Impact of ICT on the Quality of Mathematical Education

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ABSTRACT

Some results of joined research projects that have been realized during 2006 – 2011 period are described in this paper. Primary goal of these projects was set as to improve the quality and flexibility of mathematical education at the university of technology by implementing of teaching models with emphasis on creativity improvement and ICT support. With the use of the proposed new teaching model study results were improved with statistically significance. Research also showed us the need for searching of new education methods that developing not only students´ cognitive abilities but their creativity, as well.

At present the research continues in the form of project planned for two years with title „ Implementation of internal quality assurance system of education“. Project is granted from Structural Fund of EU.

Keywords: Mathematics, Teaching Model, Creativity, ICT, e-Learning

1. INTRODUCTION

Students of university of technology gain basic mathematical knowledge and competences within compulsory courses of mathematics. However, according to our experience, they are often not able to use them properly. Results of several years' research [1] showed us, that one of the sources of this problem is insufficient level of creativity. For example students are not able to overcome functional fixation. Therefore was necessary to implement into education process teaching model that uses methods improving creative thinking. Moreover this model broadly uses ICT with goal to yield students effective tool for mathematical problems solving that will face during following years of study and praxis.

2. RESEARCH PROJECT BACKGROUND

The main goal of this project was oriented onto improvement of quality and flexibility of mathematical education at Slovak University of Technology. The goal was planned to achieve by implementing of new model of mathematic subjects teaching with stress on creativity and ICT support and free mathematical software use, as well. This goal has been broken down into following tasks:

- To select appropriate free mathematical software tools;
- To develop teaching model that uses methods evolving students creativity and free mathematical tools software;
- To prepare e-content.
- To verify effectiveness of developed teaching model through pedagogical experiments;
- To work out recommendation for teaching model use
- To implement validated teaching model into teaching process on the base of proposed recommendations and evaluate its efficiency.

In case that students have to gain more than rough knowledge they need to be actively involved into educational process as it is known from huge amount of pedagogical and psychological research works i.e. [2], [3], [4] Students cannot remain only passive recipients of new information. Teacher is an important element in the educational process. He/she stops to be only information source and becomes a students' partner in learning process. This new teacher´s role, besides other, needs the will to teach experimentally and decrease the use of teacher´s authority. The main teacher´s task is to develop students' ability to learn, to work autonomously and use knowledge creatively. New teaching model was developed having in the mind W. A. Diesterweg´s truth: „Bad teacher gives truth, good teacher teaches how to find the truth. "

As a part of teaching model the method of knowledge acquisition with usage of methods supporting development of creative technical thinking was designed. Emphasis was put mainly on methods selection and teaching materials design that improve flexibility and overcome functional fixation. The method of knowledge examination that stresses understanding and creative application of knowledge was designed and verified as a part of new teaching model, as well. Students´ memory capacity is not assessed.

Example of learning material, part "Integral", supporting students to overcome functional fixation onto the use of letters "*x*" and "*y*" for dependent and independent variables respectively is in the fig.1.

1. V mechanike tekutín zložky tlakovej sily na všeobecnú plochu od rovnomerne rozloženého tlaku v smere osí x, y, z :
$$F_x = p_0 \int_{A_x} dA_x = p_0 A_x \quad F_y = p_0 \int_{A_y} dA_y = p_0 A_y \quad F_z = p_0 \int_{A_z} dA_z = p_0 A_z \ (1)$$

2. Vo fyzike. pri výpočte rýchlosti telesa s hmotnosťou m, ak naň pôsobí sila $F = F_0 e^{-kt}$.(2)
$$v(t) = \int a(t)dt = \int \frac{F_0}{m} e^{-kt} dt = \frac{F_0}{m} \int e^{-kt} dt = \begin{vmatrix} -kt = z \\ -k.dt = dz \end{vmatrix} = -\frac{F_0}{m.k} \int e^{z} dz = -\frac{F_0}{m.k} .e^{z} - A =$$
$$= -\frac{F_0}{m.k} .e^{-kt} - A$$

Figure 1 Example of e-course task oriented onto overcoming the functional fixation

The e-study materials are part of new teaching model. Bundle of e-study materials contains: education content (additional interactive courses, e-books and published lecture texts and presentations), knowledge application (sets of solved tasks and activation exercises), and self-evaluation tasks (interactive auto tests). [5] Example of interactive auto test is shown in the fig.2.

