Metadata of the chapter that will be visualized in SpringerLink

Book Title	Futureproofing Engineering Education for Global Responsibility	
Series Title		
Chapter Title	The Use of Mathematical Packages of Applied Programs in the Educational Process	
Copyright Year	2025	
Copyright HolderName	The Author(s), under exclusive license to Springer Nature Switzerland AG	
Author	Family Name	**Vitalii**
	Particle	
	Given Name	**Ivaniuk**
	Prefix	
	Suffix	
	Role	
	Division	
	Organization	Kamianets-Podilskyi Ivan Ohiienko National University
	Address	61 Ohiienkost.Khmelnytskyi Region, Kamianets-Podilskyi, 32300, Ukraine
	Email	
	ORCID	http://orcid.org/0000-0003-2506-7722
Corresponding Author	Family Name	**Maryna**
	Particle	
	Given Name	**Miastkovska**
	Prefix	
	Suffix	
	Role	
	Division	
	Organization	Kamianets-Podilskyi Ivan Ohiienko National University
	Address	61 Ohiienkost.Khmelnytskyi Region, Kamianets-Podilskyi, 32300, Ukraine
	Email	marinenka1@gmail.com
	ORCID	http://orcid.org/0000-0003-0427-6664
Author	Family Name	**Sofiia**
	Particle	
	Given Name	**Dembitska**
	Prefix	
	Suffix	
	Role	
	Division	
	Organization	Vinnytsia National Technical University
	Address	95 Khmelnitskoe Shose Street, Vinnytsia, 21027, Ukraine
	Email	
	ORCID	http://orcid.org/0000-0002-2005-6744
Author	Family Name	**Olha**
	Particle	

Given Name	**Kuzmenko**
Prefix	
Suffix	
Role	
Division	
Organization	Donetsk State University of Internal Affairs
Address	1, Velyka Perspektyvna Street, Kropyvnytskyi, 25005, Ukraine
Email	
ORCID	http://orcid.org/0000-0003-4514-3032

Abstract	Modern specialists in engineering fields need not only deep knowledge but also the ability to use mathematical packages of application programs (MPAP) to solve complex problems. Despite the significant advantages of MPAP, their use in the educational process is limited due to methodological insecurity and lack of knowledge among teachers. In this article, the authors examine the effectiveness of MPAP in the training of specialists and develop methodological recommendations for their integration into the educational process. An analysis of the didactic capabilities of MPAP (MatLab, MatchCad, Mathematica, SciLab, Octave) and an experimental verification of their effectiveness at the Faculty of Physics and Mathematics showed that MPAP: increases interest in learning mathematics; provide opportunities for visualization of material, individualization of learning, development of graphic culture, involvement in research work, independent preparation and control of knowledge. The developed methodical recommendations for the integration of MPAP in the educational process will help overcome the problems associated with their use and improve the quality of training of specialists.

Keywords (separated by '-')	mathematical packages of applied programs - digitization of the educational environment - educational process - visualization of material - research activity - formation of professional competence

The Use of Mathematical Packages of Applied Programs in the Educational Process

Ivaniuk Vitalii[1], Miastkovska Maryna[1(✉)], Dembitska Sofiia[2], and Kuzmenko Olha[3]

[1] Kamianets-Podilskyi Ivan Ohiienko National University, 61 Ohiienkost.Khmelnytskyi Region, Kamianets-Podilskyi 32300, Ukraine
marinenka1@gmail.com

[2] Vinnytsia National Technical University, 95 Khmelnitskoe Shose Street, Vinnytsia 21027, Ukraine

[3] Donetsk State University of Internal Affairs, 1, Velyka Perspektyvna Street, Kropyvnytskyi 25005, Ukraine

