Science Teaching in the XXI Century

editors

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PEDAGOGICAL UNIVERSITY OF CRACOW
Kraków 2018

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ISBN 978-83-8084-062-1

Comprehending Computer Based Laboratory Activities by Slovak and Czech Students

Background

In present, computer supported experimenting is believed to be a beneficial part of science education. Some authors tend to believe that it supports a constructivist view of education and allows using higher order learning skills (Aksela, 2005) and supports a better teacher implementation (Lavonen et al. 2003). In this context, one of the roles of researchers working in the field is to design new activities and experimental tasks for computer based laboratories (formerly Microcomputer-based Laboratory, MBL, Thornton 1990). Working in such laboratories, sometimes called real-time experimenting, allows students to figure out many features of science competencies, having a quick and continuous interaction with new learning they acquire (Tortosa et al., 2013).

Rationale

The framework for this study is a set of newly designed research-based computer aided laboratory activities for Chemistry and Biology proposed in the last 4 years by the international team consisted of researchers from 5 European countries: Spain, Czech Republic, Austria, Finland and Slovakia (Tortosa et al., 2014; Tortosa et al., 2013). Herein, we present the partial outcomes resulting from Czech and Slovak part of the research focusing on four main areas inspected after implementing the proposed laboratory activities:

1. Do students understand the objectives of the activities?
2. Do students need their teacher's help to understand the activities?
3. Do students feel that working with measuring system can help them learning?
4. Do students recognize the importance of measuring system in such experimenting?

Especially, first two areas are very important to reveal because it is believed and confirmed by the studies (Lijnse, 2004) that if students see the point of what they are doing, the processes of teaching and learning probably make more sense to them and can be more efficient.

Methods

In this study 18 newly designed computer aided laboratory activities (Table 1), 12 for Chemistry and 6 for Biology, were designed and tested with secondary school students in Slovakia and Czech Republic.

Table 1. The list of implemented activities (CHEM = Chemistry, BIO = Biology).

	Activity
CHEM 01	CO_2 in the Sea. *(pH measurement)*
CHEM 02	Antacids and the stomach acid *(Acids and bases, neutralization)*
CHEM 03	The Greenhouse problem *(Spectrophotometry)*
CHEM 04	Fire extinguisher *(Gas production, gas pressure)*
CHEM 05	Acid Rains *(Acids and bases, neutralization)*
CHEM 06	Cleaning Liquid *(Acids and bases, neutralization)*
CHEM 07	Red or white? Sweet or dry? *(Acidity of wine)*
CHEM 08	Quality of water: How to determine chloride content in a tap water?
CHEM 09	What dye is present in the drink? *(Spectrophotometry)*
CHEM 10	What is the content of the dye in the drink? *(Spectrophotometry)*
CHEM 11	Gas chromatography
CHEM 12	Redox titration: How to determine hydrogen peroxide
BIO 01	The life of Yeast. *(Fermentation)*
BIO 02	Photosynthesis
BIO 03	Eutrophication
BIO 04	What are the best conditions for seeds to germinate? *(Seed Germination)*
BIO 05	What makes your heart stand still? *(EKG)*
BIO 06	Blood Pressure, do you know what it is? *(Blood Pressure)*

The uniform structure of the activities was prepared collaboratively by all participating international partners and can be seen in Figure 1. The background for the structure was inspired by the previous research-based frameworks suggested by Pintó et al. (2010), Espinoza & Quarless (2010) and Tortosa (2012). All activities are designed to be student-centered reflecting the IBSE principles. Some parts of them also follow the well-known POE sequence (Predict – Observe – Explain) suggested by White & Gunstone (1992).

As during the testing, each student usually implemented more than one activity, 1408 evaluations (932 in Czech Republic and 476 in Slovakia) were performed in total with 664 students (518 in Czech Republic, 146 in Slovakia) attending 15 participating schools (11 in Czech Republic, 4 in Slovakia). The students mean age was 16.97 (SD = 1.20). Due to serious lack of necessary equipment in the majority of participating schools the most of the implementations (919) were realized in the university laboratories (Charles University in Prague, Czech Republic and Matej Bel University in Banská Bystrica, Slovakia). More specifically, in Czech Republic 489 implementations were performed at current schools with their current teachers who had been trained for the implementations before. On the other hand, all implementations in Slovakia were performed at university. 628 implementations (210 in Slovakia and 418 in Czech Republic) were performed with activities for Chemistry and 780 implementations (266 in Slovakia and 514 in Czech Republic) with activities for Biology.

