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 Teachers (a Comparative Study)

Introduction

Surrounded by sensors

Recently, school experimental systems slowly find their application in practice of chemistry teachers. Although it seems to be an effective tool for science education, teachers are still quite resistant to accept this instrument in their lessons. On the other hand, they must be aware of the expansion of technology into our common lives. They are not just plasma displays and smart phones or tablets that are becoming a standard even for young children, we meet various sensors almost everywhere. The sensor of proximity opens and closes the door instead of us, the light sensor enlightens dark corridors when there are people, so that it does not have to be turned on whole time, water at public places (toilets) starts flowing without touching the water tap. At households, there are thermostatic systems that control and measure the consumption of heat and energy, in the Czech Republic compulsory from year 2007. These systems work on the principle of temperature measurement through various cheap and temperature sensors, and are increasingly replacing older evaporative heat consumption indicators (Ista et al., 2014). Policemen do not check the sobriety of the driver using an orange-colored tubes filled with toxic potassium dichromate, but these tubes were replaced by analyzers with semiconductor sensors (Kubicka, 2011). In mentioned tablets and similar devices, gyro sensors and light sensors are natural thing, without them the screen would not rotate the way we are reading the screen or the brightness of display would not react on external light conditions. These sensors can then be used in newly developed applications that serve more for amusement of the user, for example Water Level or Hang Time (How much will you jump?) (Stange, 2011). In natural sciences sensors and adequate instrumentation are nowadays a must. They are used for research and monitoring some otherwise hardly visible changes (e.g. detector response radiation), but also to characterize the prepared materials and substances. It is not possible to publish some research results without the use of sensors (pH, pressure, conductivity, ...) or adequate instrumental techniques (gas or HPLC chromatography, spectra, ...). We can see that we are surrounded by various sensors, sometimes without aware of this fact. Despite the importance and high prevalence of sensors and instrumental techniques, they are only minimally reflected in science teaching at primary and secondary schools. Children that were already born in a world full of technology and they take it for granted, study nature sciences usually by performing traditional experiments, sometimes even just theoretically.

Microcomputer-based laboratory, MBL

Parallel to progress of professional instrumental devices used in research, there were efforts to develop systems that could be implemented in science education and it would illustrate specific phenomena using similar device as are used in real laboratory. The aspect of educational added value was also expected, which was confirmed in latter researches (see below). In this manner, school experimental systems were developed and used in school in so called microcomputer-based laboratories (MBL), which means rather the way how the experiment is performed – using instrumental device compared to traditional design where subjective methods are used. Today, the term MBL is sometimes being replaced by name probeware, which more refers to the equipment. When we talk about MBL or probeware, we mean sensors (pH, temperature, pressure, conductivity, spectrophotometer etc.), which are connected via a common interface to a computer, laptop, tablet, mobile phone or special logger, which serves as a control and processing/evaluating unit. These systems specially developed for school practice must have simple control and be user friendly, they must be robust and easy to maintain. An advantage is monitored and immediate display of measured data both in the form of numerical values, such as a graph, which can especially vividly demonstrate phenomena and processes that capture a certain dependence.

First attempts to use micro-computers in natural-science education were at the end of 1970s in USA (Hood, 1994), shortly after that there were publications on technical aspects (e.g. Lam, 1983; Tinker, 1985) where hardware possibilities of school devices were discussed and also publications on pedagogical aspects (e.g. Thornton, 1986). MBL was easier accepted by physics teachers and researchers, therefore we can find much more publications on MBL in physics education than in chemistry; some compared classical and instrumental design of experiment which revealed that MBL approach develops abstract thinking (Thornton & Sokoloff, 1990, Hamne & Bernhard, 2001) and increases students' scientific competencies (Tinker, 1996). The advantages of probeware are above all automatic recording and results simultaneously displayed on screen which give immediate feedback for students of measurement; collection of the data can be done with different frequencies which allows to study too fast or too slow phenomena; data can be saved and treated or revised or discussed afterwards if needed; ability to change the measurement conditions can be employed in inquiry-based learning; and the concept of the school system enables to be used in all levels of education, from primary to tertiary education. Researches also showed many pedagogical advantages of MBL (e.g. Tinker, 1986; Thornton, 1986; Mokros & Tinker, 1987; Nakhleh & Krajcik, 1991; Redish et al., 1997; Trumper, 2003): learning authority shifts from textbook and teacher to teaching tool (teacher-centered learning turns to student-centered learning); students are actively involved in the work which improves the process of learning; graphical output of experimental systems improves graphing skills; if allowed research approach students can master the experiment - formulating hypotheses, design experiments, verify hypothesis, interpret measured data; shorter collecting data gives more space for analysis, interpretation and discussion; the measurement encourages “what if” questions that indicate students’ engagement in activity; work in groups (even pair) evolves cooperation and peer learning; the technology can attract students’ interest and reduce science anxiety.

