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INCREASING THE COMPETENCE OF FUTURE ECONOMISTS TO IMPROVE THE EFFECTIVENESS OF TRAINING IN THE CONTEXT OF ACHIEVING THE PRINCIPLES OF SUSTAINABLE DEVELOPMENT

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ABSTRACT

Objective: The study aims to shed light on the opportunity of using the KmPlot software in teaching the topics of further mathematics associated with the study of functions, as well as to substantiate the feasibility of its use.

Methods: The conducted experimental study using the methods of observation, analysis, systematization, and pedagogical experiment provides qualitative and quantitative information on the expediency of using KmPlot in teaching further mathematics.

Results: The results obtained indicate an increase in the level of learning outcomes when using the KmPlot software, i.e. improved learning outcomes of future economists in the study of further mathematics by means of freely distributed computer mathematical programs.

Conclusion: The use of licensed software by Russian universities may become a topical problem in current realities. Free software products for learning further mathematics, such as graphing software, can serve as a good alternative.

Keywords: Computer Mathematical Systems, Freeware Mathematical Packages, Further Mathematics, Graphing, KmPlot

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AUMENTAR A COMPETÊNCIA DOS FUTUROS ECONOMISTAS PARA MELHORAR A EFICÁCIA DA FORMAÇÃO NO CONTEXTO DE ALCANÇAR OS PRINCÍPIOS DO DESENVOLVIMENTO SUSTENTÁVEL

RESUMO

Objetivo: O estudo visa lançar luz sobre a oportunidade de utilização do software KmPlot no ensino de tópicos de matemática complementar associados ao estudo de funções, bem como fundamentar a viabilidade de seu uso.

Métodos: O estudo experimental realizado usando os métodos de observação, análise, sistematização e experimento pedagógico fornece informações qualitativas e quantitativas sobre a conveniência de usar o KmPlot no ensino de matemática adicional.

Resultados: Os resultados obtidos indicam um aumento no nível de resultados de aprendizagem ao usar o software KmPlot, ou seja, melhores resultados de aprendizagem de futuros economistas no estudo de matemática adicional por meio de programas matemáticos de computador distribuídos gratuitamente.

Conclusão: O uso de software licenciado por universidades russas pode se tornar um problema atual nas realidades atuais. Produtos de software livre para aprender mais matemática, como software gráfico, podem servir como uma boa alternativa.

Palavras-chave: Sistemas Matemáticos Computacionais, Pacotes Matemáticos Freeware, Matemática Adicional, Gráficos, KmPlot

AUMENTAR LA COMPETENCIA DE LOS FUTUROS ECONOMISTAS PARA MEJORAR LA EFICACIA DE LA FORMACIÓN EN EL CONTEXTO DEL ALCANCE DE LOS PRINCIPIOS DEL DESARROLLO SOSTENIBLE

RESUMEN

Objetivo: El estudio tiene como objetivo arrojar luz sobre la oportunidad de utilizar el software KmPlot en la enseñanza de los temas de matemática avanzada asociados al estudio de funciones, así como fundamentar la factibilidad de su uso.

Métodos: El estudio experimental realizado utilizando los métodos de observación, análisis, sistematización y experimento pedagógico proporciona información cualitativa y cuantitativa sobre la conveniencia de utilizar KmPlot en la enseñanza de las matemáticas.

Resultados: Los resultados obtenidos indican un aumento en el nivel de los resultados de aprendizaje cuando se utiliza el software KmPlot, es decir, mejores resultados de aprendizaje de los futuros economistas en el estudio de las matemáticas adicionales por medio de programas matemáticos informáticos distribuidos libremente.

Conclusión: El uso de software con licencia por parte de las universidades rusas puede convertirse en un problema de actualidad en las realidades actuales. Los productos de software libre para aprender más matemáticas, como el software de gráficos, pueden servir como una buena alternativa.

Palabras clave: Sistemas matemáticos informáticos, Paquetes matemáticos gratuitos, Más matemáticas, Gráficos, KmPlot

INTRODUCTION

Modern pedagogical technologies for teaching further mathematics are now significantly dependent on the capabilities of computing technology and software (Mkrttchian et al., 2020; Logachev et al., 2021).

The application of computer mathematical systems simplifies and automates calculations, which gives more opportunities for the analysis itself and solving special problems, while also promoting the deepening of students' professional knowledge and skills (Keong et al., 2005; Korneev et al., 2022).

Customarily, higher education institutions in Russia use Microsoft products and proprietary (commercial, distributed for a fee) mathematical software products as the operating system (Shevchenko, 2016).

