Science Teaching in the XXI Century

editors

Paweł Cieśla & Anna Michniewska

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Evaluation and Comparison of Newly Designed IBSE oriented MBL Activities and of Work with MBL Systems by Slovak and Czech Students

Introduction

Sensors around us

We have been witnesses of the rapid development of electronics and computer technology in recent decades, until these technologies have become stage by stage an integral part of our lives. Some people may not be aware how this kind of technology is more and more becoming normal, but today's children cannot imagine what was it like "before". They are born into a world full of machines, computers, sensors and technology. Even behind the boarders of developed countries children are familiar with cell phones, tablets, smart phones or other similar type of technology. It is natural for them to rotate tablet or smart phone and see that the screen responds to the rotation, which could not happen without installed gyro sensor; the screen brightness adjusts itself according to light conditions or appropriate camera mode activates due to sensor of light intensity. Light intensity sensors are also part of the corridors' equipment of many houses and buildings; approach sensors (in other words, motion sensors) have been for a long time a part of different terminals or at the urinals, that react on the presence of an object in close proximity of a sensor. With the support of these sensors there are being developed interesting (and bizarre) applications, for example Water Level or Hang Time (How much will you jump?) (Stange, 2011). Some of these smart phones (or smart watches) even have the possibility to measure the temperature or pressure and are able to determine, among other things, altitude (Václavík, 2014). The same natural presence of sensors and instrumental technique is also in science and research. The sensors and adequate instrumentation are used not only for research and monitoring some hardly visible change (e.g. detector response radiation), but also to characterize the prepared materials and substances and it is practically impossible to publish research results without the use of sensors (pH, pressure, conductivity, ...) or adequate instrumental techniques (gas chromatography, spectrometry, ...).

School laboratory

Despite the situation in real life and real laboratory, students still often work out experiments the way they were done decades ago. The old methods have definitely their place in school laboratory practice, because it can develop the skillfulness of the students, but some experiments can be done similar to real laboratory practice, with the use of instrumental technique, that may be closer to today's students that are familiar with various technologies. School experimental (instrumental) systems, called also probeware, are not new in school laboratories, nowadays even the acquisition price is quite acceptable for the school management, but there are other obstacles that obstruct fully employment of probeware in school laboratory practice. This contribution will focus on student's attitude to probeware microcomputer-based laboratory (MBL) and activities newly designed in international project COMBLAB.

Microcomputer-based laboratory, MBL

Microcomputer-based laboratory is a way how the school laboratory practice is done – not the classical way using subjective methods of determination for example equivalence point, but using instrumental techniques that can easily visualize observed phenomena by displaying specific quantity by a graph, table or just a value. For school laboratory practice a special probeware (equipment) was prepared. It is a set of various sensors which can be connected through a common interface to a data collecting device, such as PC, datalogger, tablet, smartphone. Unlike professional laboratory devices it is quite small, mobile, robust, variable for numerous kind of sensors so that it can be used in different school subjects, it has a simple control and data treatment and easy maintenance.

The history of MBL is quite long, in USA there were first attempts to use micro-computers in natural-science education at the end of 1970s (Hood, 1994), followed by researches on quantitative, such as technical aspects (e.g. Lam, 1983; Tinker, 1985) and also qualitative pedagogical aspects (e.g. Thornton, 1986). There were researches, mostly in physics education, comparing classical and instrumental design of experiment which revealed that MBL develop abstract thinking (Thornton & Sokoloff, 1990, Hamne & Bernhard, 2001) and increases students' scientific competencies (Tinker, 1996). Obvious advantages of MBL are the quick and on-line response of the instrument, fast data treatment and immediate feedback for students that see graphical output of the phenomena that is happening in the very surrounding of the sensor.