Despite its benefits, the implementation of MBL (at least) in the Czech Republic and Slovakia suffers from problems, when price and availability of probeware needn´t to be at the top of the list. The acceptation of the technology by students as well as teachers is influenced by further factors, for example (possible) technical problems or a lack of well-designed research based MBL materials (what to do reasonably with sensors). To contribute and support the implementation of MBL into schools, in the framework of European project COMBLAB, new inquiry-based MBL activities on chemistry, biology and physics were designed and developed (Tortosa Moreno 2013a, Stratilová Urválková et al., 2014) and, the courses on MBL implementing the newly developed activities were held for Czech and Slovak teachers.

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 in some partners’ universities laboratories. There were developed 24 activities on chemistry, 11 on biology and 12 on physics in all the language versions of the countries participating in the project. Revised didactic sequence of prepared worksheets was presented by Tortosa Moreno et al., 2013b, Šmejkal et al., 2013 and Eva Stratilová Urválková et al., 2014.

This contribution focuses on the attitudes of teachers who were working with school experimental systems during the project COMBLAB and performed newly designed activities in microcomputer-based laboratory.

Objectives

The project wanted to contribute with tools for science teachers to enhance scientific, ICT and transversal competencies in secondary school students. Beside creating a community of teachers/researchers from different countries of the consortium to exchange experiences and good practices in the field, the core was in developing research based teaching materials for secondary and high school students and research based teacher training materials that would help teachers to implement MBL in their lessons. A revised didactic sequence was applied in most of the activities that were as well research based, which was reflected in highlighted context and inquiry-based aspects of the activities. The attractiveness of MBL approach and created activities were investigated with two evaluation instruments: (i) adopted questionnaire for motivation orientations and (ii) newly created questionnaire for activity evaluation. The results from students' questionnaires show that the work with probeware is not difficult for them, they appreciate this approach as well as the activities, although they are not used to such kind of worksheets (not a cook-book form). (Smejkal et al., 2017, Skoršepa et al, 2014) This was a positive finding that students are open to MBL and new activities, but the crucial point is a science teacher. Teachers are those who determine the content and the form of science lessons, they are the "gatekeepers" of whether students will ever work with probeware or just perform traditional test tube confirmation experiments (which is still more useful than refuse laboratory practice at all). Teachers' opinions are therefore essential for researchers: we wanted to know the attitudes of teachers on the created chemistry and biology activities and what can be improved in the worksheets; What are the teachers' attitudes and opinions on MBL technology (is it easy to work with it?); What was „the volume of help" of teachers to students needed to work with MBL?; as the Czech and Slovak teachers have similar educational history, we wanted to compare the results of Czech and Slovak teachers; and finally we wanted to find out the differences in teachers' and students' attitudes.

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 teachers and students in Slovakia and the Czech Republic.

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).

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 attitudes and opinions of the teachers participating the MBL courses with students or specially designed courses for teachers, which dealt with the described activities, were collected through newly designed tool (39-item questionnaire) and statistically evaluated. The courses visited totally 42 Czech and Slovak secondary school teachers (26 Czech and 16 Slovak teachers) from 23 participating secondary schools (19 in the Czech Republic, 4 in Slovakia). All the teachers participated in more than one activity, which resulted in totally 197 evaluations (74 by Czech and 123 by Slovak teachers) of the activities. In the questionnaire, teachers evaluated quality of the activity and work with MBL system. The mentioned tool (a 39-item questionnaire) has been administered to the teachers after performing each activity (implementation).

