criterion	Average representative ness rate, as %	Standard deviation in expert estimates	Variation coefficient of expert estimates, as %
Applicability in plane geometry studies	100	0.0	0.0
Applicability in solid geometry studies	100	0.0	0.0
Option to work with spreadsheets	84	0.5	6.3
Option to work with ready-made geometric figures	93	0.8	8.1
Option to model geometric figures to high precision	96	0.5	5.6
Availability of predefined templates of geometric objects	86	0.5	6.2
Option to design complex real systems	87	0.8	8.7

According to the results of expert evaluation, the most representative criteria are: applicability in plane geometry studies and applicability in solid geometry studies (100 %). The average representativeness rate of all the criteria exceeds 84 %, that is, in 84 % of cases these criteria are applicable for assessing the feasibility of ICT introduction.

The representativeness of the proposed criteria system as a whole is 82 %. The part of unrecorded criteria that can be used to assess the feasibility of ICT introduction is 18 %.

These criteria system allows for an overall assessment of the applicability and feasibility of a certain software product in school geometry studies according to their functional purpose.

The results of comparative analysis of software products based on the expert opinions are presented in Table 2.

Table 2. Comparative analysis of software products for formation of geometric competency in secondary education of the Republic of Kazakhstan

The effectiveness criterion of use in the educational process	Software product							
	Gran-2D	Gran-3D	GeoGebra	Microsoft Excel (Open Office Calc, LibreOffice Calc)	Microsoft PowerPoint	AutoCAD	MatLAB, Mathcad	Statistica
Applicability in plane geometry studies	+	-	+	+	+	+	+	+
Applicability in solid geometry studies	-	+	+	-	+	+	+	+
Option to work with spreadsheets	-	-	-	+	-	-	+	+
Option to work with ready-made geometric figures	+	+	+	+	+	+	+	+
Option to model geometric figures to high precision	+	+	+	+	-	+	+	+
Availability of predefined templates of geometric objects	+	+	+	-	-	+	-	-
Option to design complex real systems	-	-	-	-	-	+	+	+
Share of positive estimates by the criteria,%	57.1	57.1	71.4	57.1	42.9	85.7	85.7	85.7

The school curriculum in geometry, as already mentioned, consists of two parts: “Plane Geometry” (studied in the 7th-9th grades) and “Solid Geometry” (for the 10th-11th grades), therefore, the main criteria for software products comparison are feasibility of their use when studying these areas of geometry. Out of the programs presented in Table 1, the possibility of studying plane geometry is offered by all the programs with the exception of “Gran-3D”, which is used to model geometric figures in three-dimensional space. In turn, Gran-2D, Microsoft Excel (Open Office Calc, LibreOffice Calc) are inapplicable for studying solid Geometry.

The use of spreadsheets when studying a geometry course allows one to solve the areas and volumes of geometric figures, to find the length of segments, sides, the grade measures of angles, thereby simplifying work with large data arrays. The most common spreadsheet editor aimed at work with spreadsheets is Microsoft Excel (Open Office Calc, LibreOffice Calc) (Grech, 2018). It also allows one to work with Statistica spreadsheets.

Thus, from the comparative analysis (Table 2), all the software products listed above offer the option to work with ready-made geometric figures: their representation in different planes, a stage-by-stage demonstration of their construction process, a visual illustration of differences in properties of geometric figures. In addition, all the programs on this list, except for Microsoft PowerPoint, allow one to model geometric figures. Microsoft PowerPoint is a program for creating and viewing presentations demonstrating ready-made geometric figures and texts that characterize basic properties of these figures and formulas, and their scope of application.

Microsoft PowerPoint allows one to build simple geometric figures, although without high accuracy, because this program provides no opportunity to specify, for example, such data as coordinates of vertices, lengths of sides, angles, etc. (Pate, Posey, 2016).

Gran-2D, Gran-3D, GeoGebra, AutoCAD are specialized programs designed to construct geometric figures, they have ready-made templates.