Project COMBLAB

Project COMBLAB (acronym derived from Competencies for Microcomputer-Based Laboratory), titled The acquisition of science competencies using ICT real time experiments, was a European project where the researchers from six following universities belonging to five European countries were involved: (i) Universitat Autònoma de Barcelona (Spain), (ii) Charles University in Prague (Czech Republic), (iii) University for Teacher Education Lower Austria, Vienna (Austria), (iv) Universitat de Barcelona (Spain), (v) University of Helsinky (Finland) and (vi) Matej Bel University in Banská Bystrica (Slovakia). In the years 2012-2014 the project main aim was to design and implement the research based learning materials for students and teaching materials for teachers on the background of MBL. The subjects of the project interest were Physics, Chemistry and Biology and after finish of the project the activities are still disseminated via teachers' courses or laboratory courses for secondary school students that are held at some partners' universities laboratories. There were developed 24 activities on chemistry, 11 on biology and 12 on physics in all language versions of the countries participating in the project. Revised didactic sequence of prepared worksheets was presented by Tortosa Moreno et al., 2013a, Šmejkal et al., 2013 and Eva Stratilová Urválková et. al, 2014.

Objectives

According to situation in real scientific laboratory, COMBLAB project wanted to contribute with tools for science teachers to enhance scientific, ICT and transversal competencies in secondary school students. On that account research based teaching materials with revised didactic sequence were developed. The emphasis was put on context of each activity and inquiry-based elements so that students do not just work out the experiment after cook-book instructions. There were many questions that arouse before and during the project: for example, Are students motivated for laboratory work with MBL or are they saturated by computer technology?, Is the work with MBL complicated for students?, How do students perceive each activity – are they motivated to perform particular activity?, What are the variables that influence students' motivation to work out the experiment?, and many others. To answer satisfactory these questions two instruments for evaluation of prepared materials were used: (i) questionnaire for motivation orientation and (i) questionnaire for activity evaluation. Some results were also already presented, for example, by Tortosa Moreno et al., 2013b or Skoršepa et al. 2014.

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 the 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).

The attitudes and opinions of the students participating the courses were collected through newly designed tool (a 20-item questionnaire) and statistically evaluated. The courses attended totally 664 Czech and Slovak secondary school students (mean age 16.97; SD 1.20) from 15 participating schools (11 in the Czech

Republic, 4 in Slovakia). 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). Totally, 1408 (476 SVK + 932 CZE) evaluations have been performed as part of the students participated and evaluated more than one activity. In the questionnaire, students evaluated quality of the activity and work with MBL system. For evaluation purposes, a special tool (a 20-item questionnaire) has been administered to the students after performing each activity (implementation).

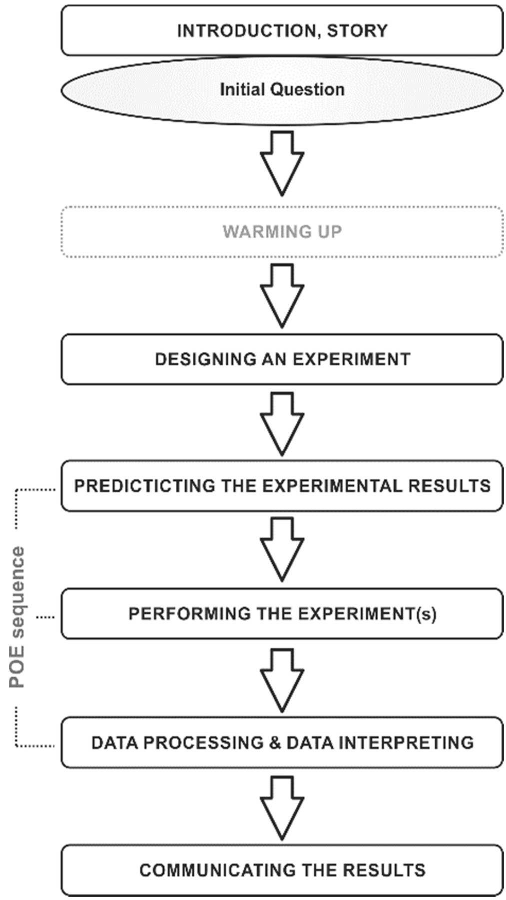

Figure 1. The uniform structure of the designed activities (The POE sequence is also depicted).

