Case study on means of information and communication technologies in teaching mathematics to distance and extramural university students

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Abstract: This paper outlines theoretical and methodological foundations of teaching mathematics to extramural students, formulates and argues requirements for the organisation of teaching mathematics to extramural students of technical universities, clarifies the concept of distance learning, develops methodology of teaching mathematics to extramural students of technical universities via program-methodological complex and it proves that it effectively improves teaching mathematics to extramural students of higher technical institutions, providing additional opportunities for individualisation of students’ learning due to the use of interactive and educational programs, which help to control acquired knowledge, skills and competences acquired in mathematics.

Keywords: extramural learning; distance learning; information and communication technologies; ICTs; independent learning; mathematics; pedagogical experiment; ‘zero’ tests; software application; technical universities.


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1 Introduction

This paper outlines theoretical and methodological foundations of teaching mathematics to extramural students, formulates requirements for teaching mathematics to extramural students of technical universities, clarifies the concept of distance learning, develops methodology of teaching mathematics to extramural students of technical universities via a computer application and proves its efficiency in teaching mathematics to extramural students of higher technical institutions, sustaining students’ independent learning via interactive and educational programs, which help to control acquired knowledge, skills and competences.

There were formulated two hypotheses to check the efficiency of developed methodical system to teach mathematics to extramural students of technical universities. H0 – zero hypothesis (the quality of learning in the control group (CG) is not higher than in the experimental group (EG) after application of proposed methodology), H1 – alternative hypothesis (the quality of learning in the EG is superior to that in CG). Two-sided criterion $\chi^2$ (nonparametric) was used to verify the statistical veracity of effect that the proposed method of training brings to the quality of training.

At the moment reforming and modernising higher education in Ukraine is a most urgent task on the way to innovative, pro-European development of Ukrainian society. At the same time, it should be realised by gradual phased introduction of European norms and standards, taking into account national traditions.

It is known that the progress and prosperity of future generations depend on how we teach a new generation now. The modern stage of development of the system of higher professional education during the transition to the market economy requires a thorough and comprehensive analysis of ways to improve the training of future specialists.

2 The development of modes of education in Ukraine and in Dniprodzerzhinsk State Technical University

Efficient higher education and professional training are crucial for further development of the country. Ukraine is witnessing reforms aiming to improve the quality of education and bring it closer to the best international standards. We should pay particular attention to the improvement of mathematical education that should be better adapted to the needs of society.

The modern stage of development of the mathematical education in Ukraine is characterised by a dynamic search of new forms and methods of teaching, new pedagogical technologies. This process should address both the needs of the students and those of the labour market. Economic globalisation requires a great number of educated employees who can quickly adapt to changes in the economic environment. The background professional knowledge and excellence in professional training should enable employees to improve their skills in order to work with constantly updated production systems. Extramural training (ET) and Distance learning (DL) give this opportunity.

Extramural learning in Ukraine was not built from scratch. It has a long history, its traditions; it is based on a fairly extensive scientific community which includes both researchers and university professors. These traditions were created in the Soviet period and largely continue to influence current trends in this area. ET is a track, rolled by many generations.
ET is a mode of training and professional development for specialists with higher and specialised secondary education, as well as a form of getting an education in the workplace. It is particularly important in technical universities, as it becomes attractive in view of the prevailing socio-economic conditions: relatively low price of education, a combination of professional practice and fundamental knowledge behind the chosen field of studies.

This mode of training was designed for people who combine education and professional employment. It involves individual work of students on course materials [Order on organisation…].

The extramural training uses in-line principle, i.e., the same education plan for all students, common terms of delivery of test and course tests (term papers). Typically, there are two exam sessions in the academic year (usually in winter and summer). The subject-course system of education is accepted in extramural higher and secondary specialised educational institutions (faculties, departments). Extramural students usually study one year longer than their full-time counterparts. Extramural students who have obtained higher or specialised secondary education are granted diplomas of unified status and generally accepted qualifications in Ukraine [Order on organisation…].

We suppose that formally extramural training equals to distance learning and in fact, it is a synthesis of full-time and distance learning aided by information and communication technologies, which allows realising the quasi-audio contact and quasi-video contact between a student and a professor (Krylova et al., 2010).