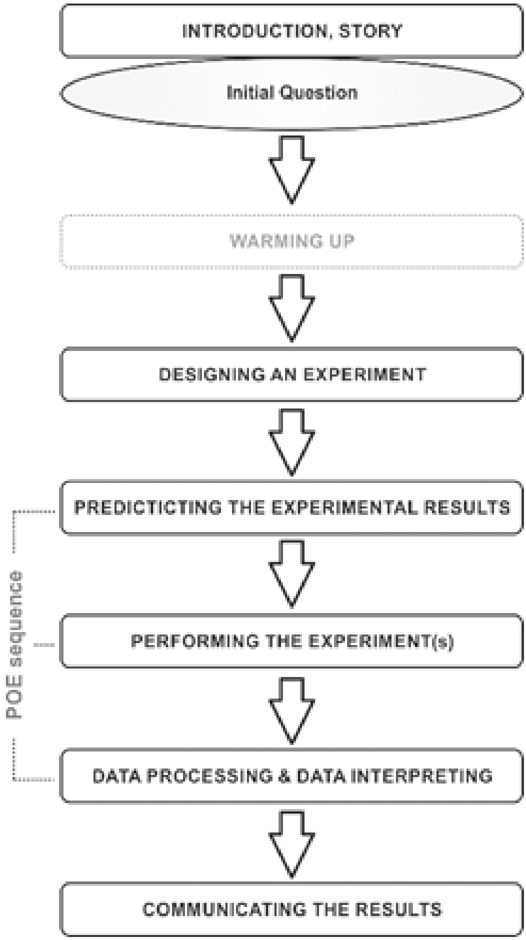

Figure 1. The uniform structure of the designed activities (The POE sequence is also depicted).

In order to gain a relevant feedback about the quality of tested activities a special tool (a 20-item questionnaire) has been administered to the respondents after performing each activity (implementation). For this study five following questionnaire items were selected to discuss in more detail considering 4 research areas listed above:

Item 01: I understood the objectives of the activity.

Item 02: List the objectives of the activity.

Item 03: I need my teacher's help to understand the activity.

Item 04: Computer measuring system helped me interpret the results (e.g. graphs).

Item 05: I think the activity could be done without computer measuring system.

As obvious, items number 1, 3, 4 and 5 are positive declarative clauses where students were asked to express their level of agreement on 4-point Likert scale (1 = I totally agree, 2 = I agree, 3 = I disagree, 4 = I totally disagree). Item number 2 is an open item where the accuracy of the responses was evaluated on the 4-point scale as follows: 1 = correct answer, 2 = more or less correct answer, 3 = not sufficient answer, 4 = totally erroneous answer.

A variety of statistical methods have been used to process collected data, e.g. descriptive statistics, analysis of frequencies and comparative analysis (gender, subject, country, age, place of implementation) where the significance was determined by non-parametric tests (Mann-Whitney U test or Kruskal-Wallis H test) at 0.05 level.

Results

ITEM 01: I understand the objectives of the activity
ITEM 02: List the objectives of the activity

According to the outputs from analysis of frequencies shown in Table 2 the most of the students (94.7%) think that they understand the objectives of the implemented activity (cumulative percent for all answers of agreement with the declarative statement has been taken into account). However, when they were asked to list the objectives the results were not so positive. It can be seen in Table 3 that respondents provided only 58.1% of correct (scale point 1) or more or less correct (scale point 2) answers. Therefore, it is obvious that students tend to overrate their ability of understanding. Nevertheless, the fact is that there really were some problems in comprehending the point of the implemented activities and it was needed to identify the most frequent obstacles.

Table 2. Frequencies and percentages to the item I understood the objectives of the activity. (1 = I totally agree, 2 = I agree, 3 = I disagree, 4 = I totally disagree).

		Frequency	Percent	Valid percent	Cumulative percent
Valid	**1**	795	56.5	58.0	58.0
	2	504	35.8	36.8	94.7
	3	56	4.0	4.1	98.8
	4	16	1.1	1.2	100.0
	Total	1371	97.4	100.0	
Missing	**0**	37	2.6		
Total		1408	100.0		

Table 3. Frequencies and percentages to the item List the objectives of the activity. (1 = correct answer, 2 = more or less correct answer, 3 – not sufficient answer, 4 = totally erroneous answer).