Among the most commonly used computer mathematical systems of universal type, which are used in different fields (economics, engineering, construction, etc.) are Mathematica, Maple, MatLab, and MathCAD (Hodges, Kim, 2013; Kramarski, Hirsch, 2003). These software environments allow carrying out mathematical calculations with high accuracy (Taylor, 2008) and also perform symbolic calculations with visualization of processes and the data received during processing (Aktümen, Kaçar, 2008).

It should be noted that these computer mathematical systems are costly (Kilicman et al., 2010) and acquiring them for educational purposes is problematic for Russian universities (Ochkov, Bogomolova, 2015).

The use of free software will provide the necessary information and communication support for the educational process of higher education institutions without significant costs for its purchase and improve the mathematical training of economics students (Smirnova et al., 2021; Aleksandrova et al., 2021).

Literature Review

The use of computer mathematical systems for solving problems of further mathematics has been considered by many scientists, who argue (Zakaria et al., 2010; Small, 2002) that the use of mathematical packages in solving a variety of mathematical problems is quite a common practice. In particular, manuals on MathCAD (Cherniak et al., 2003) give examples of using the program in solving various economic problems.

The pedagogical experience of using Mathematica (Chen et al., 2009), Maple (Olenev et al., 2020), MatLab (Zhaparov, Guvercin, 2012), and MathCAD (Abdullaeva, Sultonova, 2020; Etcuban et al., 2019; Lashchenko, 2020) environments shows that, as a rule, students do not need such multifunctional systems to conduct research in their specialty areas.

In their training and future professional work, economics students quite often face the tasks of constructing graphs (Abdullah et al., 2012) and data processing (Rashawn, Johnson, 2016). Although there is a sufficient number of freely distributed programs for the construction and analysis of graphs (Kusbeyzi et al., 2011), research on the use of freely distributed mathematical packages has so far received little attention. In this regard, following the recommendations of researchers (Botana et al., 2014), in our study, we employ the program KmPlot for building graphs and conducting their preliminary analysis.

KmPlot is a software program for graphing algebraic functions. It has a built-in powerful interpreter and is designed to build various functions simultaneously and combine their expressions to build new functions. KmPlot supports explicit and implicit functions, functions with parameters, functions in polar coordinates, and integral curves.

The user is given the opportunity to work with several coordinate grid modes. Graphs can be plotted with great accuracy at the correct scale.

The dialog with the program is done via menus and the toolbar. By default, functions defined unambiguously are plotted along the entire visible part of the abscissa axis. KmPlot calculates the function value for each pixel of the abscissa axis. Parametric functions are plotted for a value between 0 and 2π. The construction range can also be defined in the settings.

After the graph of the function is plotted, the user has the ability to change the plotting parameters: change the plot interval, color, thickness, type of line. In addition, it is possible to plot the derivative and the original function.

KmPlot also allows finding function extremes and maximum and minimum values on the selected interval and calculating the area bounded by the function graph and the abscissa axis on the selected interval.

Given the above, the purpose of the present study is to determine the possibilities of using the KmPlot software in learning the topics of further mathematics related to the study of functions and to substantiate the feasibility of its use.

Hypothesis: the use of freely distributed computer mathematical programs in the study of further mathematics by future economists leads to improved learning outcomes.

The study objectives include:

1. theoretical analysis of the application of mathematical packages in solving mathematical problems;

2. conducting a pedagogical experiment on the use of free software for graphing and data analysis in teaching further mathematics;

3. obtaining results on the dynamics of the level of learning outcomes of economics students in the study of further mathematics using KmPlot.

MATERIALS AND METHODS

We conducted a pedagogical experiment on the use of free software for graphing and data analysis in teaching further mathematics.

For this purpose, first-year economics students were recruited as study participants. This choice of the sample was due to the fact that students in this specialty are more flexible for experiments with software testing. The number of students participating in the study was eight academic groups, 140 people in total.

The experiment was conducted in the first semester of the 2021/2022 academic year on the basis of the Orenburg Institute of Railway Transport and the Orenburg State University (Faculty of Transportation).

The object of the study was the process of solving problems concerning functions, finding the area of the figure bounded by the graph of the function and the abscissa axis on a certain interval, and constructing the graph of the defined implicit function using the KmPlot software.

The approximate set of theoretical and empirical research methods employed to reach the research goal included:

theoretical methods (analysis, synthesis, comparison, generalization) – to study scientific literature on the use of computer mathematical systems;

empirical methods (methods of observation, analysis, and systematization; pedagogical experiment) – to obtain information about the feasibility of using KmPlot in teaching further mathematics.

The experimental study involved analysis of the possibility and feasibility of using KmPlot in the study of further mathematics topics related to the study of functions. The students-economists recruited were asked to perform five tasks. The proposed tasks were related to the construction of function graphs.

Sometimes, the graphs of the functions under study were quite difficult to construct. This may be due to the intervals on which the function has various kinds of convexities, to a large number of individual constituent lines of the graph, or to the complexity of the expression describing the function.

