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Inquiry in Physics Classes by means of Remote Experiments

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Abstract

The utilization of Internet accessible real laboratories within inquiry-based learning can participate in critical situation solution in physics education. The paper presents the results of the research among Slovak primary school students providing their inquiry by means of three remote meteorological stations. Our aim was to prove the positive influence of inquiry-based learning and remote experiments on students' knowledge by means of the project assignment. We approved the positive shift in their knowledge, mainly in the tasks aimed at application of acquired experimental skills. Furthermore the students revealed predominantly positive attitudes to remote experimentation.

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1. Introduction

The term "education" has rapidly changed its meaning in modern society. In the past this term was connected with broad knowledge from various areas such as history, literature, science, geography or mathematics. Besides the theory important was also the development of logical thinking of students. On the contrary, in its upgraded definition this term is understood as a certain compilation of skills and abilities that enables us to become an active member of information society. One of the reasons of this change is due to the obsolescence of knowledge. Because of this phenomenon certain skills and abilities are appreciated more, and are also emphasized in the modern process of education. These abilities, such as reading literacy, critical thinking, evaluation of different sources of information, or work with data should be gradually developed during education on all levels and types of schools.

In physics education we are going through a crisis (Wieman, Perkins, 2005). It is the international phenomenon and its basic features are: students' disinterest in the Sciences, unpopularity of Physics, and very low degree of factual knowledge and experimental skills. The minimization of memorization in physics classes could improve this situation – students could see the "real-world background" in various laws and formulas, and this connection could

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catch their interest and motivate them to further physics studies. This amendment can be achieved by means of various types of experiments integrated to inquiry-based learning (IBL). As experimentation is considered crucial to physics education, this idea is neither innovative nor revolutionary. What makes our approach different is the use of remote experiments. A remote experiment (RE) is a real experiment with real laboratory equipment that can be controlled by a user through the Internet. We can run this experiment from every place around the world, change the values of adjustable quantities and, after the measurement; we can import the experimental data into our computer. The implementation of REs to education has many advantages:

- Saving time, space and money, enabling flexible time management;
- Providing distance education, an option also for physically-challenged students (Nickerson et al., 2007);
- Demonstrating the experiments that could not be conducted in a school laboratory (e.g. proving that the acceleration owing to gravity is not constant on Earth).

The contribution presents an example of the implementation of the chosen remote experiments by means of a project to primary school physics education.

2. Inquiry-based learning

Physics on all levels of education is traditionally taught deductively (Prince, Felder, 2007). The teacher presents relevant theory and mathematical models, and then moves on to textbook exercises followed by real-world applications. Often students are not able to understand difficult theoretical explanation and they have no motivation to raise their interested in physics or to engage in classroom activities. A better way not only to motivate them but also to show them the importance of physics as a scientific field is inductive teaching. Here the teacher begins by presenting students with a specific challenge, such as an experiment to interpret, a phenomenon to explain or a real-world problem to solve. The teacher helps them to succeed in the solution of the task by providing necessary instructions and clues in the theory. In this way students construct their knowledge.

Inductive teaching and learning is an umbrella term (Prince, Felder, 2006) that encompasses a range of teaching methods. One of these is also IBL. IBL is a process that allows the teacher and students to pose questions about various topics. The questions asked are thought provoking and relevant to students and enable them to develop and use critical thinking skills, which are transferable across many subject areas. The ultimate goal is to enable students to move from mere knowledge to deep understanding (Mazulla, 2011). Their learning should begin facing a problem or a question. At this point a cycle of inquiry can be identified: asking, investigating, creating, discussing, and reflecting (Bruce, Bishop, 2002). Lillian C. McDermott and her colleagues, the authors of Physics by Inquiry (McDermott et al., 1995), give us a good example on how to implement IBL to physics education.

In the following we present the realization of IBL in primary school physics education by means of REs – three remotely controlled meteorological stations.

3. An example of IBL in primary school physics education

Slovak primary school physics curriculum contains "Temperature measurement" theme. We've decided to innovate the traditional teaching of the unit by means of IBL and remote meteorological stations. With this view, we designed and realized the project "Measuring air temperature in different EU countries" aimed at students aged 11-13. The basic requirement was to fulfill the requests defined by The State Education Programmed ISCED 2 (2008). The following demands were taken into consideration during the preparation of the project:

- To analyze a graph; to explain and interpret it;
- To compare two or more graphs and to identify their common and different features;
- To elaborate the record of the meteorological observations data; to design a table; to compare the data within the class and to present them in the form of a graph.