The possibility to engineer complex real systems is given by software products AutoCAD, MatLAB, Mathcad, and Statistica. They include a wide range of tools for modeling real systems and solving complex technical, economic, environmental, educational, psychological, and other problems by using and reinforcing geometric knowledge and skills.

Based on the results of comparing software products by the proposed criteria, program products AutoCAD, MatLAB, Mathcad, and Statistic are characterized by the highest percentage of positive expert estimates (85.7 %). Yet, given their performance specifications, it can be argued that AutoCAD is the most effective for geometry studies (Liu et al., 2017). This stems from the fact that it provides the most extensive functionality for 3D modeling of geometric objects as compared to MatLAB, Mathcad, Statistica.

Also, it should be noted that it is expedient to use this program in studying both plane geometry and solid geometry, since it allows one to work with figures on two- and three-dimensional planes, to model new figures and to demonstrate those already formed. Applied skills to work in this very program in geometry lessons would lay the groundwork for development of the future competence to model complex real systems used in the higher education system and professional activity.

However, it should be noted that in some cases, additional use of Microsoft Excel to compute and Microsoft PowerPoint to present theoretical material is advisable. It is complementary and integrated use of these software products that will ensure applied nature of the academic discipline "Geometry" and will promote development of geometric competence in secondary school students.

Based on the functionality of Microsoft PowerPoint, Microsoft Excel, and AutoCAD, topic "Cylinder Volume" was developed according to the Geometry Training Program. ICTs were used to develop the following areas of the topic, taking into account attainment of the didactic aim of geometry lessons (Table 3).

Table 3. Scope of ICT use when studying the topic "Cylinder Volume" in geometry lessons for eleven graders of Liceum № 9, Shymkent

Software product	Didactic aim	Issues to be addressed
Microsoft PowerPoint	Theoretical material delivery, visualization of knowledge	The concept and properties of a cylinder. Types of cylinders, their features. Formulas for solving the area of a cylinder base, finding a cylinder volume, height, and cross-sectional area. Applications of cylinders in engineering
Microsoft Excel	Consolidation of the delivered theoretical material, reinforcement of skills in solving geometric problems	Finding a cylinder volume, height, cross-sectional area, base radius
AutoCAD	Consolidation of the delivered theoretical material, modeling geometric objects	Construction of a cylinder with specified characteristics: the base radius, the height. Representation of a geometric figure from different projections. Cross section of a cylinder. Building real object models

Microsoft PowerPoint enables the user to visually demonstrate the model of a cylinder in different planes and draw a parallel with similar reality objects (mechanical parts, buildings) to communicate the practical significance of the topic to students. This would contribute to the formation of knowledge about the properties of a geometric figure, the ability to determine it in space, the ability to practically apply knowledge and skills. In addition, the use of presentation material enables students to repeatedly return to the material studied on their own, which will improve the perception of the material.

Microsoft Excel is proposed to be used to find a cylinder volume, height, cross-sectional area, base radius. Using spreadsheets allows one to speed up the process of solving similar problems; to sort and filter geometric objects by the following criteria: radius, area, height; to conduct a comparative analysis of objects according to these criteria; to identify the relationship between the height of a cylinder and the cross-sectional area, between the base radius and the cross-sectional area, between the grade measure of an arc that the section plane intercepts and the cross-sectional area. Consequently, the main goal is achieved, which is formation of the ability to solve computational stereometric problems, as well as the skills of operating databases: sorting, filtering, and the use of subtotals. The variety of tasks solved improves perception and acquisition of educational material.

Software product AutoCAD is used for practical consolidation of the delivered theoretical material and modeling of geometric objects (cylinders). This program makes it possible to construct a cylinder by the base radius and the height (Figure 2), to change its parameters by elongating and rotating, to draw a section plane (Figure 3), to create more complex objects consisting of cylinders (Figure 4).

