

# EFFICIENCY OF PRACTICING WITH MATERIALS USING ICT AND PAPER ONES IN MATHEMATICS

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## Highlights

- 1. • *The assessment of efficiency of practicing with materials with or without ICT*
- 2. • *74 % students chose Interactive computer Auto-Evaluation Test for practicing in mathematics*
- 3. • *Average improvement in mathematics after practicing with was 40 %*

## Abstract

The research examines the effectiveness of utilization of practicing materials using ICT and classical study support – printed material in teaching Mathematics. The research was held as a pedagogical experiment at the Faculty of Chemical Technology, University of Pardubice in academic year 2012-13. In the research group there were included 559 students in the full-time form of study, in their first semester of study. Students were subjected to pretest and posttest, between these tests they were encouraged to practice through a material on basic calculus of functions of one variable. The practicing material was prepared both in classical (paper) form, both with an application of ICT. We registered results in pretest and posttest (in points), used practicing materials, successfulness in exam and continuing in studies after the first semester. The experiment looks for statistic relations among these variables. We present part of these statistic results. Further quantitative and qualitative evaluation of the project is planned to be a component of dissertation.

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## Introduction

Education in the Czech Republic faces a decline in mathematical literacy. In results of the PISA (Programme for International Student Assessment) in 2012, the Czech Republic results in changes in mathematical literacy in the country from 2003 to 2012 were in 34th level of 39 assessed countries (Palečková, J. 2012). In 2009, the Czech Republic results in changes in the country between 2003 and 2009 were even in last place from 40 evaluated countries (Palečková, J., Tomášek, V. and Basl, J. 2009).

The findings in the preliminary research (Widenská, 2011) show that although university students tend to understand the math curriculum and regularly attend training at school, almost do not practice at home.

One of the opportunities which are offered to increase the attractiveness of domestic practice is the use of ICT. In a study from 2009 (Rideout, Foehr, and Roberts, 2010) we can see how huge amount of time young people spend on the computer and on other media. This time could become a great power if we knew how to grasp advantage of its potential.

The trend of our period becomes to help making mathematics more exciting, relevant and challenging to young learners (Oldknow, 2009).

Some students are majorly in nonmathematical fields, some feel some anxiety about math (Bennett and Briggs, 2004).

There is a challenge for us - how to approach the teaching of mathematics to students who have not been (or were only slightly) led to the logical and critical thinking, and are used

to learn mathematic „rote“ without a real understanding of the issues discussed (Friedrich, 2006).

These ideas, trends and reality of our "ICT age" led us to perform a pedagogical experiment:

*To offer students practicing material which:*

- Is connecting useful and enjoyable – because they like playing games on PC and doing different tests – they can learn at the same time, so it is possible to do auto-evaluation test (self-check test) about understanding specified subject of mathematics
- Will be available also in printed form for those who would prefer it, also as auto-evaluation test
- Will not stress with its complicated form – mostly students have much scholarly learning material, but they do not understand it
- Will be interesting and understandable even for those who "feel some anxiety about math"
- Will result with clear answers to essential subjects of specified topic to understand fundamental principles. The aim is mathematical literacy could grow: "Mathematical literacy is defined as: to know, understand and be able to use the appropriate grade curriculum, which is essential" (Hošpesová, 2011:27)
- Will cause a system in fundamental principles
- Will contain auto-evaluation test (self-check test)

*The pedagogical experiment will search:*

- Relation between taking part in an experiment and students' study results
- Efficiency of specified combinations of practicing materials in relation to study results and improving results between pretest and posttest

*The objective of the paper:*

- To determine the effect of practicing on study achievement of university students in mathematics
- The results of students using ICT are compared with the results of those who used either only classical learning support or both
- At the same time, it investigates the effectiveness of particular methods of practicing in various combinations with regard to results achieved in study

*Related to these aims we defined these main working hypotheses:*

*H1:* Taking part in the research (i.e. in pretest, practicing and posttest) has an impact to study results of involved students

*H2:* Practicing mathematics using ICT in teaching is more effective and improves understanding of the topic more than practicing with the study support in the classic form - on paper.