However, students of extramural departments are specific. It is related to employment of students and the fact, that some students had a long break between graduation from school and the start of current course at university. A lot of them have forgotten how to learn. In addition, learning ability changes with age which is a natural trait of humans. Therefore, extramural students generally do not seem to impress professors.

Distance and extramural learning can be as effective as the traditional form of learning if technologies and methods of teaching are chosen adequately to tasks, desires and capabilities of students and teachers.

3 Related work

The research of education methodology is booming due to the application of e-instruments. Research done in the 90s by Richard Mayer in educational psychology, namely in multimedia learning theory, argues that learning is most effective if the visual and verbal information is presented simultaneously (Mayer, 2009). The relevance of his results has been recently confirmed – students remember more, attend classes more often and learn better when teachers use the interactive approach in the classroom (Mervis, 2011).

Information and communication technologies improve learning process in a variety of ways (Parkes et al., 2015; Tsai, 2015).

Currently, Ukrainian researchers take great interest in enhancing the quality of teaching, namely, e-enhanced teaching of mathematics.

Information technology significantly improves students’ motivation to acquire theoretical knowledge, to solve practical problems, allows the teacher to redistribute working time and organise the learning process in the new environment (Goliver, 2005). Pedagogical experiment by Y. Trius confirms the efficiency of e-books, instrumental and
testing applications, educational computer systems for mathematics in universities (Trius, 2005).

A research on teaching higher mathematics to machine building engineers argues that students learn more effectively with information technologies, the authors confirm that with their electronic teaching aid “Higher Mathematics for future engineers” (Vlasenko, 2011).

Klochko argues the main directions of ICT use in teaching higher mathematics are:

- training software in teaching basics of higher mathematics and specialised courses in mathematics
- training e-books and the creation of electronic directories
- computer testing and assessment
- software packages and computer models in the study of applied points in specific mathematical courses
- interdisciplinary connections of courses in higher mathematics with other courses
- universal computing systems, such as MATLAB, MATHCAD, MATHEMATICA, etc. in the study of technical subjects (Klochko, 1998).

Independent students’ work can also become more effective, in particular, due to new network systems of computer mathematics (Web-SCM), especially the open-source system for mathematical research Sage (Shokaliuk, 2010).

Mobile learning which is regarded to be an instance of distance learning via smartphones, PDAs, e-books and other mobile devices improves the quality of learning and makes it more flexible (Semerikov, 2009). For example, mobile mathematical software system Sage can be an excellent platform to develop mobile courses in higher mathematics for university students (Slovak, 2011).

4 The description of experiment

Extramural learning is practised in almost all technical universities in Ukraine. In Dniprodzerzhynsk State Technical University (DSTU) highly qualified and experienced specialists, including 38 doctors of Science, professors and 147 candidates of science work with extramural students.

They teach courses in an extramural mode in the following fields of DSTU:

- metallurgy
- mechanical engineering
- electric power engineering
- physics and mathematics
- economics
- chemistry
- biotechnology
linguistics

sociology.

A questionnaire was conducted among 320 extramural students of senior courses of DSTU. They were proposed to fill out a questionnaire about what aims they followed when they entered the university, how they achieved them and how their goals changed by the end of studies. The pie chart (Figure 1) shows the distribution of aims students pursue to get higher education in extramural mode:

- 35% consider their main task is to advance in career plan consistent with a diploma and the acquired knowledge
- 29% expect to raise the level of payment for their work
- 14% consider that a diploma is important because nowadays the vast majority of jobs require a university degree
- 12% plan to change a specialty
- 10% of the students are looking for skills to excel in their current jobs.

The analysis of research data showed that during the course students’ aims have changed insignificantly and, according to their own opinion, on the whole, they will be achieved. Many people believe that extramural training has given them something that they aspired when they entered university, so their expectations were completely met.

Figure 1  Aims of extramural students (see online version for colours)

Higher educational institution enables students to be more independent, competent, to learn faster, acquire analytical skills, increase mobility in carrying out their professional functions, learn to efficiently process increasing volumes of information and based on it they can make important decisions.