Auto tests for each part of the Mathematics course taught in 1[st] study year of Bachelor studies have been developed as a tool for knowledge a competence assessment during the semester. Immediate feedback is a big advantage for the students

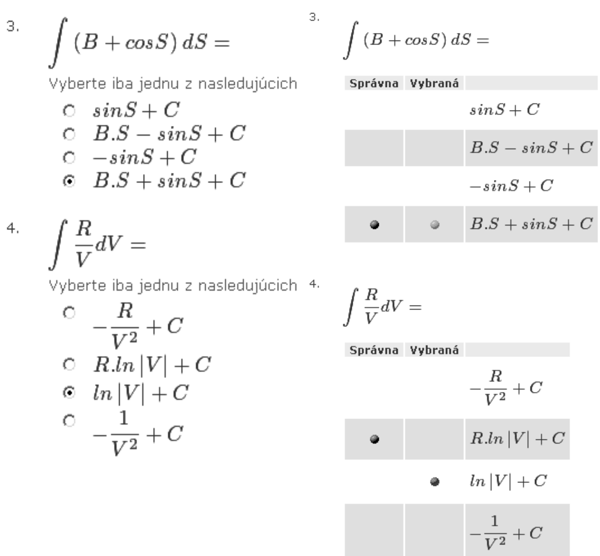

Figure 2 Example of auto test from part "Integral"

The e-study materials contain tutorials for the computational or graphical tasks solving methods, as well as guidelines for checking the tasks solutions in free software tools ***WinPlot*** and/or ***Maxima***. For illustration, graphical solution of task from "Coordinate systems" part is shown in the fig.3. Figure was created by Winplot that students regularly use in computing practice.

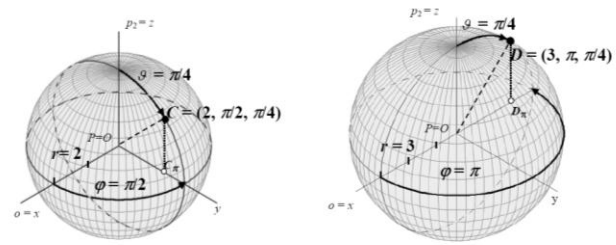

Figure 3: Graphical solution of task from "Coordinate systems" part [Math I with support WinPlot]

Multimedia programs were added to education content. They are in the form of interactive animated guides that enable the students to quickly find out hints for effective usage of mathematical software when solving stated mathematical problem.

Mathematics courses teachers proposed the content of animated guides [6], students of study program *Applied Information and Automation in Industry* realized them within thesis work. [7] They used *Adobe Flash* and *Super Screen Recorder*, that records all activities on computer screen into multimedia file in *.avi format. This format was converted to *.flv format suitable for Flash by *Quick Media Converter*.

3. RESEARCH DESCRIPTION AND RESULTS

The goal of joined research projects was set as follows:

- To verify effectiveness of new teaching model;
- To find out students´ attitude towards package of e-study materials that consists substantial part of proposed teaching model
- To implement the model into education process and evaluate its didactic effectiveness.

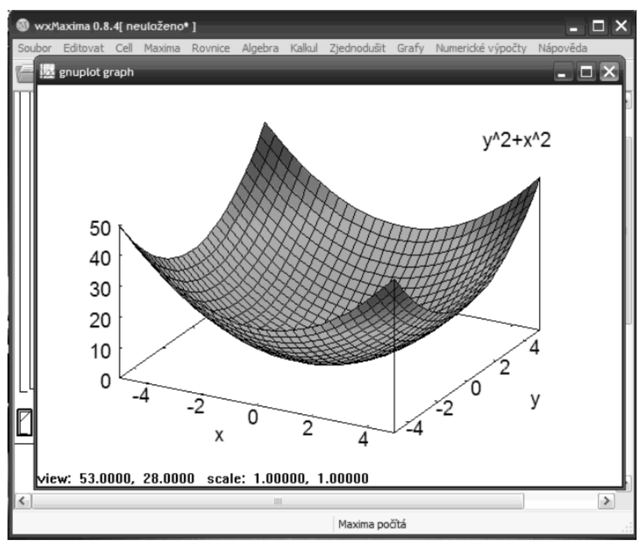

Figure 4. Example of interactive tutorial for Maxima tool

First part of research was realized during 2007/2008 academic year at the Faculty of Material Science and Technology of Slovak University of Technology in Trnava. The aim was to evaluate the new teaching model. Research sample consists of 100 first grade students of combined study of all study programs in *Analytic geometry* course. Students of analytic geometry course from previous academic year 2006/2007 were used as a follow-up group. That year (2006/2007) the new teaching model with application of ICT was not implemented.