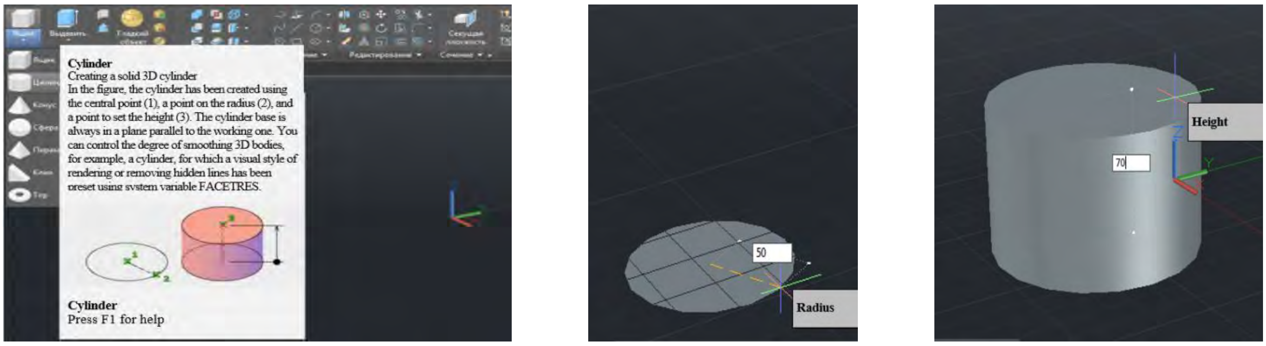


Fig. 2. Constructing a cylinder in AutoCAD

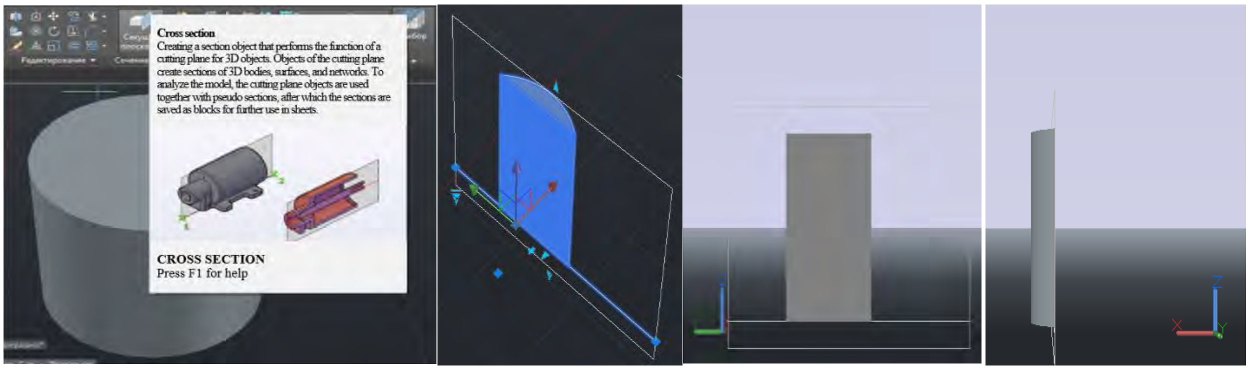


Fig. 3. Cross section of the cylinder from different projections

Fig. 4. A water pipeline elbow modeled from cylinders in AutoCAD

The use of ICTs when studying the topic "Cylinder Volume" makes it possible to attain such didactic aims of the lesson as: formation of knowledge about the characteristics and properties of a cylinder; familiarity with the cylinder construction technology in AutoCAD; acquisition of skills to construct a cylinder with specified parameters; formation of abilities to cube a cylinder, to find the base radius and the cross-sectional area.

For the cognitive development purposes, the following tasks are solved: development of spatial awareness in students; development of logical thinking, the ability to generalize and concretize; development of attention and the ability to observe and consolidate knowledge; formation of the ability to compare, to find similarities and differences; development of computer skills, and so on.