		Frequency	Percent	Valid percent	Cumulative percent
Valid	**1**	320	22.7	25.1	25.1
	2	422	30.0	33.0	58.1
	3	395	28.1	30.9	89.0
	4	140	9.9	11.0	100.0
	Total	1277	90.7	100.0	
Missing	**0**	131	9.3		
Total		1408	100.0		

Apparently, the results mentioned above don't distinguish between the activities. This is why it was also important to compare them and to uncover the most difficult ones for students to comprehend. Figures 2 and 3 show the differences in how students think they understand the objectives of the activities and how they really do in separate subjects. The results indicate that the most questionable activities are CHEM 06, CHEM 08, BIO 02 and BIO 04. These activities needed the most precise revisions.

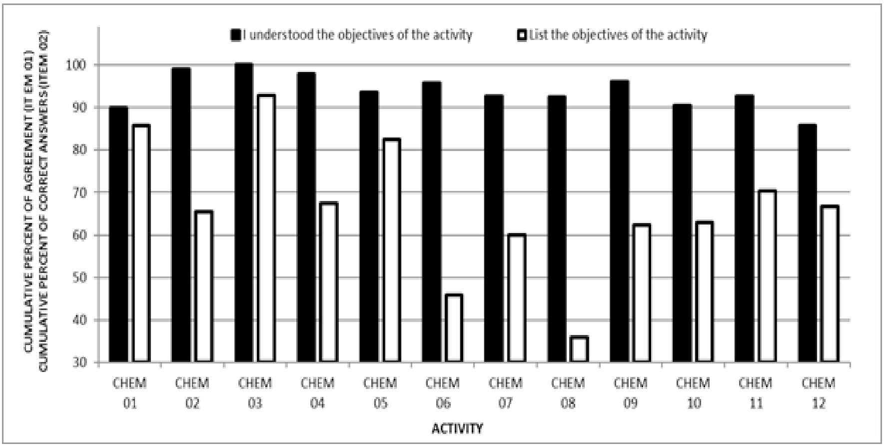

Figure 2. Understanding the objectives of activities for Chemistry.

It was less important but also interesting to perform the comparative analysis considering several factors of potential difference: (i) gender, (ii) place of implementation, (iii) country, (iv) subject and (v) age. When compared between males and females by means of Mann-Whitney U test, no significant difference was found in how they think they understand the objectives of the activities. On the other hand, significant differences appeared after listing the objectives (U =

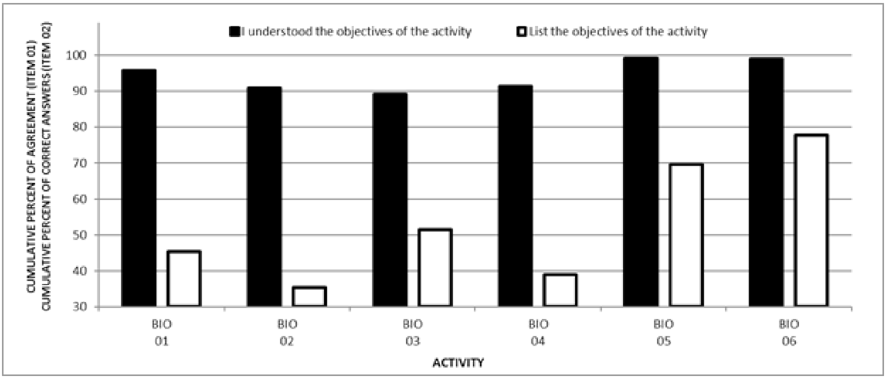

Figure 3 Understanding the objectives of activities for Biology.

181 287.500; $z = -2.955$; $\boldsymbol{p = .003}$), where male students provided correct answers more frequently (Mean Rank (MR) = 613.68) than their female schoolmates (Mean Rank = 672.68).

Interestingly, statistically significant differences regarding both first two items were also found when compared different places of implementation. The outputs from Mann-Whitney U test favour working in university compared to working in the schools (ITEM 01: $U = 251\,102.000$; $z = 6.356$; $\boldsymbol{p = .000}$; $MR_{school} = 757.25$, $MR_{university} = 643.06$; ITEM 02: $U = 251\,102.000$; $z = 6.356$; $\boldsymbol{p = .000}$; $MR_{school} = 726.75$, $MR_{university} = 596.35$). It seems that students performing in university not only felt more competent but also reported more correct answers than students working in the schools. Farther comparisons showed that some of the other factors can also generate statistically significant differences between the considered groups. Comparison between countries showed that Slovak students tend to report more positive answers in ITEM 01 ($U = 169\,110.500$; $z = -7.238$; $\boldsymbol{p = .}000$; $MR_{SK} = 593.77$; $MR_{CZ} = 735.05$) and also provided more correct answers in ITEM 02 ($U = 153\,669.500$; $z = -5.317$; $\boldsymbol{p = .000}$; $MR_{SK} = 567.51$; $MR_{CZ} = 677.63$). Subject (Chemistry and Biology) generated statistically significant difference only in listing the objectives where Chemistry produced more frequent correct answers than Biology ($U = 216\,174.500$; $z = 2.265$; $\boldsymbol{p = .024}$; $MR_{Chemistry} = 614.35$; $MR_{Biology} = 659.32$). Finally, Kruskal-Wallis H test revealed no significant difference generated by respondets' age.