We consider real remote meteorological stations to be adequate to meet all these requirements. The project was based on the work with real remote stations free accessible for all the users without registration: Trnava, Slovakia:

http://remotelab1.truni.sk; Prague, Czech Republic: http://kdt-16.karlov.mff.cuni.cz/en/mereni.html; Porto, Portugal: http://experimenta.fe.up.pt/estacaometeorologica/index.php?lang=pt.

The experiments show the possibility to monitor different physical quantities with simple technical hardware and software across the Internet. Students can obtain the experimental data from these REs and evaluate them. The use of three REs from different EU countries enables the integration of various subjects, e.g. Physics, Math, ICT, Slovak, English, Geography, or Environmental Education. The implementation of such an activity with a massive support of ICT to physics education is very desirable. It moves away from the traditional education based on the knowledge of facts, definitions, laws and arguments. Table 1 presents the specification of the designed activity in compliance with the cycle of IBL.

Table 1. Project activities in compliance with IBL

Step of the cycle	Specification	Activities of teachers	Developed students' competences
0. Confronting with problem	Problem task: weather changes according to climate zones	Moderator of the discussion	Communicative competence: to accept different opinions
1.Asking	How to prove the existence of climate zones?	Presenter of the project assignment	Communicative competence: to ask scientific questions
2. Investigating	Work with REs, search for information	Guidance	Scientific competence: to work with data, to search for relevant information; Teamwork; Planning and organization; ICT competence
3. Creating	Data collection and evaluation, preparation of the project	Guidance	Scientific competence: to work with data, to draw conclusions; Teamwork; Planning and organization; ICT competence
4. Discussing	Project presentation, discussion of the results	Evaluator of projects	Communicative competence: to present the results of the work
5. Reflecting	Consequences of the existence of climate zones	Moderator of the discussion	Scientific competence: to draw conclusions

During the introductory lesson students were acquainted with the aims of the project, they were divided into groups and individual tasks were distributed among them. Each group within the class worked with one out of three REs. Then they had three weeks to evaluate the experimental data from remote meteorological stations, fulfil the project assignment and prepare the overall design of the project. Their inquiry comprised following tasks:

- To present experimental data in a form of a table and a graph with the appropriate time intervals;
- To explore the changes in the temperature and explain their possible reasons;
- To calculate the average value of the temperature; to identify the greatest difference between the maximum and minimum of the day temperature;
- To introduce the particular country from the point of view of its latitude and use the experimental data as an evidence of it;
- To explore the relation between the temperature and the latitude.

After three weeks students presented their projects, discussed the results and together drawed the conclusions.

4. Research

To judge the effectiveness of IBL with the combination of REs we conducted a research study in which we compared our group of students – test group (TG), with the group of students taught in the traditional way – control group (CG). We tested the hypothesis: *The students acquiring knowledge via the active experimentation across the Internet will gain better knowledge and skills in the analysis of experimental data than students who are taught in the traditional way.* We used pedagogical experiment to verify the hypothesis. The participants in the research were 156 Slovak primary school students (69 males and 87 females). The independent variable was the work on the project and the dependent variable was the knowledge of the students. The research took place at six primary schools.

4.1. Results

Firstly, we used pre-test to verify the similar prior knowledge of the students of TG and CG. Table 2 summarizes the results. The average score of the students of TG was 17.75 points (maximum was 23 points) and of CG was 17.55 points (Figure 1 – left). We used non-parametric two-tailed Mann-Whitney test for the comparison of the results of TG and CG (we chose non-parametric test because we didn't prove the normal distribution of the data). We tested the null hypothesis: *There is no significant difference between the results of the pre-test of TG and CG.* Since the p-value p = 0.648 was greater than the level of significance, we accepted the null hypothesis and verified the similar prior knowledge of the students.

