The Positive Impact of the Modeling and Simulation System for Measurement Using a Computer in the Czech Republic

Radek Nemec, Andrea Berkova, Stepan Hubalovsky

***Abstract* —** The paper presents the results of research focused on the impact of the use of modelling and simulation measurement system using a computer in school science laboratories on secondary school pupils. The results of pedagogical experiment (pre-test – post-test control group design) showed a positive effect of the use of such system at a significance level of 0.05. Pupils who were taught with the aid of the measurement system acquired more knowledge than when teaching without measurement system using a computer. After two months, the re-test was also performed to confirm the previous results.

***Keywords* —** modelling, simulation, measurement system using a computer, SMPSL system, physics education

I. Introduction

THE research was conducted at the secondary school in the Czech Republic. The system SMPSL [1], [2], [3] for measuring using a computer was used in experimental group to support teaching of physics. The control group lessons of physics were managed in the traditional way (only with the support of blackboard, textbooks, etc.). The didactic test in CAA (Computer-aided assessment) platform Maple TA [4], focused on the topic of temperature (see [5] and [6]), was statistically processed at a significance level of 0.05 in MS Excel and NCSS software. The results were evaluated using the following methods: two-sample F-test for the conformity of variances and two-sample t-test to verify the hypothesis of equality of means of control and experimental group. The research question is thus: *Do gained pupils' study results differ in the context of the form of teaching (with or without the aid of SMPSL system)?*

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II. Research Sample

A sample of the research consisted of lower secondary school students (11-12 years old) in the subject Physics. Two parallel classes collaborated on the research. The research included 22 students of the control group and 26 students of the experimental group.

Before the experiment and again in the end of the experiment, the students of both groups were given didactics (pre-post) tests. After two months, the students' knowledge was checked again through re-test. Some students (one student from the control group and five students from the experimental group) did not participate in all phases of testing due to illness.

III. Used Instruments

Using various aids in teaching physics and school laboratories was being explored for many years (as in the papers [7], [8] and [9]). In this study, however, we focused on a relatively new platform SMPSL created by the first author of this paper as a cheap and flexible option apart from commercial software such as Vernier [11] or Pasco [12]. System SMPSL is interface for recording the values of transmitting via USB interface (Fig. 1 and 2) based on eProDas platform, resulting in the University of Ljubljana, Slovenia [10]. System eProDas is very affordable, easily attachable to a computer, offering many possibilities of measuring and processing of data. It is suitable for science experiments. System eProDas is seen as a platform for providing data acquisition and signal generation for performing different experiments in the natural sciences such as physics, chemistry, biology, medicine, mathematics and engineering. SMPSL system consists of hardware delivery and control software available for free (in contrast to commercial software). Instructions for the preparation of the hardware and instructions for downloading software controls are available on the website of this system [13] (Fig. 1, 2 and 3).