Abstract. Modern specialists in engineering fields need not only deep knowledge but also the ability to use mathematical packages of application programs (MPAP) to solve complex problems. Despite the significant advantages of MPAP, their use in the educational process is limited due to methodological insecurity and lack of knowledge among teachers. In this article, the authors examine the effectiveness of MPAP in the training of specialists and develop methodological recommendations for their integration into the educational process. An analysis of the didactic capabilities of MPAP (MatLab, MatchCad, Mathematica, SciLab, Octave) and an experimental verification of their effectiveness at the Faculty of Physics and Mathematics showed that MPAP: increases interest in learning mathematics; provide opportunities for visualization of material, individualization of learning, development of graphic culture, involvement in research work, independent preparation and control of knowledge. The developed methodical recommendations for the integration of MPAP in the educational process will help overcome the problems associated with their use and improve the quality of training of specialists.

AQ2

Keywords: mathematical packages of applied programs · digitization of the educational environment · educational process · visualization of material · research activity · formation of professional competence

1 Introduction

The modern world is developing dynamically, and along with it, the requirements for specialists in physical, mathematical and technical profiles are growing. These specialists must not only possess deep knowledge of specialized disciplines but also be able to use modern methods and tools to solve complex problems. One of these tools is mathematical packages of application programs (MPAP), which allow: one to perform complex mathematical calculations, visualize data, model processes, solve optimization

M. E. Auer and T. Rüütmann (Eds.): ICL 2024, LNNS 1260, pp. 1–8, 2025.
https://doi.org/10.1007/978-3-031-85652-5_57

problems, etc. The use of MPAP in the educational process has several advantages: it increases motivation due to visualization and interactivity, develops spatial imagination, logical thinking, and algorithmic culture, forms competencies related to work with modern software complexes, prepares specialists for real tasks that they will face in his professional activity. Despite the significant advantages, the use of MPAP in the educational process is still not a widespread phenomenon. This is due to some reasons, such as insufficient methodological support and teachers' lack of necessary knowledge and skills. The relevance of the research lies in the development of methodological recommendations for the implementation of the MPAP in the educational process, which will help to overcome the above-mentioned problems and improve the quality of training of specialists.

The purpose of the research is to determine the effectiveness of the use of MPAP in the training of engineering specialists and the development of methodological recommendations for their integration into the educational process.

2 Professional Mathematical Packages in the System of Applied Mathematical Training of Future Specialists

The training of engineering specialists requires high-quality mathematical education taking into account modern information technologies. The traditional education system cannot always cope with this task due to time constraints. The integration of information and pedagogical technologies, in particular the use of professional mathematical packages, can help solve this problem.

MPAPs allow students to explore complex models, independently solve more problems, gain a deeper understanding of processes and phenomena, and also make learning more illustrative and dynamic. Their use contributes to the implementation of the principles of scientificity, systematicity, interdisciplinary connections, activation of learning, professional orientation and anticipatory learning. The method of using MPAP involves their complex application with traditional educational materials, a combination of group and individual forms of education. As a result, students will not only acquire the necessary knowledge but will also acquire the skills to work with modern mathematical tools, which will prepare them for successful professional activities.

From the point of view of pedagogy, the professional mathematical package is a modern didactic teaching tool that, when designing the educational process of applied mathematics courses («Higher mathematics», «Numerical methods», «Discrete mathematics», «Probability theory», etc.), allows you to normalize and optimize the educational process, to add a qualitatively new level to it. From the point of view of informatics, a professional mathematical package is an information technology designed to automate the solution of mathematical problems in various fields of science and technology, which integrates a modern user interface, a system of analytical numerical methods for solving a fairly wide class of mathematical problems, tools visualization of calculation results, which at the stage of management decision-making makes it possible to more likely analyze the obtained results, including giving them a meaning interpretation.

The principle of scientific learning is implemented because, with the help of professional mathematical packages, it becomes possible to consider a larger number of fundamental scientific achievements in the field of mathematics, to gain knowledge about

general scientific methods of cognition and about methods of researching mathematical models. The use of professional mathematical packages unconditionally contributes to the formation of the ability to interpret and analyze the results of activities.