*H3:* Practicing math with the help of ICT improves more subjective feeling in certainty of answers in the tests and reduces more both tests difficulty rating than with practicing with the study support in the classic form – on paper.

Abbreviations used in this paper can be found in Table 1.

## Materials and Methods

### Previous research

#### *Preliminary research*

Preliminary research was carried out in the academic year 2010-11 (Widenská, 2011) at the Faculty of Chemical Technology, University of Pardubice. Unsatisfactory level of students admitted to study in basic mathematical knowledge and skills has been proven.

Also there was shown large knowledge distance among students coming from different types of schools.

Despite the relatively large effort to regular attendance and understanding of the curriculum during seminars taught math, students were practicing at home very little.

Based on these findings there were formulated the following research questions:

Will be increased understanding mathematics through applications of auto – evaluation test (AET)?

Will be the effectiveness of using the interactive computer AET (PC AET) higher than practicing with AET in printed form?

Will we be successful in motivation of students to practice the tested subject after the preliminary research showed that a large part of the seminar participants almost didn't practice at home?

#### *A pilot study*

A pilot study with 620 included students in the full-time form of study, in their first semester, was realized in academic year 2011-12. Its results were published: (Widenská a), 2012), (Widenská b), 2012), (Widenská c), 2012).

Due to the results and commentaries in *ICTE conference, Ph.D. students' section*, there were made several revisions and changes the research to be continued in academic year 2012-13.

### Plan of research

#### *Time limitation*

The research took place in the winter semester of 2012 -13 and in the subsequent examination period.

Students met the first information about the ongoing research in the eighth week of the semester. In the tenth week of the semester the students were subjected to a pretest. In the same week, just after the pretest, the students received practicing materials and in the twelfth week were subjected to a posttest. Both tests were conceived in relation to practicing material.

During the examination period, students were tested in writing, they had to solve several problems in the selected subjects of the entire semester, some of tasks here were chosen with regard to the AET. The last day of testing was 28th May 2013.

#### *Data Collection*

Students who took part in the research filled in the pretest and the posttest. Each test was rated from 0 to 20 points.

There were recorded each student's:

- pretest results (IN)
- posttest results (OUT)
- kind of used practicing material
- subjective feeling in certainty of answers in the tests
- both tests difficulty rating
- results of the exam (EXAM)
- information about continuing in study after the first semester (CONT)

Information about subjective feeling in certainty of answers in the tests and both tests difficulty rating connected with working hypothesis *H3* will be statistically processed in the dissertation.

#### *Concepts*

The practicing material included two kinds of topics:

- refreshing and summarizing some of the basic knowledge acquired during high school, necessary for understanding the principle of differentiation of functions of one variable
- for most students new topic Fundamentals of differential calculus of functions of one variable (further mentioned as a derivative)

Practicing materials were intended to lead illustratively and schematically the student to repeat, respectively understand the concepts and relations among them. This is not only a formal knowledge of definitions, but their active application in examples, where it is recognized understanding of the topic.

### The course of the experiment

#### *Information for students*

The students met the first information about ongoing research in the eighth week of the winter semester 2012-13 during lectures in all study groups. The information contained schedule, explanation, conditions and benefits to students for participation in the research.

Students were motivated to practice math as follow:

- They had opportunity to get up to 20 points for the output test (posttest). These points will be added to the exam test (there is a maximum of 100 points); entire posttest contained part of the topics discussed in the course Mathematics 1.
- They could check answering in the AET questions of a similar type like in an exam.

The tasks for the students were:

- To take part in the entrance test (pretest) in the 10th week of the semester. This pretest did not generate any point advantage for students, but its completion was a condition for participation in the output test.
- To practice using the practising materials accessible after passing the pretest. Students had minimally 12 days for practicing.
- To take part in the output test (posttest) in 12th week. The results of this test had been announced to students before the start of their exam period.

