WHAT SOFTWARE TO USE IN THE TEACHING OF MATHEMATICAL SUBJECTS?

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Abstract: We can consider two basic views, when using mathematical software in the teaching of mathematical subjects.

First: How to learn to use specific software for the specific tasks, e. g., software Statistica for the subjects of Applied statistics, probability and mathematical statistics, or financial mathematics.

Second: How to learn to use the software that is available to us to solve specific mathematical problems from different areas of mathematics and applied mathematics.

My article describes the practical use of the software in the teaching of mathematical subjects and my experience with its use by the students and the pedagogues.

In our computer laboratory our students use the following software: MS Office (MS Excel), LibreOffice (LO Calc), MATLAB 2010b, Octave, wxMaxima, and LaTeX.

We use this software in the following mathematical subjects: Operational Analysis, Linear and Quadratic Programming, Numerical Mathematics, Applied Statistics, Queuing Theory, and Fundamentals of the LaTeX.

Eight years of experience with the usage of these programs have shown us, how we can improve the teaching process of the mathematical subjects at the technical universities with freely available software.

Keywords: Teaching, Software, Mathematical Subjects

1 Introduction

It is difficult to decide what kind of software is the most suitable to use for teaching mathematical subjects at technical universities. The best software should be applicable not only for specific tasks but also students should be able to use it in various subjects It is important for students to have an easy access to get this software for studying it at home instead of limited usage of this software on the computers in PC laboratories. We should realize that students frequently use specific types of software at secondary schools therefore usage of the same or similar software could make easier transition to universities. Considering the fact that there is lack of time and space for teaching the students the usage of specific software.

I explain in this article, eight years of my experiences of using the software for teaching subjects at Department of Mathematics and Informatics of Faculty of Electrical Engineering and Informatics and also Department of aerodynamics and simulations, Faculty of Aeronautics, Technical University in Košice. I will evaluate the usage of some applications in various subjects and illustrate other options and possibilities to use easily accessible software [6, 5, 8, 10, 13, 14].

2 Software used at mathematics at Technical University

This chapter presents software that we used and still are using at teaching mathematical subjects at our faculty, Faculty of Aeronautics, respectively. In which subjects was software applicable? What kind of

response we received while using it? Finally I will try to explain how to choose the software for teaching mathematical subjects considering experience and possibilities which are available at our faculty and university.

2.1 What kind of software

In 2006 we established new PC laboratory with limited possibilities at our Faculty. Other laboratories were gradually formed with hardware which enable us to use variety of software. Four active laboratories at DMTI and DAaS, are active with relatively modern computers with high speed graphic cards, processors and memories (RAM).

The software installed on computers are:

(a) MS Office (MS Excel),

(b) LibreOffice (LO Calc),

(c) MATLAB 2010b + toolboxes,

(d) Octave,

(e) wxMaxima,

(f) LaTeX.

We are in the process of updating the infrastructure of computers for parallel calculating (Parallel Computing Toolbox for Matlab - server MDC) and also usage of graphic cards for math calculating and simulation in two laboratories.

The question is, why have we chosen this software and what is the importance of usage of software teaching mathematical subjects at our faculty. MS Excel from MS Office package and LO Calc from Libre Office package was chosen because classic spreadsheet are part of education at many secondary schools and students are familiar with basic usage of software. MS Office is frequent package used by many users. Schools are provided with bargain packages (our university uses license for buying MS Office package, we are entitled to use MS Office package with Windows). Students are also able to buy bargain MS Office package. We have also chosen alternative option Libre Office (initially we used Open Office). Matlab was picked because it is frequently used in engineering and scientific fields. Our university acquires licenses for Matlab usage for educational purposes and scientific research.

Future engineers should require basic knowledge while using it (airplane aerodynamics, thermal management engines, signal broadening, etc.). Octave software is an alternative option of Matlab. Students find the program useful even after they graduate university. Program wxMaxima is also an alternative option of Maple (Mathematics) program. Program LaTeXwas chosen as an easily accessible typographic program. It is useful for writing mathematical and engineering articles into scientific journals. Installation of software is available for operating systems Windows and Linux, except MS Office package.