The students were asked to perform the following tasks in KmPlot:
Task one:
1. Examine the function analytically.
2. Plot the graph of the function and its first derivative in KmPlot.
3. Find the maxima and minima of the function.

In KmPlot, extrema can be found very easily: Appearance→Advanced→Show Extrema. However, a more creative approach was suggested. Maxima and minima are clearly visible on the graph of a function, taking into account the graph of its derivative (the derivative is zero at the points of extremum). Students had to choose a convenient interval on the abscissa axis and find in it the maximum or minimum value of the function, respectively. Extremum points found in this way are more accurate.

The extrema found analytically and with KmPlot were compared.

Computer construction of graphs of functions is useful for checking the correctness of the construction and finding the areas of planes bounded by the given lines. High accuracy and speed of constructions and calculations, great tools for the visualization of contours, shapes, and placement of figures, which can be viewed from the screen or from its hard copy, and beautiful and clear program interface are enough to use KmPlot in the educational process when studying the topic "A definite integral and its application". The task of visualizing the process of calculating integrals is solved with much less time.

The second task was to find the area of a figure bounded by the graph of a function and the abscissa axis on a certain interval. Initially, the corresponding area was found analytically. Then it was found in KmPlot. To do so, after the graph of the function was plotted, the following actions were required: service→area under the graph→select the appropriate interval.

The values of the areas were then compared.

The third task was to construct the graph of the function defined implicitly.

In the process of the economics students' study of the topics of further mathematics related to the study of functions, the effectiveness of the proposed mathematical package was assessed by collecting continuous quantitative and qualitative observation data.

The main quantitative variable was students' learning outcomes on a 100-point scale. In addition, qualitative monitoring of the students' attitude to the learning process was carried out, analyzing the students' attendance at lectures and practical classes, engagement in independent work and group work, and the use of additional information sources.

The obtained statistical data were grouped according to the students' initial level of performance taken as performance in the further mathematics course without the use of KmPlot. The initial level was compared to performance in the course of further mathematics using KmPlot.

The effectiveness of using the program KmPlot to improve the level of students' academic performance was tested via the G sign test with the null hypothesis and the alternative hypothesis formulated as follows.

H0: the predominance of increase in the level of learning outcomes when using KmPlot relative to the level of learning outcomes without the use of KmPlot is random.

H1: the predominance of increase in the level of learning outcomes when using KmPlot relative to the level of learning outcomes without the use of KmPlot is not random.

Critical values of the G sign test: 59 ($p < 0.05$); 55 ($p < 0.01$).

Calculation of the G sign test was performed by compiling the respective table using Microsoft Excel.

RESULTS

The following was revealed in the analysis of learning outcomes:

- The students demonstrating a high level of academic achievement without the use of KmPlot retain it when using the program. They show a keen interest in studying KmPlot, independently master other features of the program, and perform additional calculations that are not required when solving specific problems. On average, the students' academic performance increases by 5-7 points on a 100-point scale;

- The students showing a sufficient level of learning outcomes without using KmPlot easily and fully master the necessary set of KmPlot functions, are able to make additional calculations independently referring to the basic example. In terms of progress in learning outcomes, they can be divided into two subgroups: the first confidently demonstrates a high level of learning outcomes (which can be explained by them initially lacking exactly the use of mathematical programs), the second remains at a sufficient level, but, in general, increases their average score by 10-12 points on a 100-point scale;

- The students demonstrating an average level of academic performance without using KmPlot, resist the requirements to study the new program at first, may show dissatisfaction with the study load, which, in their view, has increased, and try to solve problems by the habitual mathematical method. After unsuccessful attempts to solve problems independently, and in view of the rapid progress of classmates who started working in KmPlot, most of them make their attempts to study the program and 95% of them succeed in using it. They perform tasks with a certain delay, which is associated with belated attempts to start working in KmPlot, but most of them perform them correctly and learn the basic principles of solution.

Substantial progress in academic achievement is demonstrated by about 35-40% of these students, their grades increase by 15-20 points, they are able to describe and analyze the problem at a sufficient level and comment on the results obtained, some of them get high scores. Another subgroup is able to bring the task to a sufficient level, although in general, their achievement does not exceed the average;

- The students who initially balance on the verge of the baseline and average level of academic achievement show neither initiative nor resistance to learning new things. They need support, and if it is not given, they immediately abandon all attempts to perform the task. Work with them is, essentially, constant assistance and direction of their actions. Nevertheless, work with such students in small groups, in consultative classes yields good results. They are able to master both the analytical side of problem-solving and the use of KmPlot at an average, and sometimes at a sufficient level. Under constant supervision, all students of this subgroup master this section of further mathematics at an average level.