Following working hypotheses have been stated:

1. *Students from experimental group will score higher in didactic test than students from follow-up group.*

2. *Students will have positive attitude towards package of e-study materials and the use of it in Mathematics courses.*

For verification of working hypotheses, following tools and methods have been used:

- Didactic test – oriented on knowledge application; it covered two types of tasks: closed with prepared answers and open tasks.
- Questionnaire – prepared on the base of semantic differential; attitude has been measured by several 5-grade scales from the view of selected factors. Scales consisted from two adjectives or verbs. The adjective or verb expressing negative attitude correspond to value 1 and adjective or verb expressing positive attitude to value 5 on 5-grade scale.
- Statistical methods for research results processing – results have been processed with support of MS Excel.
- F-test for statistical hypotheses verification.

Hypothesis no. 1, assuming that students from experimental group will score higher in didactic test than students from follow-up group, **has been confirmed** when new teaching model was applied into Analytic geometry course. As it is obvious also from graph in fig.5, students from experimental group have reached higher relative successfulness in didactic test than students from follow-up group. Difference was statistical significant. Values of F-test for variance, calculated from values from absolute successfulness in test are in the table 1. Calculated value of testing criterion F is higher than critical value F_{crit}. ($F > F_{crit}$), for given degrees of freedom and chosen level of significance $\alpha = 0,05$.

Table 1: F-test values

Subject	Group	F- test			
		Mean value	variance	F	F_{crit}
Analytic geometry	experimental	2,75	2,23	1,68	1,54
	Follow-up	1,79	1,33		

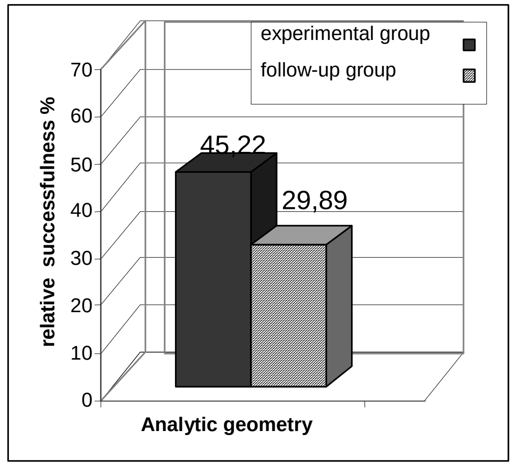

Figure 5. Relative successfulness in didactic test

The ratio of students, which successfully finished course, was increased, as well. Analytic geometry course successfully finished 81,57% of students from the group of 304 students in academic year 2006/2007. Next academic year 2007/2008, 89,74 % from group of 624 students successfully finished course. Comparison of final students´ marks is shown on graph in figure 6.

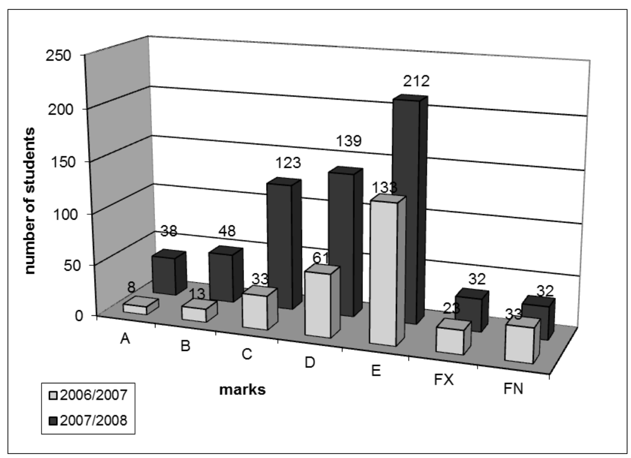

Figure 6. Comparison of final marks in academic years 2006/2007 and 2007/2008

Hypothesis no. 2, assuming that students will have positive attitude towards package of e-study materials and the use of it in learning Mathematics **has been confirmed**. Semantic profile of e-study materials is in fig. 7. Usefulness factor describes students´ attitude towards e-study materials from the point of view how the e-materials helped them in learning process. Applicability factor reflects the will to use analogical e-materials in other courses. The meaning of other factors is obvious.