The use of computer mathematics packages implements the principle of systematicity in education, which is closely related to the principle of scientificity, forming a new quality of knowledge, characterized by the presence in the minds of students of logic adequate to the existing, subject, connections and reflects content-logical connections taking into account the cognitive capabilities of students and the content of other mathematical, physical and informational disciplines, which enables students to work with a wide range of connections between various fragments of research theory and practice.

Implementing *the principle of interdisciplinary* connections determines as an independent didactic principle, that the use of professional mathematical packages contributes to their flection in the content of the educational course of the variety of cause-and-effect relationships operating in the engineering field. At the same time, interdisciplinary connections act sane equivalent to filtering disciplinary connections, the methodological basis of which is the process of integration and differentiation of scientific knowledge.

The implementation of *the principle of professional orientation* of education with the use of professional mathematical packages, which is of particular importance in higher education, is expressed in the formation of professionally significant skills and abilities in future specialists, which include: the ability to analyze the role and degree of influence of various factors and conditions on the parameters of the processes and phenomena being studied; the ability to independently formulate correct (conditionally correct) mathematical statements of problems; the ability to meaningfully interpret experimentally obtained data, presented in the form of tables, graphs, diagrams; the ability to independently use modern information technologies in the research of various causal problems.

As a result, on the one hand, the assimilation and consolidation of the necessary knowledge in the block of engineering disciplines is ensured. On the other hand, guaranteed training of future specialists for the successful implementation of professional activities is implemented. This implements the principle of professional orientation when using mathematical packages.

The *principle of ticipatory education* is implemented with the transfer of world scientific and cultural heritage to students, as well as with the formation of knowledge, abilities and skills that allow university graduates to adapt to a rapidly changing world.

The packages should be used in combination with both traditional printed educational and teaching manuals, methodical recommendations, and new electronic educational means of learning. The use of professional mathematical packages when each student performs an individual ask as part of a general task, which depends on the quality of the performance of each student's task, harmoniously combines group and individual forms of learning, thereby implementing the principle of collective character in combination with the development of individual characteristics of the personality of each student [1].

3 Means of Mathematical Modelling

Today, a wide range of software tools have been developed and are available for solving various mathematical problems. Among the most famous are Matlab, Mathematica, and Maple. In addition to universal packages, others do not have a full set of functions for a wide range of tasks but effectively cope with highly specialized tasks. An example is Comsol Multiphysics, which is used for modelling complex physical phenomena. According to the research [2], Matlab and Wolfram Mathematica are the most effective packages of computer mathematics according to some criteria – mathematical performance, graphic performance, capabilities of the software environment, data import/export interface, support for various operating systems, and calculation speed. Let's consider in more detail the key advantages of Matlab, which include high speed of calculations, a wide range of built-in functions, a simple programming environment, a large user community, compatibility with third-party tools, reliability and performance, and a wide range of visualization tools. All this makes it an ideal choice for scientists, engineers and students.

An important advantage of Matlab is a wide set of tools – Toolbox, which expands its functionality to solve problems in various fields: mathematics and statistics, engineering, finance and economics, text and data processing, etc. Examples of popular Toolbox Matlab are Simulink (modelling and simulation of dynamic systems), Signal Processing Toolbox (signal processing and data analysis), ControlSystemsToolbox (design and analysis of control systems), Image Processing Toolbox (image processing and machine vision), Statistics Toolbox (statistical analysis and machine learning), Optimization Toolbox (solving optimization problems), and Financial Toolbox (financial modelling and analysis) [3].

Matlab is not free of awareness, but its functionality and ease of use make it a valuable tool for solving complex problems.

Programming Languages for Mathematical Modelling.
In addition to specialized mathematical application software packages, there is a wide range of programming languages that can also be effectively used for mathematical modelling. The choice of programming language depends on the specifics of the problem to be solved. The most common programming languages for mathematical modelling today are Python, C/C++, R, Matlab, and Mathematica.

