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TOPICAL ISSUES OF THE DEVELOPMENT OF MODERN SCIENCE

ABSTRACTS OF VI INTERNATIONAL SCIENTIFIC AND PRACTICAL CONFERENCE FEBRUARY 12-14, 2020

SOFIA 2020

TOPICAL ISSUES OF THE DEVELOPMENT OF MODERN SCIENCE

Abstracts of VI International Scientific and Practical Conference

Sofia, Bulgaria

12-14 February 2020

Sofia, Bulgaria

2020

UDC 001.1
BBK 91

The 6th International scientific and practical conference "Topical issues of the development of modern science" (February 12-14, 2020) Publishing House "ACCENT", Sofia, Bulgaria. 2020. 1018 p.

ISBN 978-619-93537-5-2

The recommended citation for this publication is:
Ivanov I. Analysis of the phaunistic composition of Ukraine // Topical issues of the development of modern science. Abstracts of the 6th International scientific and practical conference. Publishing House "ACCENT". Sofia, Bulgaria. 2020. Pp. 21-27. URL: http://sci-conf.com.ua.

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УДК 372.8

THE MODELING AND SOLVING APPLIED PROBLEMS OF MATHEMATICAL ANALYSIS USING GEOGEBRA

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The effectiveness of using the package of dynamic mathematics of GeoGebra in solving the applied tasks of Mathematical Analysis from the position of methodological preparation of the future teachers of mathematics is proved. The introduction of modern information and communication technologies into the educational process allows improving the basic training of students, to develop modeling skills and to modernize the system of teacher's preparation.
Keywords: educational process, GeoGebra, Mathematical analysis, visualization of mathematical objects.

Introduction. The digital technologies become a part of our life very quickly. Their influence on the processes of human's activity actually causes the humans brain to evolve at an unprecedented rate. According to the theory of generations of W. Strauss and N. Howe, children of generation Z (digital generation) with a completely new type of thinking ("clip thinking") come to schools [1-2]. This type of thinking is characterized by the visual perception of information. Visual information is more readily perceived because 80% of the information is perceived by the person through eye sight. These circumstances require a fundamental change in approach to education, transfer of experience and knowledge. This is especially true for higher educational institutions that prepare future teachers. Today, there is no doubt about the necessity to use information and communication technology (ICT) in the educational process.

Many publications are devoted to the use of ICT in teaching fundamental disciplines, in the aspect of methodological preparation of future specialists in various fields, in particular the future teachers of mathematics. Most often, the use of powerful mathematical computer programs such as Maple, Mathcad [4] are considered. Nowadays, there are works devoted to the use of various tools in the process of teaching mathematical disciplines of various such as Google Play Market tools (Google Classroom, School Planner, Photomath, Science Journal, MalMath: Step by step solver, Desmos Graphing Calculator, Plickers, etc.) online platforms (PNET, Learningapps, Kahhot, etc.). The above mentioned tools allow you to solve problems quickly in different sections of mathematics, from simple constructions to complex analytical calculations, to visualize mathematical objects, to concentration as much as possible and to accelerate the perception of information. The use of modern information technology in the study of the main sections of mathematical analysis is the basis for improving the level of mathematical and professional preparation of students [5]. In the process of teaching mathematical disciplines, it is recommended to solve research problems using information and communication technologies [6]. The GeoGebra Dynamic Mathematical System is a versatile software tool used to support the teaching of all sections of higher mathematics, including mathematical analysis. The aim of the research is to use the GeoGebra computer mathematical system as a means of activating students' learning activities in the study of Mathematical Analysis. GeoGebra is used as a tool for visualizing the studied mathematical objects, to illustrate construction methods; as a environment for modeling and empirical study of the properties of the studied objects; as an instrumental measuring complex, which provides the user with a set of specialized tools for creating and transforming an object, as well as measuring it predetermines parameters. Performing students in mathematical analysis problems using GeoGebra creates an opportunity to diversify the range of tasks, including applied and research tasks, optimization problems [7-8]. Such tasks are related to the application of mathematics in engineering, physics, chemistry, economics, medicine, ecology, as well as in everyday life. These tasks are different from the typical formulation and solution methods. Usually, it takes a lot of time to solve such tasks than it does to solve standard tasks. To complete these problems, you need to make a model of the process and this step is the most difficult, and then using the appropriate theoretical knowledge to find the solution of an abstract mathematical problem. To minimize time spent on calculations, on drawing figures, objects, or functions it is advisable to use the GeoGebra environment to visualize the model [3].