#### *Entrance test (pretest)*

Pretest was assigned to show the input level of specified knowledge.

In its first half it contained repeated basic concepts (10 questions for 10 points), in its second half it contained topic derivative (10 questions for 10 points).

Both the pretest and the posttest were designed to verify understanding the topic - all of the key knowledge and skills listed in practicing material were chosen for them.

Pretests were used for later comparison with the results of the posttest.

377 students participated in the pretest.

#### *Practicing*

In addition to lectures and seminars (ongoing for the topic till 9th week of the semester) students received practicing material with its content targeted directly to the theme of the posttest.

The content of practicing material was determined both considering the results of the pretest in previous research in 2011-2012 and considering the newly acquired knowledge and skills base showing understanding of calculus.

Types of practicing materials: the theme was prepared in these types:

- Summary (S) - summarizing survey part - repetition and explanation
- Auto-evaluation tests (AET). AET aimed to verify understanding of the matter in the form of answers to questions (as in the examination test), but there were given the correct answers.

AET had two forms, both were with the same tasks. Students chose responses (multiple-choice), answered open questions with extensive or brief answers.

- “Paper” (PA) AET could be either printed on paper or worked with by watching on a computer monitor in a form of presentation. It was not interactive; for checking the correct answers there were results at the end of the test. The sequence of questions was logically arranged from the easiest task to the most difficult one.
- In “Interactive computer” (PC) AET it was necessary to click the correct answer (1 task = screen). Another question was provided to the student after marking the correct answer; in the case of wrong answer it could be marked again.

PC AET was made both in sequential version - still the same, logically arranged sequence of questions as in paper form; and random version - different order of questions generated by a computer. The advantage of the sequential test is gradually increasing demands on the understanding and application of concepts, the disadvantage is the possibility of remembering the order

of answers in the test. This disadvantage is eliminated in the test with random sequence of questions, but it is more suited for students who passed successfully through the sequential version of the test.

PC AET was created in the author system Macromedia Authorware—the University owns its licence. Macromedia Authorware is one of the most comprehensive authoring tools for creating e-learning applications, popularly educational e-books, interactive training courses. Environmental control program is simple and intuitive. It is possible to import a PowerPoint presentation into it.

The students in the research obtained .exe files with PC AET so they were able to work with no special software on their computers.

Students had the opportunity to choose any method or combination of practicing. They mentioned used methods in the questionnaire at the end of the posttest.

Because we expected students to use also different type of practicing material for preparation to the posttest (such as notes from their high school), in the questionnaire there was possibility to mark “another practicing material”.

#### *Output test (posttest)*

Posttest showed advance of students in specified skills after practicing.

The concept of the posttest was the same as the pretest, only numeric values were different.

Posttest was attended by 343 students.

## Results

Abbreviation	Meaning
AET	Auto-Evaluation Test
ALL	Amount of students who used all given practicing materials
CONT	Amount of students who continued in studying after 1 semester
CONT%	Amount of students who continued in studying after 1 semester in percents
EXAM	Amount of students who passed the exam
EXAM%	Amount of students who passed the exam in percents
IN	Amount of points received in pretest (IN-test)
NONE	Amount of students who used no given practicing materials
nonCONT	Amount of students who did not continue in studying after 1 semester
nonEXAM	Amount of students who did not pass the exam
OUT	Amount of points received in posttest (OUT-test)
PA	Amount of students who used practicing material: just Paper AET
PA AET	Practicing material: Paper AET
PA+	Amount of students who used practicing material: Paper AET
PAPC	Amount of students who used practicing material: just Paper AET and Interactive Computer AET
PAPC+	Amount of students who used practicing material: Paper AET and Interactive Computer AET
PC	Amount of students who used practicing material: just interactive computer AET
PC AET	Practicing material: Interactive Computer AET
PC+	Amount of students who used practicing material: Interactive Computer AET