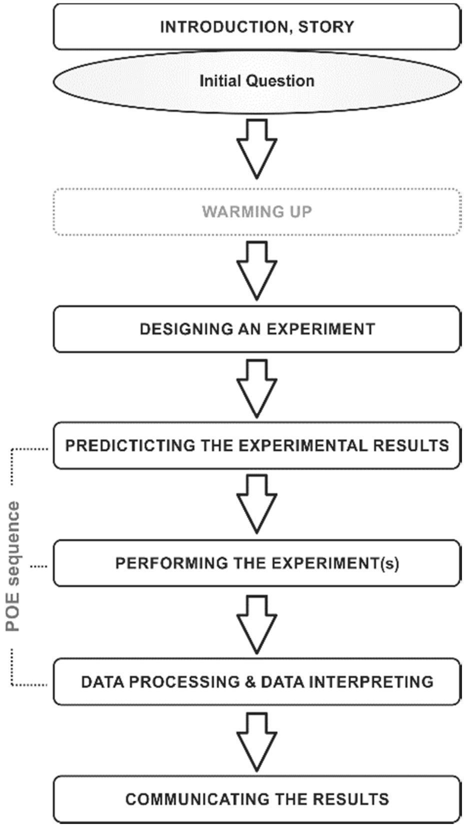

Figure 1. The uniform structure of the designed activities (The POE sequence is also depicted).

For this study, nine following questionnaire items were selected to be discussed in more detail: (Item 01) Overall, how satisfied are you with the activity as a teacher?; (Item 02) The *difficulty* of the activity is adequate to students' knowledge; (Item 03) The duration of the activity is optimal; (Item 04) The activity fits to our state educational curriculum; (Item 05) The objectives of the activity are well designed; (Item 06) Instructions for students are clear and have logical structure; (Item 07) It was easy for students to work with the computer system; (Item 08) Students needed teacher's help to comprehend the principle and the objectives of this activity and (Item 09) Students needed teacher's help to design and perform the experiments in this activity. All the items are positive declarative clauses where teachers 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 1 (☺☺☺ - ☺☺ - ☺ - ☹ - ☹☹ - ☹☹☹). 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. All the Items could be supplemented by comments and/or suggestions and the qualitative analysis of the comments was also used to interpret some results of the research.

Results

Evaluation of activities

ITEM 01: Overall, how satisfied are you with the activity as a teacher?

The analysis of Item 01 showed that, in overall, the teachers participating the evaluation were satisfied with the activities. In particular, 98 % reported satisfaction, only 2 % reported slight dissatisfaction. High level of satisfaction of teaches is also proved by high ratio of teachers, 66 %, who selected the highest degree of sixth point scale of the Item 01 ("highly satisfied"), only 18 % of teachers expressed more neutral position as they reported that they are slightly satisfied. In overall, the teachers reported slightly higher ratio of satisfaction with the activities than students (95 % satisfied, 45 % highly satisfied; Šmejkal, 2017). The average mark of the Czech teachers (1 – best; 6 - worst) at the scale of overall satisfaction was 1.4, the Slovak teaches evaluated the activities by the average mark 1.7. However, the difference between Czech and Slovak teachers was not statistically significant (U = 5 084.000; z = 1.632; ***p* = .103**; MR_{Czech} = 91.80, MR_{Slovak} = 103.33). As Czech students reported significantly less satisfaction (although still positive) than Slovak students (Šmejkal et al, 2017), we speculate that it can be a consequence of different conditions in the countries after the splitting of Czechoslovakia in 1993 into Czech Republic and Slovak Republic. As majority of teachers in evaluation was born and lived at least 15 years in Czechoslovakia, and after the splitting, many aspects of educations of teachers were the same or very similar for few years, all the students in evaluation were born in the isolated countries and some cultural and economic aspects changed and became different in both the countries. It probably led to the shift of attitudes as well as opinions of students of both the countries which led to the different evaluation of the activities and other aspects of the MBL course by the Czech and Slovak students. Nevertheless, the particular reasons for the observed differences would require more deep evaluation and new data and were not subject of this research. Surprisingly, the Czech teachers were significantly more positive in overall satisfaction with the activities than the Czech students (U = 37 672.500; z = -5.332; ***p* = .000**; $MR_{teachers}$ = 368.28, $MR_{students}$ = 505.28), in contrast, the Slovak teachers were similarly positive as the Slovak students (U = 18 298.000; z = .714; ***p* = .475**; $MR_{teachers}$ = 284.77, $MR_{students}$ = 274.06). The principal difference can be observed between the Czech teachers and students and from comments attached to questionnaires, it seems that the Czech teachers in evaluation are mostly equipped with sensors and MBL systems and they are, to some extent, more familiar to work with MBL systems and able to identify well their potential. The activities are also equipped with detailed teacher´s version, where many aspects of the activities are discussed and teachers know well what to exactly do during the activity. In the case of students, there is some ratio of uncertainty, also due to IBSE character of the activities, as they do not know the results and possible solutions, which can lead to unsuccessful implementation of the activity. Some of the students were also faced to technical problems during the activities implementation, which is another factor which led to the difference between evaluations of the activities provided by Czech teachers and students. In the case of Slovak teachers, possibly, the lack of appropriate MBL equipment and impossibility of implementation of activities in schools resulted to similar (positive) evaluation as in the case of their students. The results of evaluation of overall satisfaction with the activities are summarized in Table 2.