Windows or Linux which is important. The project of Dr. Ján Buša deals with usage of open source software at universities. It is available on website of Dr. Ján Buša: Project KEGA - 3/2158/04 - New teaching technologies. – Usage of OPEN SOURCE software in teachings at universities and publications [6, 5, 8, 10, 13, 14].

2.2 In which subjects can be software used

At the beginning we used computers only in subjects such as Numerical Mathematics, occasionally Probability and Mathematical Statistics. Limited number of students could attend these courses due to capacity of PC laboratories. Numerical Mathematics is taught in the second year of bachelor study. Students

have already mastered basic knowledge in programming in C and C++. We were able to use Matlab and consequently classrooms [7, 9, 11, 12].

Students groups were large but capacity of PC laboratories was limited as the number of classes at out Faculty. Therefore small specialized groups of students were formed in one or two PC laboratories. We succeeded in using PC with more subjects. These are: Operational Analysis, Linear and Quadratic Programming, Numerical Mathematics, Applied Statistics, Queuing Theory and Fundamentals of the LATEX. Numerical Mathematics is taught in the first year of bachelor study. Operational Analysis and Fundamental of the LATEXis taught in the third year of bachelor study, Applied Statistics and Linear and Quadratic Programming is taught in the first year and Queuing Theory in the second year of engineering study. We also use PC software in these subjects at Faculty of Aeronautics: Selected chapters from Mathematics, Applied Mathematics and Numerical Mathematics. Applied Mathematics and Numerical Mathematics is taught in the first year of engineer study and Selected chapters from Mathematics is the subject for PhD students. These subjects cover numerical mathematics, probability, mathematical statistics and mathematical optimization. At Faculty of Aeronautics the education of PC started on request of technical departments. Departments requested to use program Matlab and program Excel for calculating.

What is common for all the subjects that use PC laboratories for educational purposes? Each subject calculates mathematical assignments with great number of numerical inputs. — In all subjects the tasks are solved with the need to perform a lot of numerical calculations, work with a lot of input data, respectively. In addition to these subjects, there are other subjects taught in PC laboratories at our department since I don't have sufficient information about them I won't present them.

2.3 How to use the software

At the beginning we used program package Matlab 6.0 (7.0) at teaching Numerical Mathematics, Probability and Mathematical Statistics, available at our faculty. It was a subject of the second year of bachelor degree. Majority of students were inexperienced in using the Matlab program and had no access to commercial software. It took a great deal of time to explain the basics of the Matlab program in various tasks (prepared literature for students - [7, 9, 12]) at the beginning of semester and during the class. The time frame of lesson was shortened by explaining the basis usage of Matlab program. It caused significant time pressure nevertheless overall students results haven't been improved. The number of successful students hasn't changed due to the limited capacity of PC laboratories, students were examined without PC usage. The lack of traditional calculator knowledge and lack of effectively organizing estimation without using the computers resulted in numerous problems.Therefore the usage of computers with these subjects was stopped. The computers are recently only used on teacher's request. This subject was emphasized in this article because there were not the same methods applied with all groups.

During that period of time I have started teaching small groups of students. I have tried to find out how can we use computers effectively in teaching above mentioned subjects. I knew I didn't have any extra time to explain the Matlab program in all suitable subjects. I have decided to do a short student survey. I wanted to know what kind of software they are familiar with, what kind of software they use and whether they have any experience with programming. I have chosen the software to be installed on computers in laboratory based on student's survey. I also created rules how to use it. I explained to students that computer software is an intelligent calculator and I won't be able to monitor PC outcomes. I can only check the staff that is on graph (spreadsheet) in notebook, credit test or final exam. Since the information in computers didn't influence their final evaluation I made another rule that they can use any available computer software installed in laboratory.

Rules about software usage effected student's choice of math exercises for class, credit test and final exam. Choice of math exercises was enlarged because PC calculations were fast and effective. I also expected there won't be so many numerical mistakes in regards to students calculations.