Show the possibilities of a package of dynamic mathematics when studying a course of mathematical analysis (solving applied problems) at a pedagogical university.

Materials and methods. Research methods: theoretical - analysis, synthesis, comparison, generalization and systematization of conceptual provisions on introduction of modern Packages of Dynamic Mathematical for solving the problems of the Mathematical Analysis.

In 2018-2019 a.y., I suggested that students in the first and second years of specialty mathematics and physics use any mathematical package to solve the standard problems of the course of Mathematical Analysis. When teaching the course, I used different math packages as Maple, Mathcad, MATHEMATICA and online calculators. The result was terrible: 2 (5%) out of 40 students used GeoGebra occasionally, 5 (12%) student used online calculators. Students performed analytical calculations. I asked the students: "Why don't you use math packages that are freely available. 70% of students answered: "During lectures, you solve problems in different math packages, but do not explain how to do them" and 56% of students pointed out the many math packages you use. I took into account the students' comments. I opted for the GeoGebra Dynamic Mathematical Package. During the summer holidays through social networks I introduced students to the possibilities of GeoGebra. At the beginning of the new 2019-2020 a. y., I again suggested students to use Geogebra of when solving typical tasks course of Mathematical Analysis. The entire semester at each lecture and practical classes I show how to use the math package using students' smartphone's. The result for the first semester is impressive as 73% of the first and second year students performed the tasks using analytical methods and in GeoGebra (topics: introduction to analysis, differential calculus of functions of one and several variables, multiple integrals). Third-year students become members of the Club “Living Mathematics” in GeoGebra. But problems arise when solving applied problems. Consider examples of solving problems using GeoGebra in a mathematical analysis course. We do not aim to build complex visual models (surfaces, bodies). Our goal is to demonstrate the capabilities of Geogebra in modeling applied problems that can be solved by methods of mathematical analysis. When solving applied problems, you need to formulate a model of the process, and then, using the appropriate theoretical knowledge, to find a solution to an abstract mathematical problems.

Example 1. (Topic: Function increment and differential). In a ceramic workshop made clay souvenir balls of the same size. How much paint (cm3) is needed to cover N balls with a layer of 0,1 cm thick paint.

Comment. By the condition of the problem, we have a sphere with a diameter D (cm). The volume of the spherical layer must be calculated if the radius of the inner surface is known. The volume of a ball is determined by the formula $V=(4/3)\pi R^3$. The volume of a spherical layer is an increase in the volume of a sphere caused by a change in radius from $R=D/2$ (cm) to $R=D/2+0{,}1$ (cm). Therefore, our problem is to calculate of the differential of a function (the value of a function) $\Delta V = dV = \frac{4}{3} 3\pi R^2 dR \, (dR = \Delta R)$ for given constants $R, \Delta R, N$. Since by the condition of the problem it is necessary to calculate the amount of paint required for the manufacture of N souvenir balls, then multiply the result by *N*. We have $dV = \frac{4}{3} 3\pi \left(\frac{D}{2}\right)^2 \left(\frac{D}{2} + 0{,}1\right) N$ (cm^3). Students are very easy in GeoGebra, they build a task model. There is a problem with understanding which mathematical apparatus you need to come up with to solve the problem. In Figure 1, we can see dynamic model of Example 1 (two spheres of different diameters). Difficulties arise in the design and selection of mathematics.