Python is a universal programming language that is widely used for mathematical modelling. It has a large set of libraries for scientific computing, such as NumPy, SciPy and Matplotlib. Python is also a relatively easy language to learn, making it a good choice for beginners.

In turn, C/C++ is a high-performance programming language that is often used to solve complex mathematical problems. They give the user more control over memory and computation, which can be important for some types of models. However, C/C++ is more difficult to learn than Python. The R programming language is specially designed for statistical analysis and graphics. It has a wide range of tools for creating statistical models and data visualization. R is also a relatively easy language to learn.

The Matlab and Mathematica languages are the base languages of the respective MPAPs, offering a wide range of advantages such as powerful capabilities, flexibility,

integrated development environments, visualization and community support. Matlab is known for its speed and integration with other MathWorks products, while Mathematica is known for its powerful symbolic computing capabilities and natural language support.

Several key factors should be considered when choosing tools for mathematical modelling in education. First of all, it is important to determine the specifics of educational programs and the types of models used. For example, Python and R are good for statistical models, C++ for modelling embedded systems, and Mathematica/Matlab for complex numerical calculations.

It is important to remember that there is no universal solution. The choice of tools depends on the specific needs of the educational program, the level of training of students and available resources.

4 Applications of Mathematical Packages of Applied Programs in the Educational Process

The use of MPAP in the educational process not only improves the assimilation of new knowledge and competencies by students but also significantly expands the capabilities of teachers. Let's consider several examples of successful applications of MPAP:

- at the National Aviation University, students start studying programming with Matlab in the first year. This approach aims to provide a deep understanding and wide application of Matlab in further disciplines [4];
- at the Zaporizhia National Technical University, the teaching of disciplines takes into account the requirements of employers, among whom there is a widespread demand for a system analyst with the level of a professional MatLab user, therefore the emphasis is placed on working with MatLab and some specialized libraries: Fuzzy Logic Toolbox, Neural Networks Toolbox and Deep Learning Toolbox [4].

The research [4] proposes the joint use of Matlab and Comsol Multiphysics to replace expensive field experiments with modern numerical methods while maintaining high accuracy, flexibility and economy of research. In work [5], the use of the Matlab Simulink environment for training electrical engineers in the framework of the course «Theoretical Basics of Electrical Engineering» is considered. The author suggests using visual-oriented programming methods in Matlab and its Simulink and Power System Blockset (PSB) libraries to create educational projects that are prototypes of real problems faced by engineers in practice. In turn, the Department of Higher Mathematics of the Ivan Kozhedub Kharkiv National Air Force University actively uses Mathematica and Mathcadpackages, which facilitate scientific and educational activities [4]. The use of Matlab and Scilab packages in the educational process and scientific work is considered in [4], where it is noted that the advantage of the Scilab package is that it is distributed on a license-free basis and can be used by students on independent work on their computers.

The research [6] describes the advantages and applications of using Matlab in teaching the process of automatic temperature control, emphasizing its capabilities and strengths in facilitating practical learning and experimentation. The literature review in [7, 8] focuses on the use of Matlab as a didactic tool for mathematics. Various ways of

using the software as a tool for visualization, calculations, problem-solving, fostering a positive attitude and confidence in mathematics, increasing motivation and project performance are summarized. In the author's research [9], important developments in the use of digital technologies in teaching and learning mathematics are considered. Attention is drawn to the increased use of computer algebra systems and dynamic geometry packages.

K. Devlin [10] considers the emergence of computer algebra systems (Mathematica, Maple, and others) running on personal computers in the late 1980s as a major revolution in mathematics. These packages were mainly used in university departments of mathematics, physics or engineering because they were expensive, difficult to use and required a good computer to run, which kept them away from mainstream schools [11]. J.B.Lagrange, P.R.Richard, M.P.Vélez, S.Van Vaerenbergh, [12] presented modern developments of digital environments for mathematics education, with special attention paid to artificial intelligence techniques and prospects for developing software for mathematics education. The research [13] carried out a wide review of publications aimed at the use of information and communication technologies in mathematics education. It is emphasized that information and communication technologies provide teachers with the main tools and means that allow changing teaching methods, support students in independent learning and actively influence the quality of learning mathematical concepts and topics.