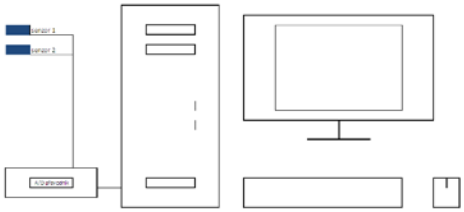

Fig. 1 – System for measuring using a computer

Fig. 2 – System SMPSL

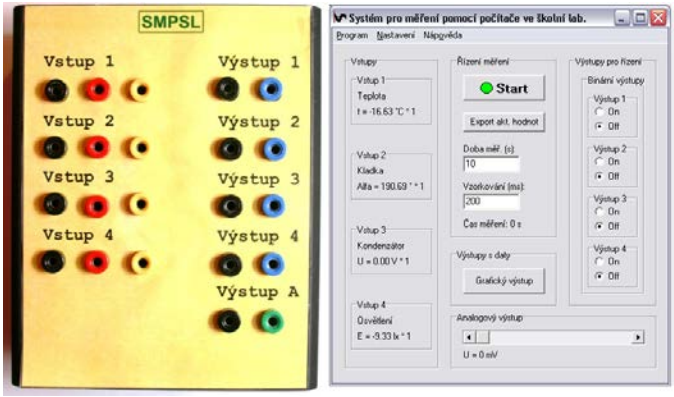

Fig. 3 – Hardware and software part of system SMPSL

For examining the pupils' knowledge objectively scored didactic test was created, which was used as pre-test, post-test and re-test. For the didactic test creation, the CAA system Maple TA was used. Maple T.A (Web-based Testing and Assessment for Math Courses) is an educational assessment system distributed by Maplesoft to support training mathematics and science subjects [14]. Maple T.A provides students rich interactive environment using Computer Algebra System Maple. The test consisted of various types of questions in MapleTA (see Figure 4).

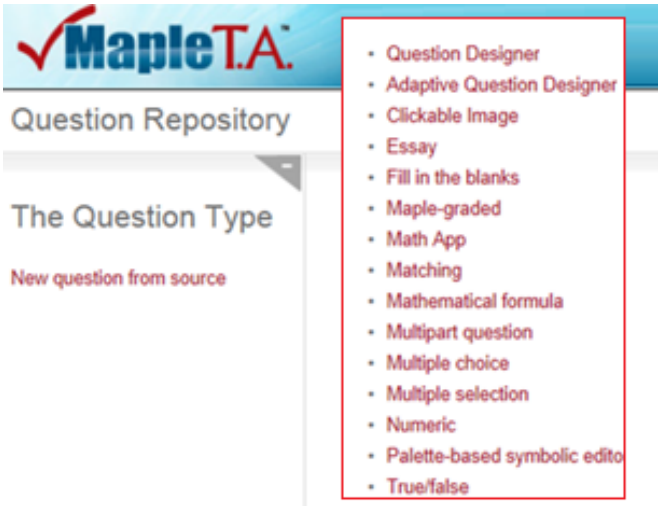

Fig. 4 The Question types in Maple TA

In order to maintain objectivity, mostly closed-ended questions and open-ended questions with short answers were chosen. The test items were scored by a maximum of one point with the possibility of granting fractions of the point in case of a partially correct answer. An example of a test question is illustrated in the following Figure 5. This question is focused on comparing melting ice cubes in fresh and salt water.

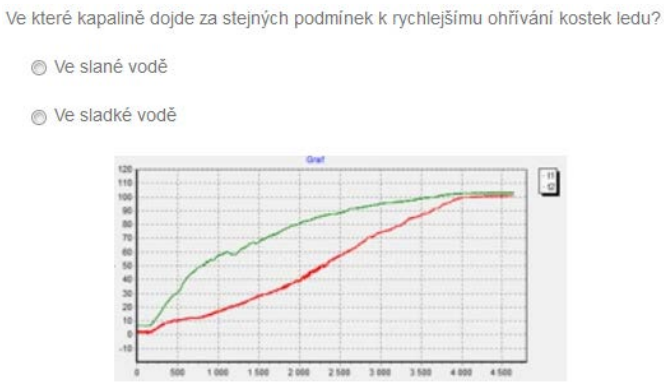

Fig.5 – Example of a test question with graphic output from the system SMPSL

IV. EXPERIMENTAL TEACHING

The experiment was focused on the impact of the use of measurement systems using computer in school science laboratories on pupils' knowledge in the field of temperature. In the experimental lessons, the following measurements were performed: measurement of temperature – for example measurement of melting ice (Fig. 6), measurement of deflection of roller (Fig. 7 and 8), light metering (Fig. 9), and measurement of charging and discharging of capacitor (Fig. 10).