To confirm the effectiveness of ICT use in geometry studies, a pedagogical experiment was conducted, whereby eleven graders of Lyceum No. 9 in Shymkent were requested to solve the tasks of two complexity levels: stereotyped tasks by the standard algorithm proposed by the teacher and described in geometry textbooks; heuristic tasks that do not have a standard solution algorithm and require the use of complex geometry knowledge.

The use of tasks of two complexity levels has made it possible to assess the formedness level of baseline competencies (the ability to solve computational stereometric problems), as well as creative, analytical, spatial problems.

Stereotyped problems

Task 1. As a result of a cylinder section, a square is obtained. At what distance from the axis of the cylinder is the section plane drawn? The cylinder height measures 10 cm, the base radius is 6 cm, and the section plane is parallel to the cylinder axis.

Possible answers:

a. 4 cm;
b. $\sqrt{16}$cm;
c. $\sqrt{11}$cm;
d. 9 cm

Task 2. A plane is drawn through a cylinderaxis. Calculate the diagonal of the rectangle resulting from the section if the cylinder base radius measures 7 cm and the height measures 4 cm.

Possible answers:

a. 8 cm;
b. $2\sqrt{53}$cm;
c. 14 cm;
d. $12\sqrt{7}$cm

Task 3. The diameter of a cylinder base (d) is equal to its height (h). $d = h = 10$ cm. In the cylinder, points in the circumferences of the lower (point K) and upper (point N) bases are connected in such a way that the angle between the radii drawn to these points is $\alpha = 60^0$. What is the angle between the straight line connecting points K and N and the cylinderaxis?

Possible answers:

a. $arctg\ \frac{1}{2}$;
b. $arccos\frac{3}{8}$;
c. 30^0;
d. 45^0.

Task 4. A line is drawn through points A and B lying in the circumference of the lower and upper bases of a cylinder, respectively. The angle between the straight line and the cylinder diameter is 45^0. What is the total surface area of the cylinder if its height measures 5 cm?

Possible answers:

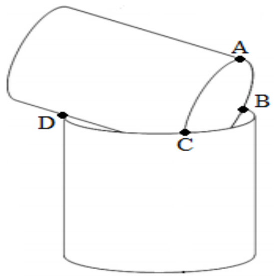
a.	28.3 cm^2	c.	53.8 cm^2;
b.	$31\sqrt{2}cm^2$;	d.	37.5 cm^2.

Heuristic problems

Task 1. If a cylinder filled with water deflects by an angle α, 1/8 of the water flows out. If the cylinder deflects by an angle 2α, another quarter of the remaining water will flow out. Find angle α.

Task 2. A cylinder with radius R stands in a horizontal plane. Another one with radius r (r <R) is placed on a larger cylinder, as shown in Figure 1.

Describe the space locus where point A can appear.



Points B, C, D are adherent points of the cylinders.

Figure 1

Criteria for assessing practical assignments

The correct answer to a stereotyped task is estimated at 1 point. The assessment range of heuristic tasks is 0-4 points:

1 point – the task is not solved, but basic formulas necessary to solve the problem are given, a graphic layout of the task is drawn;

2 points – the task is half-solved: a graphic layout of the problem is drawn, basic formulas necessary to solve the problem are given, calculations for solving the problem are made partially;

3 points – the task is solved correctly but not fully justified;

4 points – the task is solved correctly, fully justified and proved, with a graphical representation of the decision result.

In order to conduct the pedagogical experiment and evaluate the effectiveness of ICT use in the educational process, a control group (students who studied the topic "Cylinder Volume" without using ICT) and an experimental group (students who studied the topic using Microsoft PowerPoint, Microsoft Excel, AutoCAD) were formed. In order to ensure the experimental outcome integrity, the control and experimental groups were formed in such a way that the average level of students' progress in geometry was approximately the same for both groups (Berlinski, Busso, 2017).