The experience of using computer algebra systems in teaching mathematics in India is highlighted in [14]. Computer algebra systems such as Mathematica, Maple, MuPAD, MathCAD, Derive, Maxima are said to have the potential to promote an active approach to learning, allowing students to develop conceptual and geometric knowledge, gain understanding, and take a deeper approach to learning. Examples of the use of programming languages in the educational process are works [15] and [16]. In [15], interdisciplinary connections were established using Python programming in the teaching of computer modelling. The active use of programming languages as the basic ones in the educational process is also confirmed in [16], where the R language is proposed as the basic language. So, modern software tools and programming languages open wide opportunities for mathematical modelling and solving various problems. The choice of software tool or programming language depends on the needs of the user, his experience and resources.

5 Implementation of Mathematical Packages in the Educational Process of Kamianets-Podilskyi Ivan Ohiienko National University

The Department of Computer Sciences of the Faculty of Physics and Mathematics of the Kamianets-Podilskyi Ivan Ohiienko National University provides educational programs for training specialists of the first and second levels of higher education in the speciality 122 Computer Sciences. The educational programs of the department provide for the study and application of mathematical packages of applied programs for solving educational modelling and computing problems. These packages are used within the following educational disciplines: «Modern problems of mathematical modelling», «Mathematical

modelling», «Computer modelling», «Mathematical packages of applied programs» and others. In addition, packages of application programs are used when writing qualification papers.

To ensure the educational discipline of «Computer Modeling», educational and methodological recommendations have been developed [1]. Within this discipline, students perform practical tasks in the Matlab environment, as well as Octave or Scilab. Within the educational discipline «Mathematical packages of applied programs», students' work is organized in the form of project activities. Students face the task of developing computer models and their implementation with the help of one of the computer modelling languages, in particular Octave, Matlab, Python, and C++. When studying the material within the «Modern Problems of Mathematical Modeling» training course, the main tools for solving problems are Matlab/Simulink and Scilab/XCos. This is because the course pays significant attention to the structural-algorithmic approach and simulation modelling [17].

In general, Matlab is considered a basic environment for solving all educational problems. However, the high cost of this system of computer mathematics makes it accessible in the conditions of higher education institutions in Ukraine. Therefore, free systems such as Octave and Scilab are of ten used for educational purposes. These systems allow us to solve basic problems, and their syntaxis close enough to Matlab.

6 Summary

The conducted research confirms the significant advantages of using MPPP in the educational process. The implementation of MPAP in the educational process becomes an effective tool for the modernization of education, improvement of its quality and development of key competencies of students, necessary for successful professional realization in the modern world. Based on the results of the research and taking into account modern trends in education, we recommend widely implementing the MPAP in the curricula of all mathematical disciplines, providing students with the necessary software and methodical materials, developing methodical recommendations for the use of the MPAP in each discipline, clearly outlining whether goals, tasks and methods of their application, to integrate MPAP in various forms of educational activities, such as lectures, practical and laboratory classes, coursework and qualification works, and especially – research projects. It is important to note that the use of MPAP should not replace traditional teaching methods, but should complement them, making the learning process more dynamic, interactive and effective.