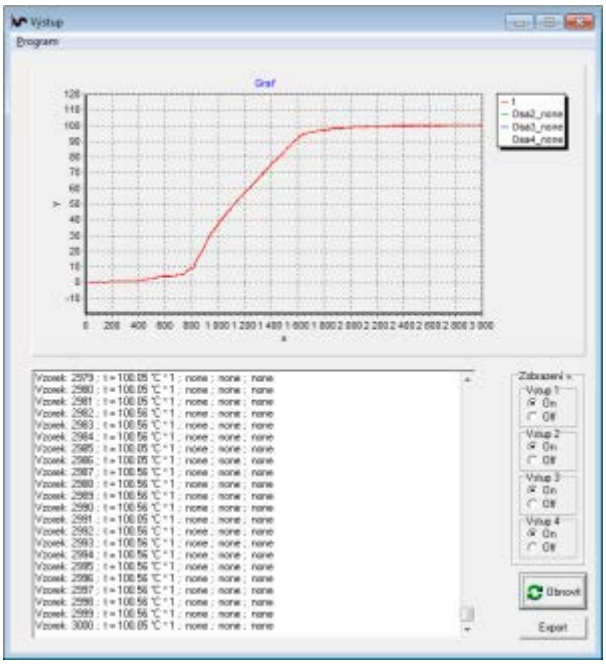

Fig. 6 Measurement of melting ice

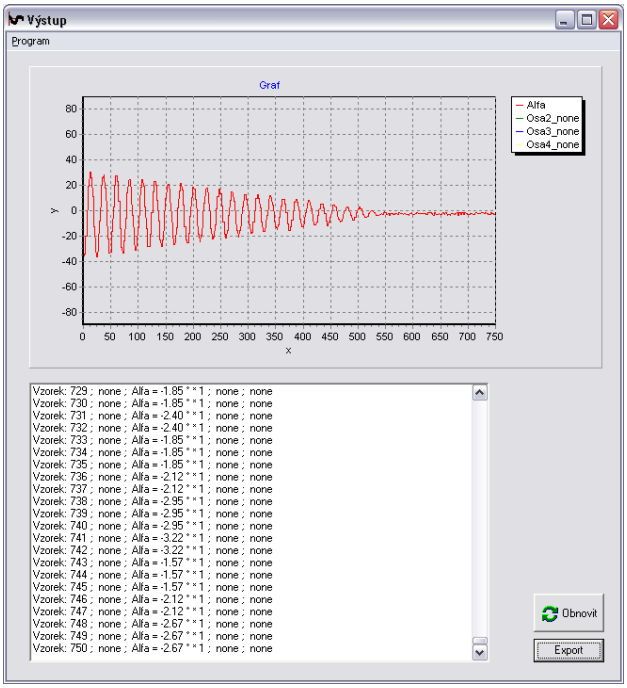

Fig. 8 Measurement of deflection of roller

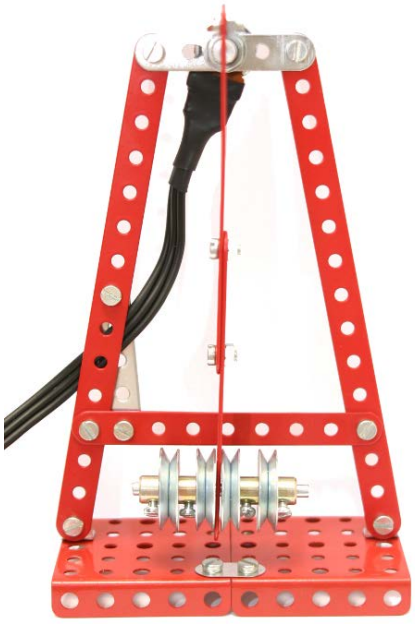

Fig. 7 Measurements of deflection of roller

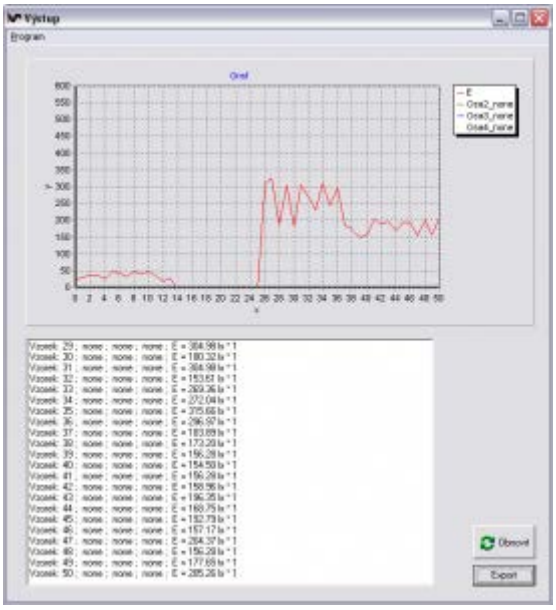

Fig. 9 Light metering

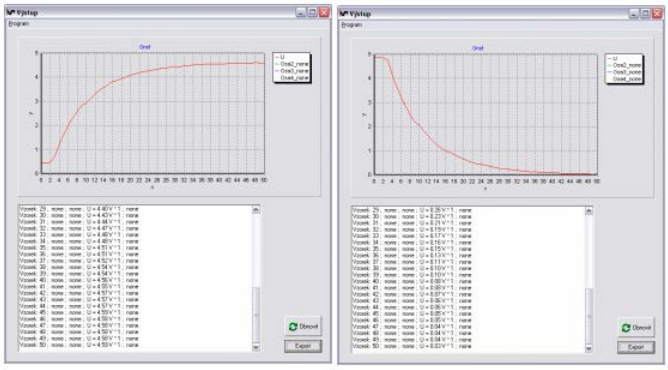

Fig. 10 Measurement of charging and discharging of capacitor

For the implementation of these physical attempts and experiments, a series of typical tasks and video clips for students were developed. Examples of types of tasks are shown in the laboratory protocol (Figure 11).

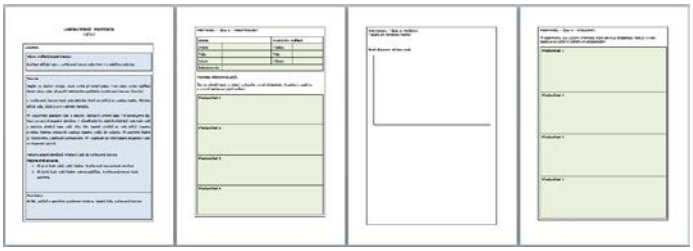

Fig. 11 – Examples of types of tasks

This laboratory protocol is focused on the rate of heating water in a kettle or pot - with or without a lid. The theory is interpreted on the first page. With the help of SMPSL system, students compiled individual tasks on the following pages of the protocol. The experiment was conducted using teaching experimental group in this way (with the aid of SMPSL system) and control group in a classical way (without the aid of SMPSL system).

V. Results of the Research

A. Pre-test

Before the execution of an experiment, a pre-test had been performed to determine comparable knowledge of control and experimental groups. The results were evaluated first using a two-sample F-test for verification of the conformity of variances. If the condition of identical variance was fulfilled, then two-sample t-test with equal variance was applied.

The results are summarized in the following tables:

Table 1. F-test of pre-test

	Control gr.	*Exp. gr.*
Expected value	3,636364	3,52381
Variance	3,385281	2,361905
Observation	22	21
Difference	21	20
F	1,433284	
P(F<=f) (1)	0,212466	
F crit (1)	2,112399	

Hypothesis of identical variances was not rejected because the test criterion F was smaller than F crit (Table 1). It was further applied to the two-sided t-test to determine whether pupils from both the control and experimental groups had comparable knowledge before the experiment. The reader can get acquainted with the results in Table 2.