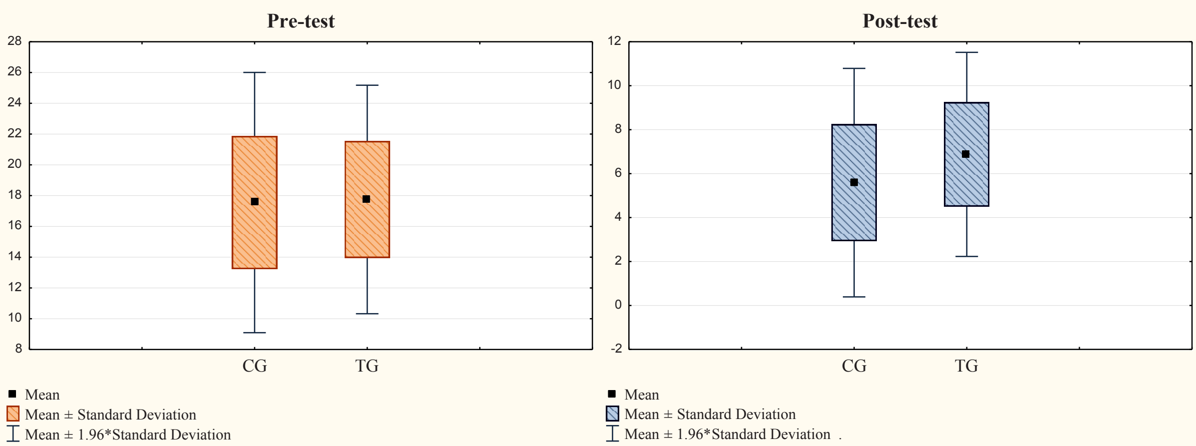

Figure 1. Box plots for the pre-test (left) and post-test results (right)

Table 2. Results of the pre-test and post-test: descriptive statistics

Statistical Variables	CG: Pre-Test	TG: Pre-Test	CG: Post-Test	TG: Post-Test
Mean	17.55	17.75	5.59	6.87
Standard Error	0.49	0.43	0.30	0.27
Median	19	18.5	5.5	7.5
Standard Deviation	4.31	3.79	2.65	2.37
Minimum	6.5	2.5	0	1
Maximum	23	23	10	10

After the realization of the experimental intervention – IBL with the support of REs – we tested the output knowledge of the students. The didactic test consisted of two parts: theoretical part and work with data. We focused on its second part, which tested the skills that could be acquired during IBL. We assumed that IBL in combination with REs will cause the positive shift in this area. This assumption corresponded with the hypothesis set in the beginning of the research: *The students acquiring knowledge via the active experimentation across the Internet will gain better knowledge and skills in the analysis of experimental data than students who are taught in the traditional way.*

The descriptive statistics proved the students of TG scored better in the test aimed at the work with data than the students of CG: average score of TG was 6.87 points (maximum was 10 points) and of CG was 5.59 points (Figure 1 – right, Table 2). We wanted to find out if this difference is statistically significant. Firstly, by means of Kolmogorov-Smirnov normality test we proved the normal distribution of the data. For the comparison of the results of TG and CG we used parametric t-test. We tested the null hypothesis: *There is no significant difference between the results of the post-test of TG and CG.* Since the p-value p = 0.002 was smaller than the level of significance, we rejected the null hypothesis. There was significant difference between the results of TG and CG. TG had significantly better results of the post-test aimed at the work with data.

4.2. Discussion of the results

The results gained in the research proved the effectiveness of the proposed methodology. IBL in the combination with REs caused the better post-test results of the TG students. They proved better skills in the work with data – to make a graph, to read a graph, or to identify average and instantaneous value of the quantity. The positive shift was influenced by the active involvement of the students in the construction of their knowledge. During IBL they had to work with the huge amount of data, they had to identify dependent and independent quantities, learn about different types of graphs (e.g. why it is not appropriate to use a pie chart to show daily values of the temperature), or compare the experimental data with other groups. It was for the first time they came in touch with tables and graph in such a project. Very important was that they had to not only read graphs but also create them – that helped them later in the post-test when they proved the better ability to plot the time dependence of the temperature.

Moreover, they revealed predominantly positive attitudes to the activity with REs. The evaluation of a short questionnaire showed, that the most beneficial for them was the work with graphs and tables and cooperation with their classmates. We were also interested if the activity is motivational for the students involved in the research. We are pleased to note that more than the half of the students (58.2 %) wanted to do another project and only 17.7 % of the students didn't like the work with REs. Because Physics is considered to be one of the most unpopular subjects we consider these results as a success and in these days we are testing another similar activity. We hope we will achieve analogous results as in the previous research.

5. Conclusions

In the paper, the implementation of inquiry-based learning with the support of remote experiments to primary school physics education was presented. The main conclusions of the presented work may be formulated as follows:

- The unique research on the implementation of IBL and REs to physics education was realized;
- For the students involved in the research it was their first contact with REs, they worked with a large amount of data, they had to edit and analyze it;
- Although the students didn't physically work with a thermometer, the project fulfilled the demands given by The State Education Programmed and they achieved better scores in the post-test than the students of CG;
- The students expressed an affirmative attitude to remote experimentation;
- According to students' opinion not only knowledge and skills were the benefits of the project, but also the chance to cooperate with other classmates, discuss some problems and look for the proper solutions.

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