Life keeps changing and also puts forward new demands to courses in mathematics. Improvement of courses in mathematics in universities is an important and continuous task. New teaching methods, based on active, independent forms of learning and work with information, displace demonstrative, informative, illustrative and explanatory methods, widely used in traditional teaching. Information technologies penetrate into all
spheres of life, and methods of teaching of each subject should take into account their originality and singularity.

In recent years the quality of training in mathematics, both in schools and in universities has considerably decreased. DSTU Professor T. Krylova believes that the objective reason for this negative phenomenon is the “lack of sufficient motivation in society to study technical disciplines in general and mathematics in particular, because of the social conditions that do not set education in general and higher education, in particular, as a top priority for young people. One of the ways to solve the problem of improving mathematical training of engineers is the use of ICT” (Krylova, 1999).

The introduction of ICTs is one of the most important ways of improving the efficiency of the learning process. Information technology is attractive for educational purposes because it grants access to educational information and also permits to work with it interactively.

ICTs in their turn provide access to non-traditional sources of information, improves the efficiency of independent work, boosts creativity, allows to implement fundamentally new forms and methods of teaching, opens new opportunities for teachers’ and students’ activities. ICTs do not only boost the information flow, they are basic tools in professional and practical human activity.

The educational system has always relied on the achievements of science and technology, contributing to their further development. At present stage of development of the higher education system, it’s impossible to achieve high-quality training in engineering institutes without ICTs. They are one of the most important reserves for increasing the effectiveness of the educational process.

Higher mathematics lays foundations for mathematical education of an engineer. For a successful study of general theoretical and special subjects which are provided by curricula of different specialties, it is important how efficiently the students master the course of higher mathematics.

Syllabus in higher mathematics for extramural students does not differ in content and scope from the one for full-time students. The maximum weekly workload for extramural students is almost 2 times less than the one for full-time students. Therefore, math teachers in technical universities are experiencing difficulties because they cannot teach all the issues that were planned for the syllabus within the set number of hours. In this regard, there is a number of problems and the key problem among them is the formal application of teachers’ practices for the full-time students to the work with extramural students.

In their turn, extramural students do not have sufficient skills to work independently with tasks in mathematics. Consequently, there is a contradiction between the social demands on educated graduates of higher technical educational institutions, who use mathematical knowledge in their professional work and the current methodical system of teaching mathematics to extramural students.

The basic forms of work for extramural students are:

- lectures
- practical classes
- independent students’ work under professor’s guidance
- consultations.
In DSTU at the department of higher mathematics, the training for the students is based on such activities as lectures, practical and laboratory classes during the session period.

The main form of teaching to extramural students is independent work on the teaching material, which consists of the following elements:

- studying of material from textbooks
- compilation of lecture notes
- the solving of mathematical tasks
- self-assessment
- test papers.

Improving the quality of math teaching to extramural students is possible due to the formation of skills of independent work of students. The results of research which was conducted by psychologists and teachers indicated that when there is a need for self-development and self-improvement, we can achieve quite a high level of professional skills, competence and creativity (Ilyin, 2000).

So, first of all, students as future specialists need to develop the skills of independent work. To achieve this goal, students’ independent work should be carefully planned, organised and controlled (Yevseyeva, 2011).

According to Ganicheva (2006), it is necessary to organise independent work of students in such a way so that they could, wanted and obtained new knowledge themselves, knew how to put it into practice and consciously controlled their activities. These qualities are necessary for a person to face contemporary environment, as long as information and scientific knowledge are the main factors, determining the trends of development in society.

For successful independent work of students the following main types of training materials should be available:

- text on the theoretical material and illustrations to it for an independent study of theoretical questions
- examples of formulating and solving typical problems for getting some practice
- questions for self-assessment
- tasks for self-control with detailed solutions
- review questions to test the knowledge gained
- benchmarks for verification of acquired skills
- guidelines to implement control works tasks for the course works and other independent work and guidelines for their implementation
- reference materials needed to work on the discipline.