Abbreviation	Meaning
PM	Practicing material
REG	Amount of all students registered in subject of Mathematics 1
S	Amount of students who used practicing material: just Summary
S+	Amount of students who used practicing material: Summary
SPA	Amount of students who used practicing material: just Summary and Paper AET
SPA+	Amount of students who used practicing material: Summary and Paper AET
SPC	Amount of students who used practicing material: just Summary and Interactive Computer AET
SPC+	Amount of students who used practicing material: Summary and Interactive Computer AET
Summary	Practicing material: summarizing survey part - repetition and explanation
Used	Amount of students who used specified practicing material
Used %	Amount of students who used specified practicing material as percentage of total
WGroup	Amount of students in specific whole group
WGroup %	Amount of students in specific whole group as percentage of total
Wrote IN	Amount of students who wrote only pretest (IN-test)
Wrote IN+	Amount of students who wrote pretest (IN-test)
Wrote IN+OUT	Amount of students who wrote pretest (IN-test) and posttest (OUT-test)
Wrote NONE	Amount of students who wrote neither pretest (IN-test), nor posttest (OUT-test)
$\chi^2$	Chi-square test of independence

Table 1: Abbreviations

Group	REG	Wrote NONE	Wrote IN	Wrote IN+OUT
WGroup	559	182	34	343
EXAM	310	15	10	285
CONT	338	31	14	293

Table 2: Amounts of students in different phases of the pedagogical experiment

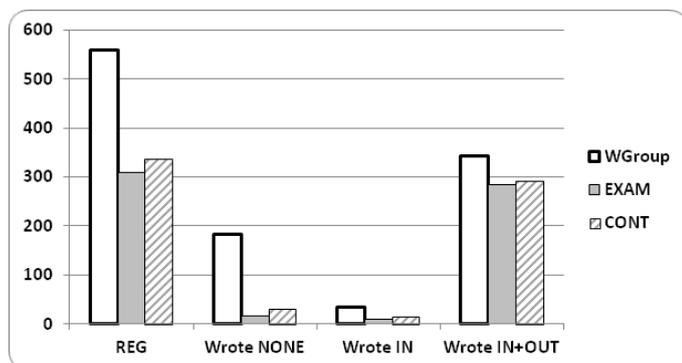


Figure 1: Graph of amounts of students in different phases of the pedagogical experiment

Group	REG	Wrote NONE	Wrote IN	Wrote IN+OUT
WGroup %	100	100	100	100
EXAM %	55	8	29	83
CONT %	60	17	41	85

Table 3: Amounts of students in different phases of the pedagogical experiment in percent of each group

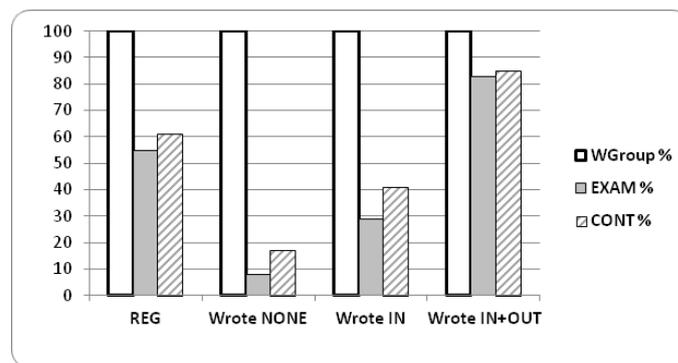


Figure 2: Graph of amounts of students in different phases of the pedagogical experiment in percent of each group

### Taking part in the experiment

Table 2 with Figure 1 shows amounts of students who took part in specified phases of the experiment, Table 3 and Figure 2 shows the same in percent of each group.

At the beginning of winter semester 2012-13 there were registered 559 (the group “REG”) students in the subject of Mathematics 1.