Table 2. Comparison of Czech and Slovak teachers′ and students′ evaluations of overall satisfaction with activities (Item 01 – Overall satisfaction with the activity).

GROUP	☺☺☺	☺☺	☺	SATISFIED	☹	☹☹	☹☹☹	UNSATISFIED
CZECH TEACHERS	70%	19%	11%	**100%**	0%	0%	0%	**0%**
SLOVAK TEACHERS	63%	11%	23%	**97%**	3%	0%	0%	**3%**
ALL TEACHERS	66%	14%	18%	**98%**	2%	0%	0%	**2%**
CZECH STUDENTS	27%	43%	23%	**93%**	4%	2%	1%	**7%**
SLOVAK STUDENTS	76%	10%	12%	**98%**	0.5%	0.5%	1%	**2%**
ALL STUDENTS	45%	31%	19%	**95%**	2%	2%	1%	**5%**

Although the overall evaluations of the Czech and the Slovak teachers showed no significant differences between them, there was significant difference observable among the particular activities ($\chi 2(6) = 58.02$; $\boldsymbol{p = .000}$). The overall satisfaction with the particular activities is shown in Table 3. We can identify that the most successful activities among the teachers were CHEM 02 (Antacids), CHEM 07 (Wine titration) and the BIO activities excluding BIO 02 (Photosynthesis). In the case of chemistry activities CHEM 06 (Cleaning liquid), CHEM 01 (CO_2 in the Sea) and CHEM 04 (Fire extinguisher), they were not evaluated so positively as other chemistry activities and their overall evaluation was shifted to the more neutral values.

Table 3. Comparison of the teachers′ evaluation of the individual activities (Item 01 – Overall satisfaction with the activity); N/E = not evaluated.

ACTIVITY	☺☺☺	☺☺	☺	SATISFIED	☹	☹☹	☹☹☹	UNSATISFIED
CHEM 01	31%	15%	46%	**92%**	8%	0%	0%	**0%**
CHEM 02	88%	12%	0%	**100%**	0%	0%	0%	**0%**
CHEM 03	50%	50%	0%	**100%**	0%	0%	0%	**0%**
CHEM 04	38%	23%	38%	**100%**	0%	0%	0%	**0%**
CHEM 05	54%	23%	23%	**100%**	0%	0%	0%	**0%**
CHEM 06	8%	8%	62%	**77%**	23%	0%	0%	**0%**
CHEM 07	80%	20%	0%	**100%**	0%	0%	0%	**0%**
CHEM 08	N/A	N/A	N/A	**N/A**	N/A	N/A	N/A	**N/A**
CHEM 09	N/A	N/A	N/A	**N/A**	N/A	N/A	N/A	**N/A**
CHEM 10	N/A	N/A	N/A	**N/A**	N/A	N/A	N/A	**N/A**
CHEM 11	N/A	N/A	N/A	**N/A**	N/A	N/A	N/A	**N/A**
CHEM 12	67%	0%	33%	**100%**	0%	0%	0%	**0%**
BIO 01	71%	17%	17%	**100%**	0%	0%	0%	**0%**
BIO 02	50%	0%	33%	**100%**	0%	0%	0%	**0%**
BIO 03	100%	19%	0%	**100%**	0%	0%	0%	**0%**
BIO 04	76%	8%	5%	**100%**	0%	0%	0%	**0%**
BIO 05	79%	0%	13%	**100%**	0%	0%	0%	**0%**
BIO 06	84%	13%	16%	**100%**	0%	0%	0%	**0%**

This is in contrast with evaluations of students, in which the rankings of CHEM 06 and CHEM 04 were among the most attractive activities and CHEM 01 activity was evaluated also more positively. By contrast, the CHEM 07 activity was more attractive for teachers than for students, probably due to the fact that teachers are much more familiar with the titration, which is the nature of the activity and teachers were able better to adapt to all the operations and/or problems connected. Both the groups, teachers as well as students, were very satisfied with CHEM 02, BIO 05 and BIO 06 activities and not very satisfied with BIO 02 activity (Šmejkal et al, 2017). According to comments to the activities evaluation, the success of some named activities is probably a result of simplicity and reproducibility of the activities and appreciable motivational potential as these activities are based on description and function of human body. Nevertheless, the relevant comparison of all of the activities cannot be done as in cases of some activities, only few teachers evaluated them (CHEM 03, CHEM 07, CHEM 12 and BIO 03).