In this mode, the student should memorise the contents of lectures and workshops and also learn advanced material that was not included in lectures and workshops. With such organisation, students become accustomed to reading scientific literature and doing systematic work.
One of the problems in organising students’ independent work is the lack of interactivity. Most of the students lack opportunities to ask questions and get answers during the period between examinations.

The practice of teaching mathematics shows that the blocks for independent study caused the biggest problems for students. Many students are behind the schedule with their control papers and the quality of work is usually only satisfactory.

These drawbacks obstruct the educational activities of technical universities, where natural sciences are included in the syllabus. For example, a course of higher mathematics is quite vast and includes a large set of new concepts, methods, theorems and formulae, requires background school knowledge in mathematics: geometry, algebra and the foundations of mathematical analysis. The course of higher mathematics includes elements of linear and vector algebra, analytic geometry and the foundations of mathematical analysis (differentiation of functions and their research), the function of several variables, indefinite, definite and improper integrals and differential equations, series.

In distance mode, it is desirable to organise more frequent face-to-face meetings with professors for consultations. Therefore, we also conduct additional and individual classes of students with teachers throughout the academic year because mathematics is an extremely difficult subject for self-study and is very difficult for students to master without personal contact with professors (Krylova and Gulesha, 2007).

The survey also revealed challenges that extramural students face during studying higher mathematics in the 1st semester: insufficient quantity and quality of course materials – 83% respondents; lack of consultations with professors – 67%, independent work in the classroom under the supervision of professors – 71%, lack of multimedia materials (educational audio, video, internet, etc.) – 79%, lack of additional materials in mathematics – 90%.

To improve the quality of mathematical preparation of extramural students it is necessary to change forms of distance learning, revise teaching methods and mode of exam session, to implement new techniques into distance learning and to create purposefully prepared teaching materials, computer-based training and monitoring programs, computer application in mathematics for students of extramural and distance learning.

A new generation of students who live in modern information environment requires a new generation of educational resources. The introduction of ICT is one of the most important conditions for increasing the efficiency of the educational process. Information technologies are attractive for educational purposes because they do not only grant access to educational information but also access to interactive work with it.

The ICTs provide access to non-traditional sources of information, improve the efficiency of independent work, provide an opportunity for creativity, allow the implementation of fundamentally new forms and methods of teaching, open up new opportunities in the cooperation of professors and students in learning activities. ICTs are not just boosters of information flow, they are basic tools in the professional and practical activity of people.

However, Ash (2015) argues that the availability of computers in the educational institution is the precondition, which does not guarantee improvements in learning. But, undoubtedly, the best experience in implementation of technologies is as important as the technologies themselves.
New technical possibilities allow us to educate with kinds of equipment which were hard to imagine a few years ago. Education in this environment relates to a new paradigm in education, which demands new methodology, new ways of organising teaching.

Due to the current economic situation in the country, not all universities can afford to implement distance learning. Therefore, universities use some elements of distance learning technologies to support its currently enrolled students and provide them with permanent access to the lectures and other information.

5 The software package for teaching mathematics

In order to optimise the learning process, we have developed a computer application in mathematics for extramural students of technical universities in order to improve the quality of mathematical training.

“The software application – is a set of training materials of various kinds, including software tool for educational purposes, presented at certain data carrier (on CD-ROM etc.), teaching aids for students and course materials for teachers and from a pedagogical point of view provides the most effective mode of work with particular topic of the curriculum. The application is necessary and sufficient for learning a particular subject or several topics within existing training programs” (Krylova, 1999).

Software and training systems are open systems of manuals providing personally oriented level of training. Today, software applications can contain up to two dozen components: a textbook, problem book, reading book, reader, workbook, textbook, work program, a set of tests, videotapes, CDs, computer programs, etc.

The application in mathematics has a block-modular structure and contains a module for elementary and higher mathematics, personalisation module for teachers who developed the course and a module of methodological assistance. The last one contains information on the ways to guide the study subjects, i.e., comprehensive and clear guidance on how to achieve the goals of learning mathematics, a description of the learning process, in which one can find guidelines for independent work of extramural students.

The presented application was created with web-based technologies – HyperText Mark-up Language (HTML) 4.0 and is compatible with both Windows or Linux, can be run by various web browsers including Internet Explorer, Mozilla, Netscape Communicator, Konquer, FireFox, etc. The material is presented via a system of hypertext links with clear icons.