343 students (61 % from the group “REG”) participated in posttest. This number highly overcame our expectation. In the pilot study 2011-12 306 students from 620 passed through the whole experiment, that was 49 %. That means in 2012-13 we had 37 students in the group “Wrote IN+OUT” more than a year ago.

310 (55 %) of the group “REG” successfully passed the exam and 338 (60 %) continued in their studies after the first semester.

182 students did not write any test, 15 (8 %) of them successfully passed the exam and 31 (17 %) continued in their studies after the first semester.

34 students wrote only pretest, 10 (29%) of them successfully passed the exam and 14 (41 %) continued in their studies after the first semester.

343 students wrote both pretest and posttest, 285 (83 %) of them successfully passed the exam and 293 (85 %) continued in their studies after the first semester.

With data from Table 2 we tested two kinds of hypotheses. Chi-square test of independence  $\chi^2$  is used to verify them; the tables with the data are Tables 5 and 6:

#### 1. Null hypothesis $H_{0EX}$ :

Number of students who will be successful in examination with participation in pretest and posttest will be the same as without participation in these tests.

Alternative hypothesis  $H_{AEX}$ :

Number of students who will be successful in examination with participation in pretest and posttest will be different from the group of students who did not participate in these tests.

2. Null hypothesis  $H_{0CON}$ :

Number of students who will continue their studies after the first semester with participation in pretest and posttest will be the same as without participation in these tests.

Alternative hypothesis  $H_{ACON}$ :

Number of students who will continue their studies after the first semester with participation in pretest and posttest will be different from the group of students who did not participate in these tests.

Both these kinds of hypotheses were tested with the chi-square test of independence  $\chi^2$  (Chráska, 2007) defined in (1). The meaning of letters in the equation is seen in the schema of 4-field table (Table 4).

	<b><math>\alpha</math></b>	<b>non <math>\alpha</math></b>	$\Sigma$
<b><math>\beta</math></b>	a	b	a+b
<b>non<math>\beta</math></b>	c	d	c+d
$\Sigma$	a+c	b+d	n

Table 4: Schema of 4-field table

$$\chi^2 = n \cdot \frac{(ad-bc)^2}{(\alpha+b)(\alpha+c)(b+d)(c+d)} \quad (1)$$

	EXAM	nonEXAM	$\Sigma$
Wrote NONE	15	167	182
Wrote IN+OUT	285	58	343
$\Sigma$	300	225	525

Table 5: 4-field table for chi-square test of independence  $\chi^2$ - successfulness of students in passing the exam (for testing  $H_{0EX}$  and  $H_{AEX}$ )

	CONT	nonCONT	$\Sigma$
Wrote NONE	31	151	182
Wrote IN+OUT	293	50	343
$\Sigma$	324	201	525

Table 6: 4-field table for chi-square test of independence  $\chi^2$ - continuing in studies after the first semester (for testing  $H_{0CON}$  and  $H_{ACON}$ )

Tested hypothesis	Default values	Tested criterion $\chi^2$
$H_{0EX}$	Table 4	272.012
$H_{AEX}$		
$H_{0CON}$	Table 5	235.378
$H_{ACON}$		

Table 7: The results of tested criterion  $\chi^2$  and default tables for tested hypotheses

In Tables 5 and 6 we see the values emerged from Table 2, with calculation of test criterion we tested the hypotheses. During testing, we compared the resulting values of the test criterion with its critical value. Critical tabulated value  $\chi^2$  for 1 degree of freedom and level of significance 5 % is 3.841.

Result for  $H_{AEX}$  is 272.012, for  $H_{ACON}$  it is 235.378, they are seen in Table 7.

Both results are highly more than the critical value. That means we can state:

1. We reject null hypothesis  $H_{0EX}$  and accept hypothesis  $H_{AEX}$ . The results are statistically significant.
2. We reject null hypothesis  $H_{0CON}$  and accept hypothesis  $H_{ACON}$ . The results are statistically significant.