For this study, seven following questionnaire items were selected to be discussed in more detail: (Item 01) I found the activity interesting and motivating; (Item 02) The instructions were clear to me; (Item 03) Overall, how satisfied were you with the activity; (Item 04) It was easy to set up the experimental equipment, (Item 05) It was easy to work with the computer system; (Item 06) I needed my Teacher's help to perform the experiment and (Item 07) I would appreciate more frequent use of MBL in my classes. All the items are positive declarative clauses where students expressed their level of agreement on 4-point Likert scale – items 1, 2, 4 - 7 (1 = I totally agree, 2 = I agree, 3 = I disagree, 4 = I totally disagree) or 6-point Likert scale – item 3 (☺☺☺ - ☺☺ - ☺ - ☹ - ☹☹ - ☹☹☹). The data were processed by several statistical methods, such as descriptive statistics, analysis of frequencies and comparative analysis. The significance was determined by non-parametric Mann-Whitney U test or Kruskal-Wallis H test at 0.05 level. The correlation between some items has been determined using Pearson correlation coefficient.

Results

Evaluation of activities

ITEM 01: I found the activity interesting and motivating.

ITEM 02: The instructions were clear to me.

ITEM 03: Overall, how satisfied were you with the activity?

The frequency analysis of the item 01 showed that, in overall, the activities were evaluated positively by participating students as the average mark was 1.6/4, which means that 93 % of students consider the activities as interesting and motivating and only 7 % of students considered the activities as non-interesting. The result indicates that, at least, warming-up part is adequately designed and students are able to identify themselves with the objectives of the activities and with the activities scheme. The result also indicates that IBSE design of the activities is not drawback for students and a prerequisite of motivation of students using the "warming up" part and IBSE approach has been carried out. Surprisingly, the significant differences have been shown comparing the Czech and Slovak students (U = 155 207.000; z = -9.569; $\boldsymbol{p = .000}$; MR_{Czech} = 757.50, MR_{Slovak} = 564.57). Slovak students reported higher involvement in the activities as ca 65 % reported the activities to be very interesting and 32 % to be interesting. In the case of Czech students, majority of 54 % considered activities as "just" interesting. About 37 % of Czech students considered the activities as very interesting. Ca 9 % of Czech students (ca 5 % higher than in Slovakia) reported the activities as not very interesting or boring. The statistical analysis also showed an influence of particular activity performed by the students, site where the activity takes place (university or school) and school/chemistry teacher of participating students. As the Czech and Slovak students performed, to some extent, different activities, and Slovak students performed the activities only at university, a reduced set of evaluations only of Czech and Slovak students implementing the same activities at university only was taken into account. Although this reduced set has 188 students (155 Slovak, 33 Czech), it also shows significant difference between Czech and Slovak students as Slovak students evaluated activities more positively.

The clarity of the instructions for the activities (Item 2) was also evaluated very well as the instructions were clear for ca 83 % of Czech students and 98 % of Slovak students. Again, there is a significant difference between Czech and Slovak students (U = 136 844.000; z = -12.386; $\mathbf{p = .000}$; MR_{Czech} = 777.79, MR_{Slovak} = 525.99), nevertheless in this case, the reduced set of evaluations with Czech and Slovak students implementing the same activities at Czech and Slovak side and performed at universities does not show a significant difference between Czech and Slovak students. It is expected result because there is no reason for differences in clarity of the instructions and majority of differences in clarity can be clearly attributed to the differences between particular activities (see later).

The overall satisfaction with the activities (item 3) shows similar pattern as in the case of item 1 (motivational aspect of the activity). Although majority of Czech (93 %) as well as Slovak (98 %) students reported high satisfaction with the activities, in the case of the Czech students, the overall satisfaction with the activities is more shifted to medium values. While majority (76 %) of Slovak students rated the activities by the highest possible mark (☺☺☺) on sixth point scale, Czech students were more sceptical voting the most the second mark on the scale (☺☺ - 43 %). Also, almost one quarter (23 %) of Czech students was shifted to neutral position evaluating the activities. Hence, there was a statistically significant difference between Czech and Slovak students (U = 110 398.000; z = -14.757; $\mathbf{p = .000}$; MR_{Czech} = 772.92, MR_{Slovak} = 470.43). This significant difference was also observed in reduced set of evaluations (U = 2 954.000; z = -5.578; $\mathbf{p = .000}$; MR_{Czech} = 272.17, MR_{Slovak} = 182.99).