3 Achievements

During eight years period of time, I observed the usage of the software teaching these mathematical subjects:

(1) how is software used in students calculations,

(2) what mistakes disappeared and what mistakes appeared,

(3) how successful will be taking these subjects,

(4) what kind of student's reaction and respond we got after using this kind of teaching.

I will give you the detailed answers to specific tasks from teaching those subjects from 2.2 section, using software described in 2.3.

For the first time I used innovative principles with usage of software in subject of Operational Analysis. I explained to students what kind of computer software is available and asked them whether they familiar with it. Most of the students were familiar with MS Excel, one of them used Matlab and one of them wasn't familiar with any software. Later on most of the students were using MS Excel (from secondary school) but majority were also using Matlab or Octave. Some students have already used program language C meaning C++.

Basic model was used in subjects mentioned in chapter 2.2. Evaluation of students is based on constant chart. Student can get score of 100 for each subject. Score of 20 stands for credit test and score of 80 stands for exam test. Student is required score of 11 for getting credit. Exam test consists of two parts – practical and theoretical (both are valid score of 40). According to school system student is required to get score of 51 (credit and written exam test) and score of 41 for written exam test to successfully pass the exam. Illustration of individual tests will be described with each subject. Students were evaluated according to above mentioned chart. Every year we compared information how successful students were, which software they used and what was their basic knowledge with software before taking individual subject course. At the end of semester I had feedback information from students.

3.1 Operational analysis, Linear and Quadratic programming

Students used software at subjects as Linear programming (simplex method, dual simplex method), integer programming problem (Gomory's algorithm) and tasks of quadratic programming. Quadratic programming is a subject of the first year engineer students. These students are pretty much familiar with using Matlab and Octave software.

I experienced that the most frequent (99 %) program was MS Excel or LO Calc, students were using it during the class and during the exams. They chose Matlab even though it has function which can solve linear programming through simplex method.

Their choice was obvious because they needed simplex tables with feasible basic solutions and find pivoting for their next outcomes. They have to decide which pivot to choose for solving individual task or specific tasks of linear programming. They used MS Excel (LO Calc). These programs easily formed readable sheets with applied pivoting, considering the function of program. Student can get final result without information which leads to results while using Matlab program and its optimization function for simplex method. Some students used this program to verify the credibility of acquired results. See the sample figure 1.

$$
\begin{aligned}
x_1 + 2x_2 - x_3 - 2x_4 + x_5 - x_6 \quad &\longrightarrow \quad \min \\
x_1 + x_2 - x_3 + x_4 + x_5 \quad &= \quad 4 \\
x_1 - x_2 + 2x_3 - x_4 + x_6 \quad &= \quad 3 \\
x_{1-6} \quad &\geq \quad 0
\end{aligned}
$$

	A17		f_x						
	B	x_0	x_1	x_2	x_3	x_4	x_5	x_6	
	--	0	1	2	-1	-2	1	-1	0 - I + II
	x_5	4	1	1	-1	1	1	0	
	x_6	3	1	-1	2	-1	0	1	
	--	-1	1	0	2	-4	0	0	0 + 4P1
	x_5	4	1	1	-1	1	1	0	P1
	x_6	3	1	-1	2	-1	0	1	II + P1
	--	15	5	4	-2	0	4	0	0 + 2P2
	x_4	4	1	1	-1	1	1	0	I + P2
	x_6	7	2	0	1	0	1	1	P2
	--	29	9	4	0	0	6	2	
	x_4	11	3	1	0	1	2	1	
	x_3	7	2	0	1	0	1	1	

Picture 1: Linear Programming Problem – MS Excel applied

The sheets are displayed within limited space but we can easily see every step of solution from incoming variables into base and pivot. We can see which columns corresponds to the variables as such and which corresponds to the basic variables. They used the same approach with the tasks of Integer linear programming, where they add rows (Gomory cuts) and columns (Gomory variables). They also use it with quadratic programming with simplex tables.

Students showed less mistakes while using software. If there were mistakes it was because of basic mistake not only wrongly applied mathematical operation. There were also mistakes caused by inadequate usage of software. These mistakes are difficult to spot or we can't find them at all (especially with credit and exam written tests).