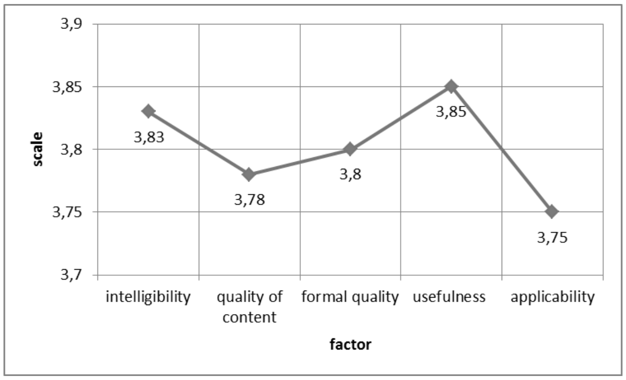

Figure 7. Semantic profile of e-study materials for Analytic geometry course

Research covered the investigation of usage degree of particular study materials types, as well. Therefore question about interactive learning materials e-lectures, e-texts, interactive self tests, and notes from lectures and consultations were placed into questionnaire. Students most often used e-lectures and e-texts with set of solved tasks and exercises during analytic geometry course study, as it can be seen from fig. 8. These materials have been used more often than material self prepared by students e.g. notes from face-to-face teaching. Doubtless, e-material enabled the students to choose appropriate time for them to study and not to take part in face-to-face teaching, because the most of the students live outside the campus. They at least used the self tests.

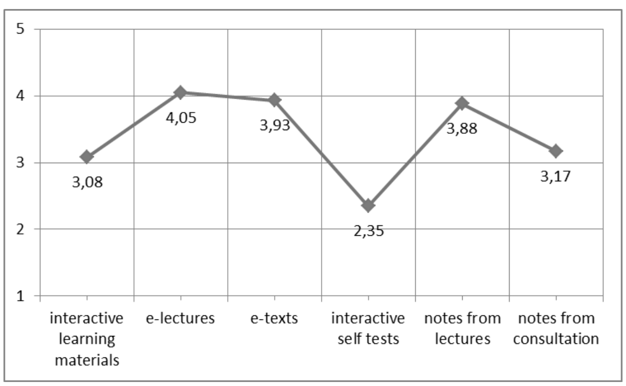

Figure 8. Usage of different study material types within analytic geometry.

Research project continued by application of new teaching model into Mathematics I course in next academic year (2008/2009). For this part of research a two-step experimental plan has been used. Students had at disposal e-lectures, presentations from lectures, e-texts with set of solved tasks and exercises and during computational exercises they could use a free software tool *Maxima*. Students of Mathematics II course had at disposal e-lectures only and computational exercises had traditional scenario without the use of software tool. The experimental group was created by 70 Mathematics I course students of 1st grade of regular study of all of study programs, follow-up group consisted of all of Mathematics II course students. The research was extended with the question: if positive correlation between attitude to the new technology in teaching of mathematic subjects and students' performance in educational test that contains tasks focused on basic creativity factors exists?

The following working hypothesis was investigated:

A positive correlation between attitude towards the new technologies usage in mathematics courses and the performance in the tests that contain tasks oriented onto basic creativity factors exists.

For verification of working hypothesis following tools and methods have been used:

- Test that contains tasks oriented onto basic creativity factors: fluency, flexibility and originality. Score (max.18) reflected the ability to overcome functional fixation, alternate the way of perception of patterns, readiness, and originality of thinking;
- Statistical methods for research results processing – results have been processed with support of MS Excel.
- Pearson's coefficient of correlation,
- t-criterion for determination of statistical significance of correlation coefficients i.e. if the correlation discovered in selected sample exists in the whole set, as well.

Research **confirmed** the **validity** of **hypothesis**, assuming that there exists a positive correlation between attitude towards the new technologies usage in mathematics courses and the performance in the tests that contain tasks oriented onto basic creativity factors.