The index of stereotyped problems reliability for knowledge assessment on the "Cylinder Volume" topic, calculated by formula 3, is 0.77; the validity index (formula 4) is 0.71, which testifies of this test applicability to students' knowledge assessment.

The validity index was also calculated for heuristic problems. At the same time, the correct answer to such a task scored 4 points. The validity coefficient for was 0.97 the first heuristic task and 0.99 for the second one. Consequently, the proposed test is applicable for assessing the level of students' knowledge in the "Geometry" discipline when studying the topic "Cylinder Volume".

The average score of the students' knowledge test results in the control and experimental groups was 7.4 points for the control group and 8.9 points for the experimental group.

As shown by the pedagogical experiment, a significant difference in the levels of knowledge between the two groups of students was observed when solving heuristic tasks: 3.9 points (control group), 5.1 points (experimental group).

The coefficient of ICT use effectiveness calculated by formula 6 was 1.09for solving stereotyped problems and 1.31 for heuristic ones.

To test statistical significance of the differences in the level of knowledge gained by the students in the control and experimental samples, Pearson's chi-square test (χ^2-test) was used (equation 5). Based on the calculation results, an excess of the χ^2-test calculated value (7.73) over the tabulated one (3.84 at a significance level of 0.05) has been determined, which indicates statistical significance of differences in the level of knowledge of the control and experimental group students.

4. Discussion

Thus, the effectiveness of using such software products as Microsoft PowerPoint, Microsoft Excel, AutoCAD in the process of teaching geometry in the secondary education system has been confirmed by the outcome of the pedagogical experiment, especially in terms of formation of creative, analytical, and spatial competencies in students. The average grade in geometry in the experimental group of students exceeds its level in the control group by 1.5. The use of ICT has proved to be especially effective in performing heuristic geometry tasks, whereby the level of the experimental group knowledge exceeds the level of the control group by 1.2 points.

An essential advantage of using Microsoft PowerPoint, Microsoft Excel, and AutoCAD in the process of forming geometric competency is to ensure applied nature of learning as the main problem of studying geometry in the present day Russian secondary education system. Its applied nature is ensured by individualization of learning and intensification of students' independent work, an expansion of the assignments scope in class and of information flows when using the Internet. In other words, the use of ICT contributes to a more intensive study of the academic discipline over the standard time allocated for geometry studies. This approach can solve such an existing problem as teaching the fundamentals of solid geometry in preceding grades, for example, in the 8th-9thgrades.

The use of ICT gives new opportunities to the teacher, allowing them together with the student to enjoy fascinating cognitive process, to delve into a vivid colorful world by means of advanced technologies. Such an activity causes emotional uplift in children; even slow learners are willing to work with computers (Mukminova, 2016).

Integration of a regular geometry class with ICTs, in particular, with software products Microsoft PowerPoint, Microsoft Excel, AutoCAD allows the teacher to shift part of their work to the computer, thereby making the learning process more interesting, diverse, and intense. In particular, the process of writing down definitions, theorems, and other important material is speeded up, since the teacher does not have to repeat information several times (instead, they screen it), whereas the student does not have to wait until the teacher repeats exactly the fragment they need.

This approach to teaching provides many advantages for teachers: it helps them to better assess children's abilities and knowledge and to understand them, encourages them to look for new, unconventional forms and methods of teaching, and stimulates professional growth and further development of ICTs in the teaching process (Heitink et al., 2016).

The use of computer tests and diagnostic kits in class would provide an insight for teachers into the level of the studied material acquisition by all students in a short time and to adjust it in a timely manner. At the same time, it is possible to select the complexity level of a task for a particular student

In lessons integrated with ICTs, students acquire computer literacy and learn to use one of the most powerful modern universal tools, a computer, to work with geometry material, whereby they solve equations, construct graphs and diagrams, prepare texts and drawings for their papers. This is an opportunity for students to show their creative potential (Rambousek et al., 2015). It means that the use of an interactive geometric environment contributes to a student's personality development: inuring self-control and self-reflection in students, changing their role in the educational process from being passive observers to becoming active researchers. The quality of mathematical training also increases through the development of logical, heuristic, algorithmic thinking and spatial awareness in students.