Credit test – consists two tasks, each scores of 10. The first assignment is graphic solving task of LPP with two real variables. The second assignment is solving task with simplex method.

Exam test – consists of four tasks, each scores of 10 and 10 theoretical questions, each scores of 4. The first task includes simplex method, the second includes method of CPM, or PERT, the third task includes transportation problem and the last fourth task is integer programming problem or task about max flow problem (Ford Fullkerson algorithm). Two questions are fill in definition questions or theorems. Four questions are theorems, definitions or properties and four questions are multiple choices questions a,b,c or d, where correct answer can be from 0 to 4.

Process of academic years results is illustrated in Table 1, it shows the subjects of Operational analysis (OA) and Mathematics 3 (Linear programming) (M3). (WT – winter term, ST – summer term)
We can see that average evaluation of exam results from (OA) and (M3) was improved. Students used software in the second task of credit exam and in the first and the fourth task of exam test. They used MS Excel respectively LO Calc in majority tasks. They used standard calculator in four cases, they did not use anything in two cases and they used Matlab respectively Octave in two cases. Students became more advanced in using software (mainly from secondary school - showed in research from the beginning of term). More than 85 % student's feedback showed satisfactory approach about using PC during tests and

Table 1: Results of subjects OA and M3

Subject	Academic year	Average
M3	ST 2009/2010	2.63
M3	ST 2010/2011	2.46
M3	ST 2011/2012	2.22
M3	WT 2012/2013	1.89
M3	WT 2013/2014	2.88
OA	ST 2006/2007	2.63
OA	ST 2007/2008	2.38
OA	ST 2008/2009	2.56
OA	ST 2010/2011	2.21

exercises. More than 70 % of students were satisfied about their familiar software choice. They claimed that mistakes were decreased due to familiarity of software (research at the end of term). The results were improved due to students skilfulness of used software. Students were also excited that they can use the software they are familiar with which resulted in lack of mistakes caused by unknown software. WT 2013/2014 subject M3 shows worsen result due to the fact that students were repeating the class (unsuccessful students from previous academic year).

Evaluation of mistakes using simplex method showed anticipated result. Mistakes of incorrect addition and multiplied numbers were nonexistent. Incorrect results were caused by wrong set of initial entries and by inaccurate usage of algorithm calculation. Mistakes created by imprecise usage of software were not identified by presented tests. We became aware of those mistake from students after finishing their tests at the end of term.

Results from subjects Linear and Quadratic programming were not revealed due to the lack of sufficient number of information even though this subject is taught according to above mentioned a scheme.

3.2   Numerical mathematics and Applied statistics

Tests structure of Numerical mathematics:

Credit test – contains five tasks. (1 − 4 points) Find the domain of function (2 − 3 points) Derivation of three functions a) basic derivative of formulas, b) product rule, chain rule, c) quotient rule (3 − 3 points) Application of derivation , i. e. local extremum, monotonicity etc. (4 − 6 points) Integration of 3 functions a) basic formulas of integrations, b) integration by parts, c) substitution method (5 − 4 body) Application of integral e. g. area of planar surface.

Exam test – contains of ?ve tasks for 40 points and 10 theoretical questions for 4 points. (1 − 4 points) The domain of function (2 − 6 points) least square method or Lagrange interpolating polynomial (3 − 10 points) numerical method for solving of nonlinear equations with one unknown variable (4 − 10 points) numerical evaluation of the definite integral (5 − 10 points) numerical method for solving of system of linear equations. Three fill in questions, meaning theorems or definitions. Two questions are: write theorem, definition or properties and five multiple questions with correct answer from a, b, c or d choices, where correct number of answers can be from 0 to 4.

Test structure of Applied statistics:

Credit test – contains of four tasks. (1 - 4 points) Probability (2 − 6 points) probability (3 − 4 points) random variable, distribution function, probability density function (4 − 6 pints) descriptive statistics.

Exam test – contains four tasks for 10 points and 10 theoretical questions for 4 points. (1) Probability (2) probability (3) con?dence interval or single-sample test of statistical hypothesis (4) regression and correlation analysis or test for two samples. Six theorem, definition and properties questions and four multiple questions with correct answer from a, b, c and d choices where correct number of answers can be from 0 to 4.