Comparison of the individual activities also showed statistically significant differences among them (Item 1: $\chi 2(4)$ = 118.269; ***p = .000***; Item 2: $\chi 2(4)$ = 182.197; ***p = .000***; Item 3: $\chi 2(4)$ = 172.817; ***p = .000***). Although the Slovak students tend to be more positive in evaluation, which can influence success of activity in evaluation, on the basis of additional information provided by students in their comments and experience of teachers from evaluations, the most favourite activities among students could be identified (Item 03). They were activities CHEM 02 (Antacids), CHEM 04 (Fire extinguisher), CHEM 05 (Acid rains) and CHEM 06 (Cleaning Liquid). All of these activities gathered over 70 % in highest mark (☺☺☺). The activities CHEM 02 and CHEM 04 were also very positively evaluated with respect to the clarity of the instructions as majority of students evaluated them very positively (78 % and 77 %, respectively). In this category, also activities CHEM 03 (Greenhouse problem), CHEM 05 (Acid rains), BIO 05 (ECG) and BIO 06 (Blood pressure) were rated very positively (all over 60 % of the highest rankings). The most successful biology activities showed to be BIO 05 and BIO 06 (47 % and 64 %, respectively), probably due to the fact that they are oriented to human body, which is theme very familiar to the students and also due to high clarity of the instructions and high reproducibility of the results. Surprisingly, the highest motivational effect has been identified at activity CHEM 11 (Gas chromatography – the highest ranking provided by 75 % of students). The reason probably is that in this activity, students solve a criminal case (presence of methanol in alcoholic drink) using modern method, similarly to CSI cases (Wikipedia, 2017), for example. Unfortunately, the analysis takes time and it is a little bit boring to be rated higher in overall evaluation. The other motivational activities are the same as the activities rated very positively in overall evaluation. This result indicates that there is some correlation between motivational potential (Item 01) of the activity and its positive overall evaluation (Item 03) as shown in Table 2.

*Table 2. Correlation matrix (Pearson) for Items 01 - 03. (**- correlation is significant at 0,01 level (2-tailed)).*

	Item 01	Item 02	Item 03
Item 01	1		
Item 02	0,38**	1	
Item 03	0,53**	0,39**	1

Therefore, if students are adequately motivated, they are more satisfied with activity and, vice versa, it is reasonable not to underestimate the motivational ("warming up") part of the activity. On the other hand, the instructions clarity (Item 02) does not correlate very much with the overall satisfaction with the activity (Item 3; see Table 2), which indicates that more complicated instructions usually provided in the case of IBSE oriented activities are not necessarily complication for students in implementation of the activity and the motivation can play more important role and, to some extent, better motivation can partially compensate more complicated instructions (if it is necessary).

On the tail of the activity rankings, the more open IBSE activities with unclear instructions and, especially, activities with problems with reproducibility of results were positioned. They were the activities CHEM 12 (Redox titration - problems with software during titration), CHEM BIO 03 (Eutrophication - "very" open IBSE, reported relative lack of motivational aspects), BIO 02 (Photosynthesis – low reproducibility of results) and BIO 04 (Germination - low reproducibility of results). Surprisingly, activities focused on spectroscopy (CHEM 03, CHEM 09, CHEM 10), which was a new and not very simple theme for the students in evaluation, were also evaluated very positively and their rankings were also very positive as overall satisfaction and motivation exceeded 80 % and, at least 30 % of students reported highest evaluation mark in overall satisfaction. Despite the fact that some activities are less successful than the others, also these activities were, in overall, evaluated positively, gathering in all the cases more than 50 % of positive or neutral marks. It indicates, as some activities would certainly deserve some corrections, all of them provide sufficient motivational potential, clear instruction and can be implemented in secondary schools with respect to practicability and the motivation of students. The comparison of results for the individual activities can be found in Table 3.

Table 3. Comparison of the students' evaluation of the individual activities (Item 03 – Overall satisfaction with the activity).