ITEM 03: I need my teacher's help to understand the activity

In Table 4 it can be seen that about 45% of the students declared the need of their teacher's help in understanding the objectives of the activity (again, cumulative percent for all answers of agreement with the declarative statement has been taken into account). On the other hand, we can say that almost 55% of them did not need help like this. One way or another, it is necessary to know what activities require the most acute teacher's help. Data comparison between the activities (Figure 4) revealed that the most frequent request for the teacher's help was reported in activities CHEM 10 and BIO 03.

Furthermore, comparative analysis showed that no significant difference between compared groups is generated by gender and subject. On the other hand, students performing in university reported significantly less frequent need of their teacher's help then students implementing in the schools (U = 178 029.000; z = –5.486; $\boldsymbol{p}$ **= .000**; MR_{School} = 612.51; $MR_{University}$ = 730.13). The difference between countries was also statistically significant, where Czech students asked for the teacher's help more frequently then Slovak respondents (U = 269 984.500; z = 8.279; $\boldsymbol{p}$ **= .000**; MR_{SK} = 805.69; MR_{CZ} = 628.1). Kruskal-Wallis H test revealed no significant difference generated by age of respondents.

Table 4. Frequencies and percentages to the item I need my teacher's help to understand the activity. (1 = I totally agree, 2 = I agree, 3 = I disagree, 4 = I totally disagree).

		Frequency	Percent	Valid percent	Cumulative percent
Valid	**1**	139	9.9	10.1	10.1
	2	487	34.6	35.3	45.4
	3	482	34.2	35.0	80.4
	4	270	19.2	19.6	100.0
	Total	1378	97.9	100.0	
Missing	**0**	29	2.1		
	System	1	.1		
	Total	30	2.1		
Total		1408	100.0		

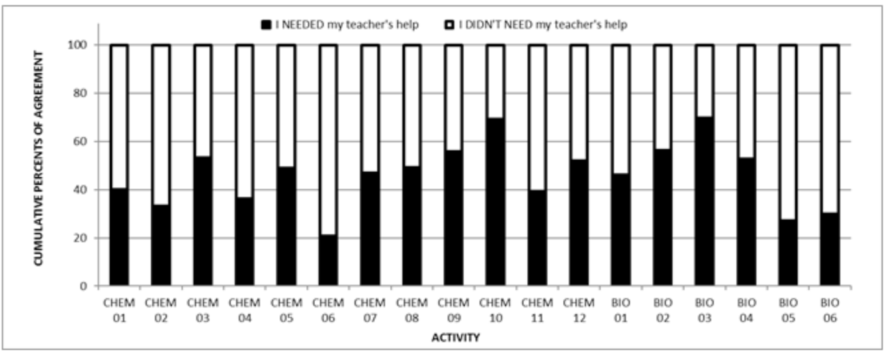

Figure 4. The need of teacher's help in understanding the objectives of the activity. Comparison between the activities.

ITEM 04: Computer measuring system helped me interpret the results (e.g. graphs).

In ITEM 04 the most students reported that computer measuring system helped them in interpreting the results (Table 5). When compared the relevant groups, the results were similar to the previous item (ITEM 03). We found significant differences generated by place of implementation and country. Students working in university laboratories considered computer measuring system helpful more often than students working in the schools ($U = 250\,486.000$; $z = 5.916$; $\boldsymbol{p = .000}$; $MR_{School} = 765,95$; $MR_{University} = 647,80$). Analogously, Slovak students provided similar responses when compared to Czech students ($U = 282\,292.500$; $z = -7.314$; $\boldsymbol{p = .000}$; $MR_{SK} = 593.05$; $MR_{CZ} = 738.98$). Again, no significant difference regarding age was recorded by Kruskal-Wallis H test.