We assumed the relation between two variables (students' attitude towards usage of the new technologies in mathematics courses and score in creativity test). In order to verify the hypothesis, the correlation coefficient between the mean values of attitude and score in creativity test was enumerated. Calculated value of correlation coefficient r=0,36 means that students´ attitude towards usage of new technologies in mathematics courses positively correlates at low level with abilities for creativity. Statistical significance of coefficient has been tested with t-criterion. For selected level of significance α=0,05 and appropriate number of freedom degrees, enumerated value was t_{stat} = -5,39. Critical value of tested criterion was t_{cr} = 1,67. Since $|t_{stat}| > t_{cr}$ it is possible to conclude that correlation coefficient is statistical significant and hypothesis **is valid**.

New teaching model was improved on the base of experiments´ results and enriched with methods supporting creative thinking and helping to overcome the functional fixation in next academic year 2009/2010. Recommendations for its effective implementation into education process have been adapted, as well. Some of the recommendations follow:

- Didactic effectiveness of teaching is higher in case the students have at disposal, in addition to face-to-face teaching, interactive on-line courses, presentations from lectures and supporting e-learning materials.
- It is suitable to develop the learning content in the form of e-lectures, e-texts and interactive modules in that the orientation is easy and needed information is easily found.
- Materials for knowledge assessment and self-evaluation are necessary to develop in such a way that the students´ abilities will be tested not theirs memory. Materials have to demand creative application of knowledge from

learning content basics and from the whole course content, as well.

- It is necessary to use the database of tasks oriented on the specific and nonspecific transfer in materials development.
- Materials for self-evaluation it is necessary to develop so that they enable the students to follow the level of their progress.

Adapted new teaching model was implemented into Mathematics I course in 2010/2011 academic year. Number of Mathematics I course students during research period (academic years 2007/2008 - 2010/2011) is depicted in table 2.

Table 2. Number of research respondents

Number of research respondents				
Academic year	2007 /2008	2008/ 2009	2009/ 2010	2010/ 2011
number	1337	1000	1070	970

Growth of relative successfulness, as it can be seen from graph in figure 9, is the result of application of new teaching model. Substantial improvement of successfulness, after implementing new teaching model, occurred in academic year 2008/2009 when compared to previous academic year. Next year the successfulness had not been changed. The next positive change occurred when adapted teaching model was implemented.

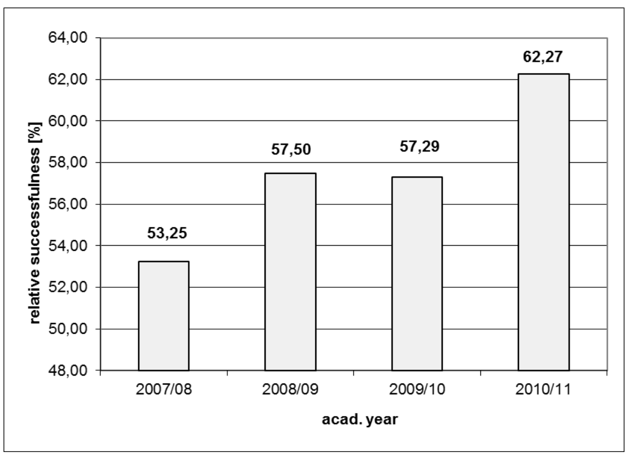

Figure 9. Relative successfulness of students in Mathematics I course

4. CONCLUSIONS

Set of research experiments oriented onto improvement of the quality and flexibility of mathematical education was realized during 2006 – 2011 years period at the Faculty of Material Science and Technology of Slovak University of Technology. Research proved the effectiveness of proposed new teaching model with emphasis on creativity improvement and ICT support. With the use of the proposed new teaching model, the study results were improved with statistically significance. Research showed us the need for searching of new education methods that developing not only students´ cognitive abilities but their creativity, as well. Creative person with high flexibility in thinking may reach better and more original results than person with full information support, which is not able to flexible work with information at disposal. The students´ attitude towards study courses is improved by application of creative methods.

At present the research continues in the form of project planned for two years with title „ Implementation of internal quality assurance system of education“. Project is granted from Structural fund of EU. The goal of this project is to develop and verify system of objective appraisal of quality, efficiency and usefulness of education in bachelor study programs at Faculty of Material Science of University of Technology.

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