Table 2. t-test of pre-test

	Control gr.	*Exp. gr.*
Expected value	3,636364	3,52381
Variance	3,385281	2,361905
Observation	22	21
The common variance	2,886073	
Hyp. median difference values	0	
Difference	41	
t Stat	0,217167	
P(T<=t) (1)	0,414578	
t crit (1)	1,682878	
P(T<=t) (2)	0,829155	
t crit (2)	2,019541	

The test criterion |t Stat| is lower than t crit and therefore the hypothesis of identical means is not rejected (in the case of two-sided and also one-sided alternative). It is assumed that pupils from both the control and experimental groups have comparable knowledge before teaching itself. This can be seen also in histograms showing the frequency of students who achieved given points in the pre-test. (Fig. 12)

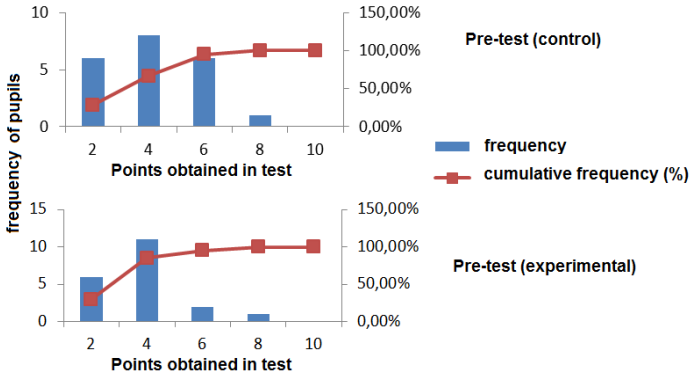

Fig. 12 – Histograms of pre-test

B. Post-test

The teaching of control and experimental group ended with post-test (pre-test identical).

Post-test results are indicated in the following tables:

Table 3. F-test of post-test

	Control gr.	*Exp. gr.*
Expected value	4,909090909	8,952381
Variance	4,467532468	2,447619
Observation	22	21
Difference	21	20
F	1,825256456	
P(F<=f) (1)	0,091975987	
F crit (1)	2,112398899	

The hypothesis of identical variance, whereas the F test criterion is smaller than F crit, is again not rejected (Table 3). Therefore, t-test can be used (Table 4).

Table 4. t-test of post-test

	Control gr.	*Exp. gr.*
Expected value	4,909090909	8,952381
Variance	4,467532468	2,447619
Observation	22	21
The common variance	3,482208848	
Hyp. median difference values	0	
Difference	41	
t Stat	-7,102222093	
P(T<=t) (1)	5,91293E-09	
t crit (1)	1,682878002	
P(T<=t) (2)	1,18259E-08	
t crit (2)	2,01954097	

In this case, test criterion |t Stat| is higher than t crit and therefore the hypothesis of identical means has been rejected. Based on the results of two-sided and mainly one-sided test in Table 4, it is suggested that students in the experimental group showed more knowledge than when teaching without measurement system using a computer. This can be seen also in frequency histograms (created in MS Excel) in Figure 13.

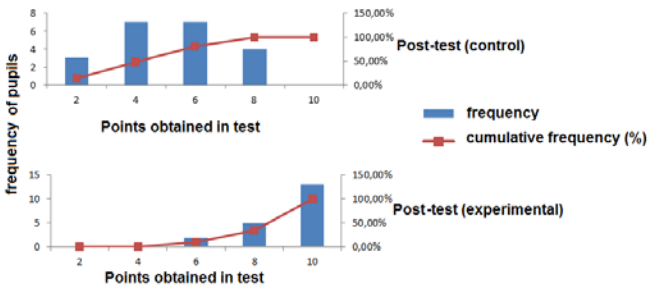

Fig. 13 Histograms of post-test

More than fifty percent of students in experimental group reached maximum points (ten points). For better visualization the box plot was created in NCSS software (Figure 14).

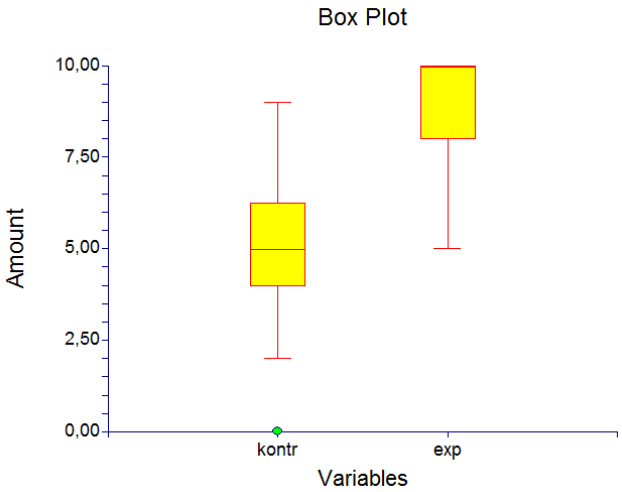

Fig. 14 Box plot of post-test

C. Re-test

Two months after the experiment, the same test (re-test) was given to students. Re-test results are as follows:

Table 5. t-test of re-test

	Control gr.	*Exp. gr.*
Expected value	5,761904762	6,692307692
Variance	2,99047619	1,981538462
Observation	21	26
Difference	20	25
F	1,509168885	
P(F<=f) (1)	0,16377622	
F crit (1)	2,007471499	

The hypothesis of identical variance, whereas the F test criterion is smaller than F crit, was not rejected (Table 5). Therefore, t-test can be used again (Table 6).

Table 6. t-test of re-test

	Control gr.	*Exp. gr.*
Expected value	5,761904762	6,692307692
Variance	2,99047619	1,981538462
Observation	21	26
The common variance	2,429955	
Hyp. median difference values	0	
Difference	45	
t Stat	-2,03432	
P(T<=t) (1)	0,023919	
t crit (1)	1,679427	
P(T<=t) (2)	0,047838	
t crit (2)	2,014103	

Test criterion |t Stat| in this case is greater than t crit and therefore the hypothesis of identical results is rejected. On the basis of these results, it is suggested that students in the experimental group showed even two months after the post-test, which took place immediately after the lessons, more knowledge than students who were taught with no measurement system using a computer [15]. It is possible to see results of re-test in the box plot (Figure 15).

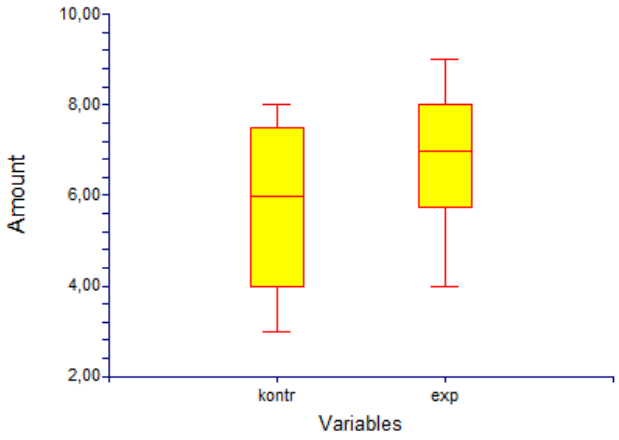

Fig. 15 – Box plot of re-test

It is interesting that the one-sided hypothesis about better results of experimental group was shown in the re-test with not such a great clarity as in the previous post-test. Students of control group achieved somewhat better results than in the post-test this time. The reason may be the fact that the students filled out the test for the third time. On the other hand, the results of the experimental class were slightly worse than in the post-test. This discrepancy is explained easily by the fact that filling the re-test was attended by five students who were not present at all stages of the experiment due to illness. However, despite this limit, the results of experimental class were still significantly better than results of control group.

VI. Conclusion

Due to the use of measurement systems using a computer, as indicated by the experiment, positive effects on student's knowledge were found in the field of temperature learning at the Czech lower secondary school. The study results of students, as shown by the Box plot, were significantly higher after completing the classes taught with the aid of SMPSL system than the knowledge of the pupils who were taught using the traditional approach.

Two months after the experiment, the new measurement (re-test) was performed to determine whether the use of measurement system using a computer had a long-term positive effect on the acquired knowledge of students. The results were fascinating, the knowledge of the experimental group concerning the field of temperature was still significantly higher than of the control group.

Although the research was carried out with only a small number of participating students, and the research was conducted just in one of the secondary schools in the Czech Republic, the authors believe that the conclusion of this paper can help teachers to consider adding SMPSL system or similar systems into teaching physics.

Acknowledgment

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