The application is focused mainly on Windows operating system, not forcing the user to install any extra software. If the users are already equipped with MS-WORD, DJVU, PDF, they can open special tutorials on elementary and higher mathematics in section “Literature”. This program functions offline, directly from the CD or in a local university network and had a user-friendly interface.

The learning path can be made flexible, it is determined either by the student or the teacher based on initial skills of the students. We have tried to simplify and unify the user interface for the independent work as well as the amount of information that the student can learn. We did our best to point possible links between the parts of this software package. Taking into account all of these factors allowed to develop a fully functionally and user-friendly software package.
The students can see the general structure of the software kit on the screen, the contents of each module, they can comfortably access its components (as well as sections and subsections) by selecting the appropriate navigation elements of the interface (icons, buttons, menu items, etc.).

The application contains a section on elementary mathematics, because many extramural students have serious gaps in knowledge in mathematics from previous years, as many of them have graduated from school long time ago.

Reference guide for elementary mathematics includes the following sections (Figure 2.)

- arithmetic operations with ordinary, decimal and periodic fractions
- identical algebraic and trigonometric transformations, the solution of algebraic, exponential, logarithmic, trigonometric equations
- the solution of text algebraic and geometric tasks.

**Figure 2**  The module on elementary mathematics (see online version for colours)

Practical assignment in elementary mathematics is primarily designed for recapitulation and consolidation of knowledge in mathematics acquired in high school. It contains a set of individual tasks and guidelines for their implementation.

The module on higher mathematics consists of the following units (Figure 3):

- workbook on higher mathematics (including electronic textbook written by the staff from the Department of Higher Mathematics of DSTU)
- instructive examples of solutions to test paper
- individual assignments (test papers for extramural students)
• simulator
• a control system (tests)
• glossary
• guidelines developed by the teachers
• bibliography.

The theoretical section on higher mathematics should help those students who do not have enough time to take notes during the lecture, who may miss a few lectures, if the material is given for independent study, if the students find something difficult to understand using other textbooks or if they do not have time when there is a lot of factual material that should be studied in limited time. Theoretical material is presented in a way to enrich students of any level. In the practical part, we can find a large number of conventional tasks, which teachers and students normally lack a successful learning process. Most tasks are supplied with answers, solutions or detailed instructions.

Figure 3  Module on higher mathematics (see online version for colours)

We developed three kinds of thematic tests for formative assessment and self-assessment in higher mathematics:

• multiple choice
• open answer (short response)
• open answer with detailed calculations.
6 Results

In the period 2002–2013, there was organised and conducted a purposeful pedagogical experiment which included the development, research, correction and verification of the effectiveness of proposed methodology for teaching mathematics to extramural students of technical universities using the software application.

At the first ascertaining stage of the experiment (2002–2005), there was conducted the analysis of the scientific, psychological and pedagogical, methodological literature on methods of teaching mathematics to extramural students of technical universities, the technical literature on information technology, the established practice of implementation of e-learning. The topicality and the way of solving the problems of research were proved,

- together with the organisation of independent work – 87%
- inability to cope with the large amount of information and choosing the most important topics – 97%
- weak natural science base – 89%
- inability to work with the textbook, sources and the media – 56%
- the reluctance of students to participate in research, classroom, extracurricular work – 56%
- lack of independent work skills – 84%
- low motivation to study mathematics, extramural students at this stage are not yet convinced of the necessity of mathematical knowledge in their future professional activity – 74%
- students need of additional courses on elementary mathematics 73%, 17% – are undecided, and the rest do not recognise this need
- do not possess the object, subject, goals, objectives and basic methods were defined; besides the role and place of ICT in the extramural education were explained.

An initial collection and analysis of empirical data have been conducted. Observations during the ascertaining phase of the experiment and the results of the survey at the beginning of the first year helped to identify areas in which students have difficulties in learning mathematics at a technical university:

- skills of self-control in learning – 97%.

Interviews, surveys for teachers and extramural students led to the conclusion that the creation of a modern methodical system of teaching mathematics to extramural students of technical universities is objectively a necessary condition.