Using of practicing materials

Furthermore we can see results of using different combinations of practicing materials (PM). Students could choose any type of offered PM and their combinations. As we expected, some students used also different types – they announced it in a posttest questionnaire. They were 22 and we did not include them into the statistics about effectiveness of using given materials. This means we continued the research with the group of 321 students. In this paper we present (also shown in Table 8 with Figure 3 and Table 9 with Figure 4):

Amounts of students using each combination of PM

In Table 8 with Figure 3 we can observe three most frequent used combinations:

- 239 (74 %) students used Interactive computer auto-evaluation test (PC AET) or PC AET plus some other PM.
- PC AET was a favourite PM – mostly in combination with other PM, but also in use when students chose only one PM.
- 171 (53 %) students used Summary (S) or S plus some other PM.
- 115 (36 %) students used S and PC or S, PC plus Paper AET (PA AET).

Relation between using specified combination of PM and successfulness in exam

When we see (Table 9 with Figure 4) percentage successfulness in exam in each combination of PM, we see these three leading PM:

- PA AET with 92% successfulness in exam
- PA and PC AET with 87% successfulness in exam
- S and PC AET with 86% successfulness in exam

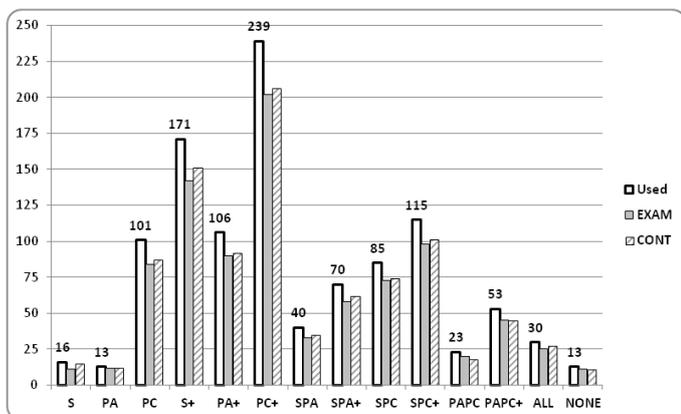
Relation between using specified combination of PM and continuing in studies after the first semester

In observing (Table 9 with Figure 4) continuing in studies after the first semester in relation to used combination of PM, we see these three main PM:

- S with 94% of students continuing in studies after the first semester
- All PM (this means S, PA and PC AET = ALL) with 90% of students continuing in studies after the first semester
- SPA+ with 89% of students continuing in studies after the first semester

	Used	EXAM	CONT
S	16	11	15
PA	13	12	11
PC	101	84	87
S+	171	142	151
PA+	106	90	92
PC+	239	202	206
SPA	40	33	35
SPA+	70	58	62
SPC	85	73	74
SPC+	115	98	101
PAPC	23	20	18
PAPC+	53	45	45
ALL	30	25	27
NONE	13	11	11

**Table 8: Amounts of students using different combinations of practicing materials and their success in exam and continuing in studies after the first semester**

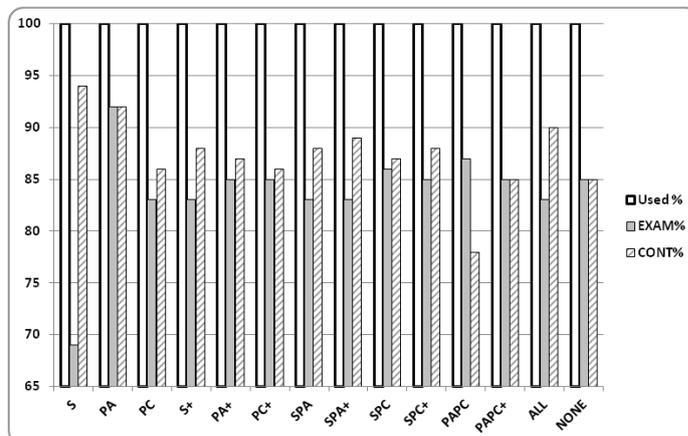


**Figure 3: Graph of amounts of students using different combinations of practicing materials and their success in exam and continuing in studies after the first semester**