We used completely different software in Numerical mathematics and Applied statistics than in Operational analysis and Quadratic programming. Students made different choice in subject but also in actual theme. 90 % of students chose Matlab (Octave) in numerical calculations of nonlinear equation. Only 10 % of students used spreadsheets of MS Excel (LO Calc). Matlab (Octave) provides easier application of functional instructions, clear illustration of functional graphs, calculations of functional value and precise monitoring of results through included functions for numerical calculations of nonlinear equations. 50 % of students used spreadsheets of (MS Excel and LO Calc) and also 50 % of students used Matlab (Octave) in numerical integration. Similar choice was with numerical calculations of linear equations. Students used Matlab (Octave) to monitor only the results in subject of M1-A1 where was linear algebra. Students chose MS Excel (LO Calc) to monitor in between results. The results are not so significant in these subjects as they were in other subjects, Table 2.

Table 2: Results of subjects NM and M1-AI

Subject	Academic year	Average
NM	ST 2007/2008	2.85
NM	ST 2008/2009	2.98
NM	ST 2009/2010	2.95
NM	ST 2010/2011	2.88
NM	ST 2011/2012	2.94
NM	ST 2012/2013	2.88
NM	ST 2013/2014	2.75
M1-AI	WT 2009/2010	2.43
M1-AI	WT 2010/2011	2.61
M1-AI	WT 2011/2012	2.73
M1-AI	WT 2012/2013	2.40
M1-AI	WT 2013/2014	2.57

These kind of results were expected since It is necessary for students to acquire basics knowledge and skilfulness of mathematical analysis from secondary school. Many tasks are not able to be resolved only with available software (for example domain of function, derivative of function, derivative function with steps of solutions, integration of the function with the steps of solutions etc). Many students were unable to effectively use available software for task solving. I will present set of mistakes, which were made by students in solving nonlinear equations. Equation which has three roots, where one is the furthest one was not found or they only found one root. Even when they used domain for graph domain presentation they often used incorrect interval on which graph was supposed to be presented. Another example is when there were two roots next to each other, students could not find one of them because of inaccurate graph readability and they did not realize possible existence of two roots instead of one. Students also did not used correct functioanl expresion in form $f(x) = 0$ which should be used to calculate of functional values.

The results have improved in subject of Applied statistics, it is shown in Table 3. Choice of suitable software also influenced the results. Majority of students chose Matlab (Octave), it provides variety inbuilt functions and is easily operated. All of the students used MS Excell (LO Calc) or with combination

of Matlab (Octave) in Descriptive statistics. Main advantage of worksheet processors in Descriptive statistics is their overview representation of entries in frequency tables and its basic calculation. Matlab has its functions for file processing by the help of rules of Descriptive statistics but the outputs are not clear and used entries from frequency table is more complicated than in case of worksheet processors. The absolute and relative addresses of calculating cells, conditional formatting and visualization (which is very important in Descriptive statistics) are the greatest as sets.

Table 3: Results of subject AS

Subject	Academic year	Average
AS	WT 2008/2009	2.75
AS	ST 2011/2012	2.59
AS	ST 2012/2013	2.40
AS	WT 2013/2014	1.89

Reaction of the students of bachelor study who did not have adequate experience and skilfulness in their particular software was vague since they had to spend their time studying individual subject but also mastering software. Only 50 % of students found beneficial using software in subject NM and M1-AI in final checklists. Opinions of 30 % of students were neutral and 20 % of students actually considered using software as disadvantageous. The first year engineering students of subject of Applied statistics were thrilled to be able to use software in PC laboratories. Majority of students used at least one of the mentioned programs in varied subjects during their study so they were not slowed down by software study but they were able to use it in subject of Applied statistics.

Systematic not numerical mistakes were prevalent. There were invalid reasoning, evaluation of verified conditions to solve the problem or in some cases wrong set of operations and methods. There is a tendency of great data of mistakes with these subjects. Students make mistakes in tasks solving in Numeric mathematics, Probability and Mathematics statistics.