During the second search stage of the experiment (2006-2009) the data, obtained by observation, questioning, testing of extramural students was held, features of distance learning process were identified, the method of Math teaching to extramural students was developed and tested, modes of work with extramural students were identified, the preparation of training and methodological support, development of program-methodical complex were implemented. The structure was designed and algorithm behind the
development of this application was created, the technique of study organisation at universities with its use was proposed.

During the second stage of the experiment, the following problems were solved:

- the experience of ICT use in the educational process application was studied and summarised
- the theoretical analysis of terms “educational technology”, “distance learning”, “software and methodical complex” was carried out
- the definition of ‘distance learning’ was formulated
- the conceptual position of maths teaching to extramural students at higher technical school was formulated
- requirements for training and methodological support of distance learning process were identified and substantiated (the presence of orientation, training, control and diagnostic units, as well as detailed explanations for the solutions to tasks and related issues)
- the development and initial testing of application for the organisation of extramural students’ independent work on mathematics were carried out, the tests were based on adaptive and interactive information and educational resources.

During the third forming stage of the experiment (2010–2013) the shaping phase took place, alongside with scientific justification and measuring the effectiveness of software for teaching mathematics, evaluation of results, summarising the research, formulation of conclusions.

There was also conducted a pedagogical survey among 1st-year-students of DSTU. The goal of the survey was to identify the influence of the developed software kit on the quality of students’ knowledge. 654 extramural 1st-year students were invited to participate in the experiment (total – 33 groups), they were divided into two groups, control group (CG – 322 students) and experimental group (EG – 332 students.).

To test the efficiency of new teaching mode we used training system using the software application to teach mathematics in experimental groups and traditional teaching mode in control groups.

In the first practical lessons on higher mathematics in CG and EG students were given ‘zero’ tests to identify the knowledge and skills necessary to study the course of higher mathematics. There were revealed some differences in the initial results of these groups. To conduct the experiment groups with the similar level of mathematical competences were chosen.

Then, students from experimental groups were invited to study the course of higher mathematics using the application and those from control groups studied without it. During the experiment, the results were systematically analysed, corrections were being made, the technique was being improved.

The results of the exam in higher mathematics, conducted at the end of the first semester in groups EG and CG showed that the learning process has been a redistribution of quality levels of mastering mathematical knowledge, skills and abilities. To determine the feasibility of this application in the educational process we conducted a survey at the end of the examination session among extramural students who participated in the experiment. It asked the following questions:
1 Did the package help you in self-learning of mathematics?
2 Did it boost your cognitive activity, the desire to expand knowledge in mathematics?
3 In your opinion what was the most successful in this application?
4 What would you like to see in the application, but you did not?
5 What difficulties did you have while using the package?
6 Please rate this application on a scale where 1 – very bad, and 5 – excellent.

Results:
1 86% of extramural students believe that the use of application helped them to cope with the test and prepare for the tests in higher mathematics between the exams.
2 79% of students believe this application boosts their cognitive activity, the desire to expand knowledge in mathematics.
3 According to students, the most successful in this piece of software was:
   a introducing a module in elementary mathematics – 65% of the students
   b a sufficient set of teaching materials – 90%
   c a demonstration of solutions to tests – 73%
   d self-assessment and simulator – 56%
   e usability – 63%.
4 82% of the students wished to see video lectures, but did not.
5 When using the application students felt very comfortable, with only 9% experiencing psychological barrier and fatigue when working on computer;
6 The rate of satisfied students when using the tool:
   a in 2010 – 61%
   b in 2011 – 77%
   c in 2012 – 85%.

The analysis of the application in the educational process leads to the following conclusions:
1 Extramural students of technical universities are ready to use the software and methodical system for learning higher mathematics at the university.
2 Students are ready to use the specialised software in the learning process at the university both psychologically and physically.

The analysis brought about the development of a methodical system for teaching mathematics to extramural students in technical universities using this software package.

The main objective of the formative stage was large-scale approbation of this tool for teaching higher mathematics at technical universities. It was done by analysing the
statistical significance of differences between students’ marks of residual knowledge in elementary mathematics in experimental and control groups.