	Used %	EXAM%	CONT%
S	100	69	94
PA	100	92	85
PC	100	83	86
S+	100	83	88
PA+	100	85	87
PC+	100	85	86
SPA	100	83	88
SPA+	100	83	89
SPC	100	86	87
SPC+	100	85	88

	Used %	EXAM%	CONT%
PAPC	100	87	78
PAPC+	100	85	85
ALL	100	83	90
NONE	100	85	85

**Table 9: Amounts of students using different combinations of practicing materials in percent of each combination**



**Figure 4: Graph of amounts of students using different combinations of practicing materials in percents of each combination**

The results of the research showed the importance of involving students in research itself. Participation in the pretest greatly increased the success rate for the exam and the percentage of students who continued their studies after the first semester. This suggests the participation of all interested students to study and awareness of ongoing activities. Given the choice of PC AET was voluntary, and students who chose this kind of practice, were even several times better than in the beginning (the best improving was 267 %). The computer practical exercises had great educational significance. At the same time, however, the practice of traditional paper form had for students a positive effect on the outcome of the final test as well. Any method of practicing in our case had a positive impact on students' knowledge.

### Discussion

Input and output tests with questionnaires were developed for the specific needs of students at the Faculty of Chemical Technology, they were not standardized. The requirements regarding the level of mathematics may be different at different schools and they could hardly be compared with other similar studies in terms of quantitative data.

However, an investigation of this method with respect to the size of the sample is of great importance. This confirms the importance of practicing with any of techniques and practicing with materials with ICT played an important role for those students who chose this method.

The best result with 92% successfulness in exam was with students who used PA AET. We can ask why just this kind of practicing had the best result. With careful using PA AET the study result can be very good. But the number of these students was 13 and it is statistically very small sample of the whole group Wrote IN+OUT of 343 people – less than 4 %. In the questionnaire in the posttest some students mentioned they had preferred this kind of practicing, it had been the best for them.

We would suppose the students using all practicing materials

will have the best results. The percentage of success in the exam respectively in continuing in study is not the highest, but is very high (83 %, resp. 90 %). So students had very good results – on the other hand using all kinds of materials need not mean using all of them carefully.

Special group of students are those who mentioned using no practicing material. They were 13. This is also a very small statistical sample – but surprisingly they have very good result in passing the exam and continuing in study (85 %). 11 of these students passed successfully the exam and continued studying after the first semester. Their average pretest result was 17.0 points. This number is highly greater than average pretest result of the *Wrote IN* group (it was 12 points). During personal asking some of them about no practicing they answered they had had no need to practice.

Those 2 students, who did not practice and did not pass successfully the exam and did not continue in their studies after the first semester, had their average pretest result 9.5 points. They answered they had not managed practicing.

## Conclusion

We found the motivation for students to be involved in the pedagogical experiment was more successful than in the pilot study in 2011-12. 12 % more students of REG took part in the whole experiment.

We proved as statistically significant relation between taking part in the experiment and successful passing exam, respectively continuing in study after the first semester.

High percentage of students (74 %) used for their practicing Interactive Computer Auto-Evaluation test.

Data from the experiment are intended to use in another statistical research. We will search relation among using different types of PM and progress between pretest and posttest. Now we can present average improvement in group “Wrote IN+OUT” between these tests from 12 points in pretest to 17 points in the posttest (40 %). 137 students (42 %) improved these results more than 50 %.

The students, who had excellent results already in the pretest, e.g. 19-20 points, could have their posttest result maximally 5 % better. This group of students will be investigated separately in the dissertation.

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