The statistical probability of the prevalence of positive changes in the level of learning after the introduction of KmPlot at two levels of significance is confirmed by the calculation of the G sign test ($G_{emp} = 22$; $G_{emp} < G_{cr}$).

DISCUSSION

Practice shows (Small, 2002) that students are enthusiastic about the study of further mathematics when the computer is used in the classroom as a means of creating problem cases in learning, thereby stimulating students' independence, research motives, creative thinking, and daring intuitive conjectures in learning (Aktümen, Kaçar, 2008).

In our work, we use freeware software KmPlot, which does not require special installations on the computer, registration, and the like. This enables its use on any computer from any medium. This choice is also justified by the fact that the necessary software should be accessible and easy to master (Abdullah et al., 2012). The algorithm of the program is easy and understandable, so students are able to make their first calculations when they first get acquainted with the program. The KmPlot mathematical system provides opportunities for plotting, which also causes difficulties for students in the traditional approach (Rashawn, Johnson, 2016).

The use of the program KmPlot allows selecting the training material so as to reduce the time required to train the technical skills to perform those mathematical operations that can be performed by a computer. This gives additional free time to study general concepts and theorems in their practical orientation, to ensure the formation of a system of students' fundamental knowledge and skills. In addition, KmPlot gives an opportunity to optimize the distribution of training material between lectures, practical classes, and self-study.

Researchers also suggest that additional free time enables the teacher, depending on the level of students' training, to: pay more attention to the demonstration of the essence of the problem (Olenev et al., 2020); place additional emphasis on the sequence and logic of problem solution (Ochkov, Bogomolova, 2015), allocate more time to developing students' problem-solving skills by increasing the number of problems (Ochkov, Bogomolova, 2015), diversify the problem statement, show various possible formulations of one problem (Kramarski, Hirsch, 2003), demonstrate the solution of problems of increased complexity (Kramarski, Hirsch, 2003), explore non-standard approaches to problem analysis and show the equivalence of the obtained results (Taylor, 2008).

In general, the described approach brings a significant increase in students' interest in the learning process and a higher quality of their skills in solving problems.

It is worth noting that the results of observation of the experiential training demonstrate that the very work in the program also requires an attentive and responsible attitude. Same as any applied software, KmPlot has its own rules and language.

Naturally, at the initial stages of studying the environment, this causes additional mistakes. However, these additional difficulties play a certain educational role as they teach students the order of operations, the formalization of value notation, and how to find and correct syntax errors on their own (Botana et al., 2014).

Thus, the student develops a healthy positive attitude to the process of learning and research and adopts the habit of conducting calculations clearly and formally, independently finding possible errors, and checking various solutions.

Thus, the use of freely distributed computer mathematical programs in teaching economics students further mathematics grants the opportunity to compensate for the low level of mathematical skills of students with the use of applied mathematical programs.

The study of applied mathematical programs in mastering individual sections of further mathematics can not only simplify the learning process but also encourage the student to independently acquire new knowledge. Acquiring practical skills in working with mathematical software packages encourages students to use all the features of the program, even without guidance from the teacher, when studying other subjects.

Facilitation of mathematical calculations not only reduces the burden on students and increases the quality of their knowledge and skills, but also fosters their positive attitude towards the learning process as a whole.

CONCLUSION

In conclusion of the study, it can be inferred that the use of the KmPlot software in the study of mathematical disciplines can: reduce the time for the development of mechanical skills in students; increase the intensity and number of tasks, exercises, and problems; ensure the optimal pace of work; enhance material and technical support of lectures and practical and laboratory classes; promote students' motivation for learning activities. All these factors combined give an opportunity to change the educational process and teaching methods while preserving the traditional methods, techniques, and means of learning.

The described approach will promote the integration of interdisciplinary knowledge and the development of creative thinking, enhance students; engagement in learning activities, and, eventually, inevitably improve the quality of mathematical training.

The use of the mathematical software package KmPlot when solving mathematical problems increases the overall performance of students, which is observed in all groups, regardless of the initial level of learning outcomes.

Thus, the study confirms the hypothesis that the use of freely distributed computer mathematical programs in the study of further mathematics by future economists results in better learning outcomes.

Our further research focuses on developing a methodology for students to study freely distributed mathematical packages in order to further use them for data analysis in the preparation of courseworks and theses. At the moment, we are developing a package of additional creative tasks, the level of which goes somewhat beyond the scope of the curriculum.

The solution of these tasks will require the student to have a more in-depth knowledge of mathematics and to create their own program of calculations based on the skills acquired in mastering the basic material in the program. It is expected that students who usually demonstrate a sufficient level of knowledge in most major subjects will be able to cope with tasks of a higher level of difficulty.

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