Measurements were carried out via a ‘zero’ test. According to the results of the ‘zero’ test students were divided into four levels. Table 1 shows the results of the ‘zero’ test in the EG and CG according to 5-grade assessment mode:

<table>
<thead>
<tr>
<th></th>
<th>Low (mark ‘2’)</th>
<th>Medium (mark ‘3’)</th>
<th>Satisfactory (mark ‘4’)</th>
<th>Excellent (mark ‘5’)</th>
<th>Total (students)</th>
</tr>
</thead>
<tbody>
<tr>
<td>EG</td>
<td>51</td>
<td>266</td>
<td>14</td>
<td>1</td>
<td>332</td>
</tr>
<tr>
<td>CG</td>
<td>47</td>
<td>261</td>
<td>13</td>
<td>1</td>
<td>322</td>
</tr>
<tr>
<td>Total</td>
<td>98</td>
<td>527</td>
<td>27</td>
<td>2</td>
<td>654</td>
</tr>
</tbody>
</table>

Table 1. Distribution of students to four levels according to the ‘zero’ test results

To test the statistical significance of differences between answers from CG and EG we used the criteria of comparison that are applicable both to numerical and ordinal aggregates. The use of these criteria does not require any assumptions about the distribution of the variables.

As long as their application does not require estimation of distribution parameters, these criteria are called nonparametric (the term coined by Wolfowitz in 1942), parameter-free criteria or freely distributed criteria (Glass, 1976).

Since with present state of teaching science, we have a very limited set of quantitative indicators characterising certain aspects of the learning process and its results, nonparametric criterions are in most cases the only way to test pedagogical hypotheses.

In addition, the undoubted advantage of nonparametric criteria lies in relatively simple computational procedures associated with the practical application of these criteria.

In nonparametric statistics they use a number of sets for position measures (e.g., median, mode, quartiles, etc.) and scattering ones (e.g., rank, quartile range etc.), allowing to present a ‘fuller picture’ of the data (Grabar, 1977). Therefore, a median criterion was used in the study.

After the comparison of ‘zero’ test results in EG and CG the authors expected to verify the hypothesis of no difference in the level of background knowledge in mathematics, skills and competences.

We used the distribution of extramural students from EG and CG according to the marks gained by each student at ‘zero’ test as an indicator of knowledge, skills and abilities.

Under the conditions of the experiment, it is possible to use the median criterion to detect differences of central tendency (that of medians) in the state of checking the quality of background knowledge in mathematics in two experimental groups.

The results of the ‘zero’ test passed by EG and CG students showed that the difference between the two groups at the beginning of the experiment is negligible: for significance level $\alpha = 0.05$, $t_{\text{critic}} = 3.84$ and $t_{\text{empir}} = 0.01$, $t_{\text{critic}} > t_{\text{empir}}$.

Thus, the level of quality pre-formed knowledge, skills, abilities in mathematics in CG and EG is practically the same (Figure 4):
We checked the effectiveness of our application for teaching mathematics to extramural students from technical universities by comparing via statistical methods student performance in EG (working with the application) and students from CG (learning within traditional teaching system).

In each group the experiment was carried out as follows: we start with a course of higher mathematics from the first semester to the end of it, when final exam takes place.

We evaluated EG and CG students based on statements about examinations in maths. The results of the exam, conducted at the end of the first semester in EG and CG groups showed that during the course the levels of mastering knowledge, skills and abilities in mathematics were reshuffled.

The EG students yielded the selection with the volume $n_1 = 332$, CG students yielded the selection with volume $n_2 = 322$. In accordance with specially developed criteria for evaluating the exam results, each student could get up to one of four levels: low, medium, sufficient and high according to 5-grade assessment mode (see Table 2).

To check the efficiency of the developed methodical system for teaching mathematics to extramural students of technical universities two hypotheses were stated:

$H_0$: zero hypothesis (the quality rate of training in CG is not higher than in the EG after the offered methodology),

$H_1$: alternative hypothesis (the EG quality rate transcends the CG one).

The authors checked the static authenticity of influence, made by the offered teaching method on the teaching effectiveness was implemented due to the bilateral (nonparametric) criterion $\chi^2$.