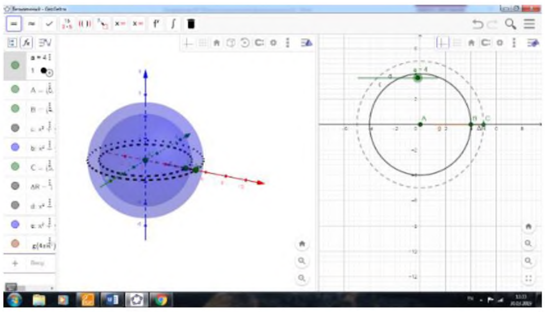

Fig. 1. Dynamic model of Example 1

Example 2. (Topic: Differential calculation of the function of several variables). At gas stations or motor vehicles, we can see tanks in the form of straight wheel cylinders for storing and transporting fuel, various liquids. Few people think of the proportions of such tanks: the same volume of fluid can be stored in a narrow and high or wide and low cylinder. Will the surface area of the cylindrical tank be the smallest, provided the base diameter and height are equal in this volume. After all, the production of such a container will take less metal, the painting - less paint, the insulation - less insulating coating.

Comment. So we have a cylinder whose base diameter (circle radius R) $D = \frac{R}{2}$ is equal to the height H. We are known formulas for calculating the volume V and the area of the full surface S of a cylinder with radius of base R and height H. The area of the full surface S is written as a function of the two variables R and the V: $S = S(R,V) = 2\left(\frac{V + \pi RH^2}{H}\right)$. The problem is to find the smallest value of the function of two variables $S = S(R,V)$. In Figure 2, we can see a dynamic model of Example 2 at different values of height, diameter and geometry of the upper base of the cylinder.

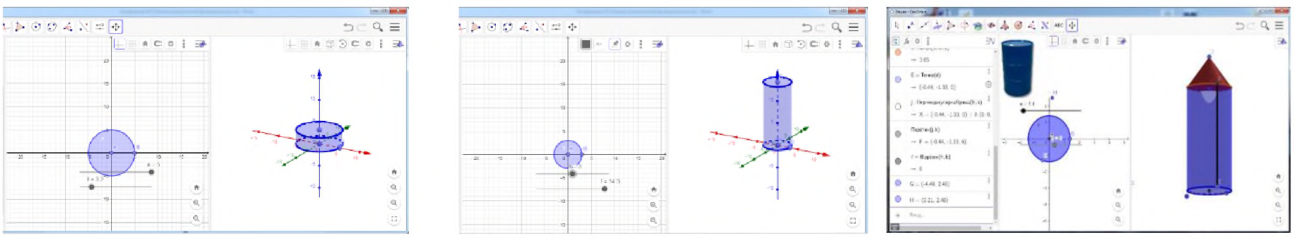

Fig. 2. Dynamic model of Example 2

You can also ask students to build the following objects and think about how this will affect the solution: cylinder without top cover, make a vertical central partition of a given thickness in the cylinder, cylinder covered with a hemisphere, the cone is covered with a flat and spherical lid. Performing such tasks shifts the accent techniques of carrying out typical calculations to a deeper understanding of theoretical propositions, tools for their practical application in real life [4].

Example 3. Calculate the amount of caffeine that gets into the human body, provided that every day for 30 days consumed: from 1 to 5 glasses of different sizes *S, L, XL* are popular coffee drinks (espresso, americano and latte). We are known caffeine content per 100ml (espresso *(n=1)*, americano *(n=2)* and latte *(n=3)*) in glasses of sizes *S, L, XL.*

Comment. It is not difficult to build a glass model. There are several options in the Geogebra cloud. We made ours. Difficulties arise when calculating the amount of caffeine in volume. There is a glass volume. There is a volume of liquid in the glass. These are different quantity. You need to realize this. The amount of caffeine in a given volume is calculated by the formula: $K_n = \frac{V_{S,L,XL} \cdot C_n}{100}$, where $V_{S,L,XL}$ –the amount of liquid in a glass with sizes *S, L, XL; Cn* - caffeine content per 100ml beverage. The values found must be multiplied by 1, 2,3,4,5 and 30. In Figure 3, we can see a dynamic model of Example 3. According to the calculations, we can conclude that the safest drink is Late, even if we use it for 5 glasses a day. But espresso can by no means be consumed in such quantity, since one glass (size S) contains a daily rate of caffeine.