Table 5. Frequencies and percentages to the item Computer measuring system helped me interpret the results (e.g. graphs). (1 = I totally agree, 2 = I agree, 3 = I disagree, 4 = I totally disagree).

		Frequency	Percent	Valid percent	Cumulative percent
Valid	**1**	718	51.0	52.2	52.2
	2	575	40.8	41.8	94.0
	3	66	4.7	4.8	98.8
	4	17	1.2	1.2	100.0
	Total	1376	97.7	100.0	
Missing	**0**	31	2.2		
	System	1	.1		
	Total	32	2.3		
Total		1408	100.0		

ITEM 05: I think the activity could be done without computer measuring system.

In ITEM 05 we asked students if they think the activity they are just performing could be also realized without computer measuring system. In general, more than one third of them (35.4%) reported positive answers (Table 6). A comparison between the activities (Figure 5) uncovered that students tend to consider the measuring system not necessary in activities CHEM 03 and BIO 06. Mann-Whitney U test and Kruskal-Wallis H test for other comparisons (considering all already mentioned factors) did not show statistically significant differences between relevant groups.

Table 6. Frequencies and percentages to the item I think the activity could be done without computer measuring system. (1 = I totally agree, 2 = I agree, 3 = I disagree, 4 = I totally disagree).

		Frequency	Percent	Valid percent	Cumulative percent
Valid	**1**	118	8.4	9.0	9.0
	2	348	24.7	26.4	35.4
	3	550	39.1	41.8	77.1
	4	301	21.4	22.9	100.0
	Total	1317	93.5	100.0	
Missing	**0**	89	6.3		
	System	2	.1		
	Total	91	6.5		
Total		1408	100.0		

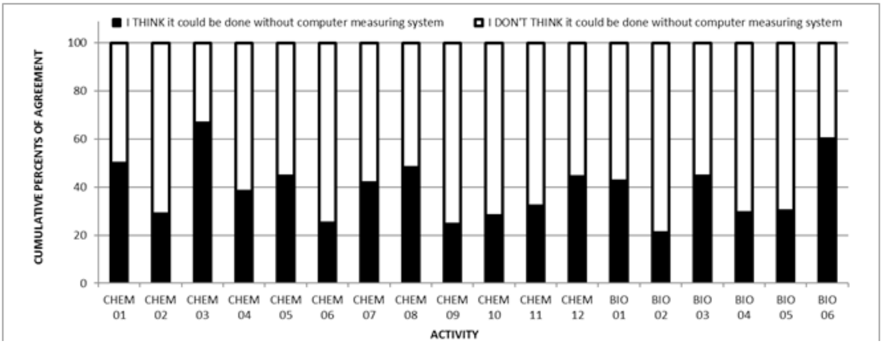

Figure 5. The necessity of computer measuring system in performing the activities. Comparison between the activities.

Conclusions

A new research-based framework for computer based laboratory activities in science education has been proposed and implemented. In accordance with our previous studies (Tortosa et al., 2013; Skoršepa, 2015), the actual study also uncovered that most students tend to perceive their level of understanding the activity more overrated then reality. This fact is one of the important fragments being able to help us in refining the activities. Furthermore, the study also showed an interesting indication of place of implementation impact on student's level of engagement. It seems that students working in university probably felt more competent to figure out the activities then students implementing in the schools. They also reported less need of their teachers help in understanding the activities when working in the university labs. Accordingly, the level of help of computer measuring system in interpreting the results was declared more notably by the students working in university. We are not sure about the reasons of such findings but we can presume that new, not-known and serious environment like university and its laboratory can also influence students in their behaviour and make them more engaged and active for learning.

It is very promising that almost all students considered computer measuring system helpful in figuring out the experimental problem that they were working on.

A bit surprising fact was that about one third of responses haven't recognized the importance of computer measuring system support in the activities. In some activities students thought they could be performed without computer measuring system. We suppose that such opinions could be influenced by not sufficient experience of our students with work in computer based laboratories. Namely, it was the first experience with computer measuring system for the most of our respondents. In conclusion, our findings suggest that tested research-based laboratory materials could be useful and of quality for the most of the students. However further research is needed to comprehend all relations recorded by this study.

Acknowledgements

We thank students and teachers who participated in the implementation and evaluation of the proposed activities. The work has been supported by grants KEGA No. 029UMB-4/2014 and EACEA No. 517587-LLP-1-2011-1-ES-COMENIUS-CMP.

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