ACTIVITY	☺☺☺	☺☺	☺	SATISFIED	☹	☹☹	☹☹☹	UNSATISFIED
CHEM 01	50%	45%	10%	**100%**	0%	0%	0%	**0%**
CHEM 02	78%	28%	12%	**100%**	0%	0%	0%	**0%**
CHEM 03	60%	11%	13%	**100%**	0%	0%	0%	**0%**
CHEM 04	79%	34%	9%	**98%**	2%	0%	0%	**2%**
CHEM 05	77%	47%	15%	**98%**	0%	0%	2%	**2%**
CHEM 06	71%	64%	4%	**96%**	0%	0%	4%	**4%**
CHEM 07	43%	45%	13%	**96%**	4%	0%	0%	**4%**
CHEM 08	29%	28%	19%	**96%**	0%	4%	0%	**4%**
CHEM 09	36%	11%	29%	**99%**	0%	1%	0%	**1%**
CHEM 10	30%	34%	41%	**95%**	1%	4%	0%	**5%**
CHEM 11	36%	47%	14%	**96%**	4%	0%	0%	**4%**
CHEM 12	22%	64%	15%	**78%**	15%	7%	0%	**22%**
BIO 01	45%	37%	16%	**98%**	1%	0%	2%	**3%**
BIO 02	28%	43%	18%	**89%**	5%	5%	0%	**11%**
BIO 03	11%	39%	39%	**89%**	4%	3%	4%	**11%**
BIO 04	34%	34%	24%	**92%**	5%	2%	1%	**8%**
BIO 05	47%	37%	12%	**97%**	2%	0%	0%	**3%**
BIO 06	64%	16%	14%	**95%**	2%	2%	1%	**5%**

Evaluation of MBL approach

ITEM 04: It was easy to set up the experimental equipment.

ITEM 05: It was easy to work with the computer system.

ITEM 06: I needed my Teacher's help to perform the experiment.

The attitudes of students to MBL approach used in implementation of the described activities was studied using Items 04 – 06 and it was followed whether it was easy to set up the experimental system (Item 04), whether it was easy to work with MBL system (Item 05) and whether some teacher´s help was necessary during the activity implementation. The results of the evaluation indicate that, in overall, for majority of students in evaluation, it was very easy (51 %) or easy (38 %) to set up the MBL system and very easy (57 %) or easy (33 %) to work with the MBL system. Only 11 % of students reported problems with set up of the equipment and 10 % considered work with MBL system to be complicated. It indicates that students consider handling of the MBL systems as simple and it does not seem to be a drawback in implementation of MBL in schools. Slovak students consider set-up of MBL systems as more simple than Czech students, as can be demonstrated by Mann-Whitney U test made for reduced set of evaluations of students and activities implemented in Slovakia as well as in the Czech Republic and at university (as Slovak students implemented the activities at university only) - (U = 2 030.500; z = -2.224; $\boldsymbol{p}$ **= .026**; MR_{Czech} = 110.47, MR_{Slovak} = 91.10). Nevertheless, no statistically significant difference between Czech and Slovak students was observed for Item 5 (work with MBL systems). The small difference between Czech and Slovak students can be explained by higher reported motivation of the Slovak students and higher effort which they want to put into the activity implementation. The more important factor influencing work with MBL is the particular activity (Item 04: $\chi 2(4) = 119.744$; ***p = .000***; Item 05: $\chi 2(4) = 176.077$; ***p = .000***). Analysis of answers of questionnaire shows that problems with set-up and measurement can happen in the case of activities where titration is made (see Table 4 – CHEM 07, CHEM 08 and CHEM 12) and where the more complicated, in comparison to "time-based" measurements, manual set-up of axes and manual input of volume are necessary. It can cause some issues and problems, for example with not correctly entered values, changes of scale of axes etc. leading to negative reports of students.

In the case of spectroscopic measurements (CHEM 03, CHEM 09 and CHEM 10), more rarely, students also reported some issues in set-up and measurements with MBL system, mostly connected to unwanted clicks in the control program accompanied with change of the screen of the program. These issues cannot be simply ignored as they are connected to nature of the measurement, nevertheless, teacher should put an exceptional effort to explain prior the experiment students all the aspects of the MBL system set-up and measurement in the case of titrations and spectroscopy measurements to focus later only on taught phenomena.

Table 4. Comparison of the students′ evaluation of set-up and work with MBL system (Items 04 and 05) for the particular activities.