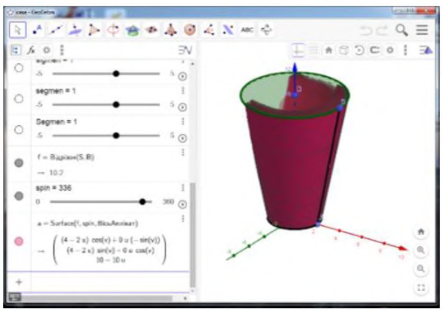

Fig. 3. Dynamic model of Example 3

Example 4. (Topic: Geometric applications of a definite integral). Calculate the cost of purchase of soil for planting indoor flowers in *N* pots with specified parameters (*h=a* - height of pot, *D1=b, D2=c (cm)* - diameter of the lower and upper bases of the pot, respectively).

Comment. In order to calculate the cost, we need to determine the amount of soil to be purchased. The volume of the correct figure in the GeoGebra environment can be calculated using the "Volume", but in this case we cannot do it. From the course of mathematical analysis, we know $V = \pi \int_a^b f^2(x)dx$. By the formula we calculate the volume by writing it in the command line. The result obtained is calculated in *(cm³)*. To calculate the cost of the required amount of soil, translate *(cm³)* to liters. Let a liter of soil costs 8 UAH. To determine the price of soil required for one pot volume is divided by 1000 ml and multiplied by 8 UAH. To find out the cost of all costs, we multiply the price of soil of the 1st pot by 8. With the given parameters (*h=20,5* - height, *D1=6, D2=8* - diameter of the lower and upper bases of the pot, respectively) we get volume 1 pot 4563,98 (cm3) and the price of soil of the first pot 36,51 UAH and for 8 pots 292,09 UAH. The Geogebra pot model is created as a surface, rotating an arbitrary curve around the axis. In Figure 4, we can see a interactive model of Example 4.

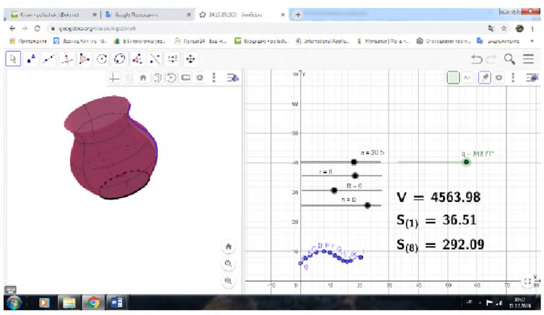

Fig. 4. Interactive model of Example 4

Conclusions. Based on our research, we can come to following conclusions. The use of the GeoGebra system in the studying of the course Mathematical Analysis allows to optimize the learning process, increases the efficiency of learning, activates cognitive activity, promotes the formation of algorithmic thinking style for future teachers of mathematics. It also creates an opportunity to demonstrate the results of their learning activities by creating an interactive model of different phenomena, and most importantly, enhances the interest of students in basic science through the ability to visualize the use of mathematical apparatus to solve applied tasks. It was also noted that work on solving an applied problem in a GeoGebra effective if a group of students (3-4 people) worked on its solution. Further research will be directed in several ways: application of GeoGebra to solving problems of the theory of function of complex variable, graph theory, statistics and modeling of physical phenomena in a given mathematical environment in the context of methodological preparation of teachers of mathematics and physics.

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