References

1. Ivaniuk, V.A: Mathematical Packages of Applied Programs: Studyguide. Kamianets-Podilskyi Ivan Ohiienko National University, Kamianets-Podilskyi (2015)
2. Steinhaus, S.: Comparison of Mathematical Programs for Data Analysis. 5.03 edition. Munchen (2008)
3. MathWorks. www.mathworks.com/products.html. Accessed 28 April 2024

4. MATLAB and Computer Calculations in Education, Science and Engineering. Kyiv (2019). https://www.researchgate.net/publication/332655611_MATLAB_and_computer_calculations_in_education_science_and_engineering
5. Buhaieva, P.V.: Determination of pedagogical conditions for the use of the Matlab Simulink environment in the professional training of future electrical engineers. Sci. Educ. **3**, 33–35 (2013)
6. Jurayev, A.X.: The use of Matlab in teaching the process of automatic temperature adjustment in higher education institutions. Galaxy International Interdisciplinary Research J. **11**(2), 351–356 (2023)
7. Abdul Majid, M., Huneiti, Z.A., Balachandran, W., Balarabe, Y.: Matlabas a teaching and learning tool for mathematics: a literature review. International Journal of Arts & Sciences **6**(3), 23–44 (2013)
8. Majid, M.A., Huneiti, Z.A., Al-Naafaand, M.A., Balachandran W.: A study of the effects of using MATLAB as a pedagogical tool for engineering mathematics students. In: 15th International Conference on Interactive Collaborative Learning (ICL), Villach, Austria, pp. 1–9 (2012). https://doi.org/10.1109/ICL.2012.6402183
9. Engelbrecht, J., Borba, M.C.: Recent developments in using digital technology in mathematics education. ZDM Mathematics Education (2023). https://doi.org/10.1007/s11858-023-01530-2
10. Devlin, K.: Teaching mathematics as a way of thinking – not calculating. Estonian Journal of Education **91**, 33–59 (2021)
11. Devlin, K.: Does AI Pose a threat to Mathematics Education? MAA website (2023). https://www.mathvalues.org/masterblog/86s4ajn3is69fzwpu6wi5iopqmw2y3
12. Lagrange, J.B., Richard, P.R., Vélez, M.P., Van Vaerenbergh, S.: Artificial intelligence techniques in software design for mathematics education. In: Pepin, B., Gueudet, G., Choppin, J. (eds) Handbook of Digital Resources in Mathematics Education. Springer International Handbooks of Education. Springer, Cham (2023). https://doi.org/10.1007/978-3-030-95060-6_37-1
13. Trinh Thi Phuong, T., et al.: Research on the application of ICT in Mathematics education: Bibliometric analysis of scientific bibliography from the Scopus database. Cogent Education **9**(1) (2022). https://doi.org/10.1080/2331186X.2022.2084956
14. Educational Interfaces between Mathematics and Industry in India AND Use of Technology in Mathematics Education in India, Proceeding of International conference on "Educational Interfaces Between Mathematics and Industry" (An ICMI-ICIAM International Study), Oct. 11–15, 2010 at Lisbon, Portugal, ISBN No. 10:1–933223–64–2
15. Georgieva-Trifonova, T.: Establishing cross-curricular connections through python programming in computer modeling education. TEM Journal **12**(3), 1786–1791 (2023). https://doi.org/10.18421/TEM123-61/
16. Wiedemann, K, Chao, J., Galluzzo, B., Simoneau, E.: Mathematical modeling with R: embedding computational thinking into high school math classes: ACM Inroads **11**(1), 33–42 (2020)
17. Fedorchuk, V.A, Ivaniuk, V.A: Modern problems of computer modelling: Educational and methodological guide. Kamianets-Podilskyi Ivan Ohiienko National University, Kamianets-Podilskyi (2023)

Author Queries

Chapter 57

Query Refs.	Details Required	Author's response
AQ1	This is to inform you that corresponding author has been identified as per the information available in the Copyright form.	
AQ2	Please be aware that your name and affiliation and if applicable those of your co-author(s) will be published as presented in this proof. If you want to make any changes, please correct the details now. Please note that after publication corrections won't be possible. Due to data protection we standardly publish professional email addresses, but not private ones, even if they have been provided in the manuscript and are visible in this proof. If you or your co-author(s) have a different preference regarding the publication of your mail address(s) please indicate this clearly. If no changes are required for your name(s) and affiliation(s) and if you agree with the handling of email addresses, please respond with "Ok".	