	Very easy		**Easy**		**Difficult**		**Very difficult**	
ACTIVITY	ITEM 04	ITEM 05	ITEM 04	ITEM 05	ITEM 04	ITEM 05	ITEM 04	ITEM 05
CHEM 01	30%	90%	20%	10%	40%	0%	10%	0%
CHEM 02	60%	66%	40%	34%	0%	0%	0%	0%
CHEM 03	40%	33%	53%	53%	7%	13%	0%	0%
CHEM 04	70%	77%	28%	23%	2%	0%	0%	0%
CHEM 05	60%	70%	38%	28%	2%	2%	0%	0%
CHEM 06	75%	92%	25%	8%	0%	0%	0%	0%
CHEM 07	36%	39%	36%	41%	25%	16%	2%	5%
CHEM 08	34%	25%	32%	32%	21%	21%	13%	21%
CHEM 09	43%	53%	43%	35%	13%	9%	2%	3%
CHEM 10	39%	52%	44%	33%	17%	13%	0%	1%
CHEM 11	39%	68%	54%	32%	7%	0%	0%	0%
CHEM 12	21%	22%	21%	19%	21%	37%	36%	22%
BIO 01	48%	51%	45%	43%	5%	3%	2%	3%
BIO 02	44%	47%	48%	43%	8%	9%	0%	1%
BIO 03	43%	36%	49%	49%	7%	16%	1%	0%
BIO 04	63%	59%	32%	35%	2%	5%	3%	1%
BIO 05	60%	72%	33%	25%	6%	2%	1%	1%
BIO 06	57%	69%	32%	20%	4%	3%	7%	8%

Despite relative simplicity in set-up and measurement with MBL system, more than half of participating students reported some help necessary provided by their teacher (Item 06; see Table 5).

Table 5. Amount of help provided by teacher reported by students (Item 06).

	VERY HELPFUL	HELPFUL	MARGINAL HELP	NO HELP
CZECH STUDENTS	20%	47%	22%	11%
SLOVAK STUDENTS	4%	35%	37%	24%

Slovak students stated statistically significant less help demand than Czech students (U = 284 984.000; z = 10.531; $\boldsymbol{p}$ **= .000**; MR_{Czech} = 612.40, MR_{Slovak} = 837.21), which was also observable in the reduced evaluation set (common activities made at university; (U = 1 776.500; z = -2.930; $\boldsymbol{p}$ **= .003**; MR_{Czech} = 118.17, MR_{Slovak} = 89.46). Although it seems, that Slovak students worked more autonomously, surprisingly, the Czech and Slovak teachers who led the activities report similar and not statistically significant difference in the help provided to students and, help provided by Czech teachers well corresponds to the help reported by their students. Hence, we speculate that higher reported motivation of Slovak students just underestimated their feeling of help provided by their teachers. The statistical significant differences among the activities were also observed ($\chi 2(4)$ = 235.312; $\boldsymbol{p}$ ***= .000***). The reports of students regarding the Item 06 with respect to performed activities are summarized in Table 6. From this point of view, the most demanding activities are the activities based on titrations (CHEM 07, CHEM 08 and CHEM 12) again and, to smaller extent, spectroscopic activities (CHEM 03, CHEM 09 and CHEM 10).

Table 6. Amount of help provided by teacher reported by students (Item 06) sorted by activity.

ACTIVITY	VERY HELPFUL	HELPFUL	MARGINAL HELP	NO HELP
CHEM 01	20%	70%	0%	10%
CHEM 02	3%	41%	41%	14%
CHEM 03	33%	47%	20%	0%
CHEM 04	6%	23%	26%	45%
CHEM 05	2%	68%	17%	13%
CHEM 06	4%	25%	38%	33%
CHEM 07	28%	45%	20%	7%
CHEM 08	29%	54%	14%	4%
CHEM 09	12%	54%	25%	10%
CHEM 10	20%	57%	20%	3%
CHEM 11	18%	71%	4%	7%
CHEM 12	46%	43%	7%	4%
BIO 01	13%	48%	29%	10%
BIO 02	33%	41%	15%	10%
BIO 03	9%	59%	29%	3%
BIO 04	12%	37%	31%	19%
BIO 05	4%	27%	36%	34%
BIO 06	10%	33%	40%	17%