Database is enriched by information from subjects of Applied mathematics and Numeric mathematics which are taught at Aerodynamics Faculty TUKE of engineering study. Available information is incomparable since Aerodynamics Faculty's studying groups had lesson outside of PC laboratories which resulted in mistakes generation (mistakes mainly resulting from using standard calculator and also classic numeric mistakes plus mistakes by numeric rounding). We do not have students feedback from Aerodynamics Faculty like we had from FEEI students.

3.3   Queuing Theory

The second year engineering students showed the best knowledge and skilfulness of software in Queuing Theory subject. Students used effectively their knowledge in solving tasks. It is difficult to specify the most common program which they used because their approach was individual and almost every student used more than one program. They used Matlab, Octave, MS Excel, LO Calc and also wxMaxima. According to available information, 50 % of students used more than one software program at solving individual tasks. For example, in task of Markov processes where vectors of probability were solved with Matlab or MS Excel, but in system of linear equations which leads to limited vector were solved with wxMaxim.

Positive results are shown in table 4.

Students enjoyed subject in all forms. All students appreciated the opportunity to chose their own programs which made their study easier. More than half of the students couldn't image solving tasks without PC, it would take them much longer.

Table 4: Results of subject QT

Subject	Academic year	Average
QT	WT 2008/2009	2.24
QT	WT 2009/2010	2.76
QT	WT 2010/2011	2.75
QT	WT 2011/2012	2.20
QT	WT 2012/2013	1.93
QT	WT 2013/2014	2.36

Numerical mistakes and mistakes were nonexistent in solving Queuing theory tasks while using software (only 6.5 % of students were familiar with available software) The most common mistakes appeared from unfinished parts of task, missing some steps of calculation, wrong interpretation of results or wrong set of operations. All these mistakes emerged from lack of theoretical knowledge.

Usage of schema was bene?cial in PC laboratory Teaching subject of Queuing theory in PC laboratory was enriched by beneficial schema.

4   Conclusions

We created PC laboratories with numerous installed programs for teaching these subjects at Department of Mathematics and Informatics but also at Department of Aerodynamics of TUKE. The students are able to decide which software they use in solving math problems. This type of software should improve the students results but only if they are familiar with available software and are able to use it effectively.

This approach is more successful among the advanced bachelor, engineering and PhD-students at Technical university. The problematic subjects are in the first year bachelor study. Software could be used in more effectively, if students could apply their secondary school knowledge and skilfulness. It would be also beneficial to create lesson time frame for introduction of available software. We need to take into consideration the fact that some of the students in the first year of study will not be able to pursue their study after failing their exams, etc.

We were able to provide identical conditions in described subjects from 2.3 chapter in short period of time. At the beginning we verified the possibility of software usage. Standard structure of credit and exam tests and comparable score evaluation. We received feedback from students about each subject after semester was finalized.

We do not acquire applicable subject information from Faculty of Aerodynamics. There would be sufficient amount of information in the long run but Faculty of Aerodynamics hasn't used the same infrastructure. Results were influenced by subject changes. Even though the single subject was not changed but there were changes in followed up subjects which would influence results. That is why I have not mentioned any information from Faculty of Aerodynamics. The most interesting results are from two subjects, which are taught simultaneously – Applied Mathematics and Applied Mathematics 1 with comparable context. The first one is taught without PC and the second one is taught in PC laboratories. I was not successful in getting steady information during the whole time.

Academic year of (2014/2015) is the last year that I am able to collect the information about individual subjects. New significant changes will take place in studying programs and obtained information will not be usable for comparison. There is a possibility to create new infrastructure for new research but it would be difficult to guarantee the stability of infrastructure for longer than 5 years.

In the future it is our interest to introduce expanded available software using high speed servers and computers in laboratories. We would like to prepare new studying concepts which will partially include

software usage in teaching some of the subjects. At the same time we are preparing the project about students experience and opinions with software usage in solving some of the problems (electronic check-lists).

We applied GeoGebra program for linear and Integer programming in the subjects of Operational analysis and Linear programming. We are planning to publish the results of this change in the near future.

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