For the number of freedom degrees $C = C - 1 = 4 - 1 = 3$ and $\alpha = 0.05$ the critical significance of the criteria statistic is found: $X_{1-\alpha} = T_{\text{critic}} = 7.815$. Therefore we have $\text{Tempir} > T_{\text{critic}} (39.024 > 7.815)$, i.e., according to the decision-making rules the given results give ample background for rejecting the zero hypothesis.
Table 2  The EG and CG students’ distribution into 4 levels according to exam results in higher mathematics for 2010–2013

<table>
<thead>
<tr>
<th></th>
<th>Low (mark ‘2’)</th>
<th>Medium (mark ‘3’)</th>
<th>Sufficient (mark ‘4’)</th>
<th>High (mark ‘5’)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>EG</td>
<td>8</td>
<td>312</td>
<td>11</td>
<td>1</td>
<td>332</td>
</tr>
<tr>
<td>CG</td>
<td>50</td>
<td>269</td>
<td>3</td>
<td>0</td>
<td>322</td>
</tr>
</tbody>
</table>

Therefore, the excerpts do not belong to one general combination anymore and their differences are defined by experimental teaching influence that gives the possibility with a reliability of 95% to state an achievement of a higher level of mathematical competence in experimental groups.

The analysis of the statistic significance of differences between the grade excerpts (the exam results in high mathematics by EG and EC external students) demonstrate that the differences are significant therefore we can confidently state about the positive effect of the methodical system on the level of knowledge and skills in mathematics (Figure 5).

Figure 5  The diagram of skills in mathematics obtained by the CG and EG students after the experiment

7  Summary

The results of the stating period of research confirm that experimental methodology can yield better results when teaching higher mathematics to distance students in comparison with the previous methodology.

The investigation and its experimental check let us come to the following conclusions:

1  Critical review research in pedagogical and psychological aspects of independent work of distance students on mathematics in technical universities within the first stating period of research (2002–2005) let us outline the main trends in improving extramural training in higher mathematics in universities, mainly: introducing new technological developments, developing specialised teaching aids (e-manuals and
lectures, digital trainers, tests, applications etc.). ICTs improve the efficiency of students’ independent work proposed methodology for teaching higher mathematics to extramural students with the aid of software boost the self-learning of extramural students, develops competences in parallel with learning methods of mathematics, improves quality of teaching.

2 The second search phrase (2006–2009) shows that:

- The presented method of teaching mathematics with this application is an effective means of improving the quality of teaching mathematics to distance students of technical universities due to interactivity and test modules of the application.

- The use of special software in teaching increases the quality of students’ independent work, reduces expenses for holding independent work (for instance, by bringing down the costs of paper materials), cuts professors’ hours for consultations as the students can find answers to the majority of questions in thus application.

- The contents of application are the responsibility of university faculty, department and the specialty of the students. The issue can be solved in two principal ways. One of them consists of creating the specialised software for certain specialties (which is quite difficult but possible). Another way consists in developing the ‘unified’ application (to a certain extent) for a group of adjacent specialties, the contents of such application might be a bit redundant for other specialties but nevertheless sufficient for most of them.

3 The validity and reliability of results and conclusions of the research are confirmed by the results of the forming stage of the experiment (2010–2013) analysed by the methods of mathematical statistics. The present application improves the quality of acquired knowledge, stimulates mental efforts, positively motives students for learning (revealed via a questionnaire after winter examinations) and develops skills of self-guided learning and self-assessment of learning. In respect to extramural students, one can state that they have undoubtedly developed skills of information search and acquirement.

The research results can be used for teaching high mathematics at universities to the students of non-mathematical professions who study in full-time, extramural and remote forms of education and during other courses as well (physics, chemistry, specialised subjects), for the development of computer-aided learning tools.

The authors are conscious that this research does not fully solve the problem of improving the methods of teaching higher mathematics in universities with the use of specific software in the framework of extramural training therefore it’s necessary to carry out further scientific research and go deeper into this really important issue particularly when it comes to the creation of the methodical support for the course of mathematics. It is also important for the development and use of the software tools.
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