In all these cases, only a minority of students reported that no or less help is necessary during the activity implementation. Nevertheless, also some of the successful activities were, to some extent, relatively demanding, for example CHEM 11 (Gas chromatography) or CHEM 05 (Acid rains). In the case of biology activities, the BIO 02 (Photosynthesis) and BIO 03 (Eutrophication) activities were the most demanding with respect to help provided to students by teacher (see Table 6). On the basis of students´ comments, the help provided to students by teachers was divided into four groups. The groups were the following: (a) Technical problems connected to MBL set-up and control (hardware and software problems); (b) "Laboratory work problems" (preparation of solutions, how to use a pipette etc.); (c) Theoretical problems (calculations, theoretical background etc.) and (d) "Other problems" ("Where is WC?" etc.). Quantification of the answers allowed us to estimate that majority of problems and provided help are those connected to work with MBL system (ca 59 %). Only 17 % was attributed to help connected with work in laboratory and 22 % were theoretical problems. Comparing to the "regular" laboratory course without MBL, the course with MBL seems to be ca 2 times more demanding for the teacher. It can be considered to be a problem in implementation of MBL into secondary schools and should be taken into account when organizing MBL course. The result also indicates, that problems connected to MBL approach are rather frequent and teachers must be well prepared and experienced to conduct a MBL course, which also rationalize appropriate courses for pre-service teachers in the framework of their university curriculum as well as for in-service teachers in the framework of their professional development.

Support of MBL implementation into secondary school curriculum

ITEM 09: I would appreciate more frequent use of MBL in my classes

In overall, majority (ca 86 %) of students support the implementation and more frequent use of MBL in secondary school. Slovak students are again more positive (ca 97 %) than the Czech students (ca 80 %) as the difference is statistically significant (U = 165 585.000; z = -8.683; $\boldsymbol{p = .000}$; MR_{Czech} = 700.11, MR_{Slovak} = 586.37). Although the Slovak students are more positive in evaluation of activities as well as in work with MBL systems, surprisingly, there is almost no correlation between Item 03 and Item 09 (ρ = .316, $\boldsymbol{z = .000}$) and between Item 04 or 05 and Item 09 (ρ = .155, $\boldsymbol{z = .000}$; ρ = .178, $\boldsymbol{z = .000}$, respectively). Nevertheless, despite the difference between Czech and Slovak students, the results indicate that, in overall, the attitudes of students, despite the difficulties appearing during the work with MBL systems, should not be considered as an obstacle in implementation of the MBL systems into secondary school education as the students support it.

Conclusions

A new research-based framework for computer based laboratory activities in science education has been proposed and implemented. The activities were evaluated by students very positively, more positively by Slovak students than by Czech students. The evaluation of the activities by students showed they can be considered as interesting and motivating, with clear instruction. Although all the activities gained the positive evaluation, some of them were evaluated more positively, especially those which are simple, with clear instruction, with well treated motivational part and oriented to human body and with well achievable and reproducible results (for example CHEM 02 – Antacids, CHEM 04 Fire Extinguisher, CHEM 11 (Gas chromatography) or BIO 05 (ECG) and BIO 06 (Blood pressure). On the other hand, open IBSE activity (BIO 03 - Eutrophication) and activities providing less reproducible results (BIO 04 -Germination and BIO 02 – Photosynthesis) were less successful among the students. Also set-up and work with MBL system were rated positively by the participating students as majority of them considered them to be simple. Also, majority of students support more frequent use of MBL systems in secondary school education. In this evaluation, the students preferred simple activities, the minor problems were identified in the case of activities based on titration, where the set-up and work with MBL is more complicated by the nature of the measurement and this aspect must be taken into account during preparation and implementation of the activity. Surprisingly, relatively complicated spectroscopic activities were, in general, evaluated more positively than activities based on titration and although there were more issues in set-up and measurement in comparison to the most successful activities, it seems that these activities can be implemented easier than we originally expected and they are not as demanding to teacher´s attention.

Despite very positive evaluation of the activities as well as of set-up and work with MBL systems, the course with MBL can be still considered more demanding for teachers than "regular" courses held without the MBL systems. The issues and obstacles connected to usage of MBL systems which require teacher´s attention and help, which must be provided to students, give still relatively high ration of all the help provided to students (ca more than 50 %). This drawback in implementation should be compensated by appropriate teacher´s preparation before MBL course and also rationalize existence of appropriate courses for pre-service teachers in the framework of their university curriculum as well as for in-service teachers in the framework of their professional development.

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