However, along with the positive aspects of ICT use in the process of teaching geometry in the secondary education system, there are various problems both in preparation for such lessons and in class.

One of the main problems of effective ICT use in teaching school students is the facilities and equipment in Kazakhstan schools that are not sufficient for teaching such classes. As of 2017, Kazakhstan ranks 75th in the world in terms of ICT use in education (Almaty Education Department, 2013). Computer availability in schools of the country is 25 %, which means one computer per 12 students (Ministry of National..., 2018). An exit strategy for the current situation could be implementation of the following measures:

– teachers forming a geometry training agenda in computer classrooms for a semester or for the entire academic year by reference to time necessary to use computers for educational purposes;

– heightened interest in the use of information technology in learning other disciplines, not just mathematical ones by organizing and demonstrating lessons using ICT, developing creative assignments, publishing information about grade and school achievements online, organizing various competitions using multimedia and useful software products.

The next factor restraining ICT introduction in the learning process is strict compliance with sanitary-engineering standards for a personal computer use in geometry classes. Since a prolonged computer use is quite harmful for the child's body, it is necessary to fix optimal time limits for its usage (Miidla-Vanatalu, 2014). In this case it will be expedient:

– for the teacher to specify a list of geometry topics, the study of which is a priority with the use of ICT;

– to involve a wide range of programs in the learning process without requiring additional programming knowledge;

– to accurately plan geometry lesson stages using ICTs as much as possible according to the permissible standards of computer usage time by students (Miidla-Vanatalu, 2014).

Also, a significant destructive factor in extensive ICT use in training is a competition with the conventional learning technology. First of all, this problem is accounted for the lack of a major teacher interest in the use of computer technology in class. In this regard, it is necessary to take a purposeful action in respect to teachers: to ground them in computer literacy; to introduce them to specialized software intended for the educational process; presentation of the advantages of ICT use in geometry classes, in particular, of such software products as Microsoft PowerPoint, Microsoft Excel, AutoCAD; preparation for testing (for example, the Unified State Examination) using computers; centralized inclusion of certain sections or tasks that require the use of ICT in geometry textbooks, and other.

An immature student culture of operating a personal computer also leads to negative implications in the ICT-based learning process. Currently, the main purpose of using a computer by students is leisure activities: online networking, games of various kinds and so on. It is the main teacher's role to demonstrate the usefulness of a computer and various software products in the learning process. Therefore, the following seems expedient for the teacher to do: to clearly set learning objectives for students before starting work on a computer; to demonstrate an extensive use of computers and ICTs as supporting aids in teaching.

5. Conclusion

Thus, the following inferences can be drawn based on the empirical investigation:

1. The key problems of geometry studies in the present day secondary education system in the Republic of Kazakhstan are the following: the lack of a fundamental educational base for studying solid geometry in the form of a logical connection with plane geometry for secondary school students and an insufficient level of applied orientation of the training course. These destructive factors reduce the level of students' comprehension of the connection between solid geometric figures and the surrounding three-dimensional world, as well as the applicability of school geometry knowledge in practice.

2. The established effectiveness criteria for software products use have led to the conclusion that Microsoft PowerPoint, Microsoft Excel and AutoCAD are the most appropriate in studying geometry in the secondary education system. Integrated use of ICT data ensures applied nature of the academic discipline "Geometry" and contributes to the most complete formation of the geometric competency in students.

3. Advanced planning of geometry lessons in computer classrooms, accurate planning of ICT lessons, increased level of teachers' computer literacy and fostered motivation for ICT use in

teaching geometry will help to eliminate competition with conventional learning technologies and to mainstream effective software products into the educational environment. It will ensure intensification of independent and creative work of students in the learning process as a factor in formation of practical geometric competencies.

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