ITEM 02: The difficulty of the activity is adequate to students' knowledge.

ITEM 03: The duration of the activity is optimal (for particular purposes of teachers, especially with respect to "standard" duration of their lab courses).

ITEM 04: The activity fits to our state educational curriculum.

The overall positive evaluation of the activities by teachers manifested themselves also in the other items related to the evaluation of the activity, in particular in items evaluating difficulty of the activities (the average mark was 1.6 of 4-point scale), adequacy of duration of the activity (1.6) and adequacy to the state educational curriculum (1.6). Also, in this case, there were no statistically significant differences in all the items 02-04 between the Czech and Slovak teachers (Item 02: $U = 4\ 335.500$; $z = -.625$; $\boldsymbol{p = .532}$; $MR_{Czech} = 101.91$, $MR_{Slovak} = 97.25$; Item 03: $U = 4\ 996.500$; $z = 1.280$; $\boldsymbol{p = .201}$; $MR_{Czech} = 92.98$, $MR_{Slovak} = 102.32$; Item 04: $U = 4\ 821.500$; $z = 1.158$; $\boldsymbol{p = .247}$; $MR_{Czech} = 92.53$, $MR_{Slovak} = 101.20$). Nevertheless, there were statistically significant differences among the particular activities evaluated by the participating teachers (Item 02: $\chi 2(4) = 39.700$; $\boldsymbol{p = .001}$; Item 03: $\chi 2(4) = 29.584$; $\boldsymbol{p = .030}$; Item 04: $\chi 2(4) = 43.547$; $\boldsymbol{p = .000}$). Although some activities were implemented and evaluated by only few teachers, an experience of teachers as well as researches from evaluation and some comments in questionnaires allow us, to some extent, to compare the activities from the point of view of Items 02 – 04. With respect to difficulty, teachers considered as the most appropriate majority of activities, especially CHEM 02 (Antacids), CHEM 07 (Wine titration), CHEM 05 (Acid Rains), BIO 06 (Blood pressure), BIO 04 (Germination), BIO 01 (Yeast Fermentation) and BIO 05 (EKG). All of these activities are, with respect to their difficulty, considered by teachers as very appropriate (> 40 %) and less than 10 % of teachers consider them as inappropriate (see Table 4).

On the other hand, the activities CHEM 01 (CO_2 in the Sea), CHEM 03 (Greenhouse), BIO 02 (Photosynthesis) and BIO 03 (Eutrophication) can be considered as more difficult with average mark around 2 (see Figures 2 and 3) and with majority of teachers indicating that difficulty is just appropriate or slightly inappropriate.

Duration of the activities is also mostly reported by teachers to be optimal (see Table 5). The only activities with longer duration are BIO 02 (33% of reports indicating inadequately time consuming activity) and BIO 03 (Eutrophication). On the other hand, at the edge of adequate duration, they are the activities CHEM 01, CHEM 03, CHEM 04, CHEM 05, CHEM 06, CHEM 12 and BIO 06. It indicates that the MBL course using these IBSE activities must be well prepared and organized to finish all the tasks in time and possible technical problems have to be eliminated as much as possible.

Table 4. Comparison of the teachers′ evaluation of difficulty of the activity (Item 02) for the particular activities.

ACTIVITY	VERY ADEQUATE	ADEQUATE	DIFFICULT	VERY DIFFICULT
CHEM 01	8%	54%	38%	0%
CHEM 02	72%	28%	0%	0%
CHEM 03	0%	100%	0%	0%
CHEM 04	38%	62%	0%	0%
CHEM 05	46%	54%	0%	0%
CHEM 06	31%	62%	8%	0%
CHEM 07	60%	40%	0%	0%
CHEM 12	0%	100%	0%	0%
BIO 01	58%	38%	4%	0%
BIO 02	33%	67%	0%	0%
BIO 03	0%	50%	50%	0%
BIO 04	62%	38%	0%	0%
BIO 05	58%	33%	8%	0%
BIO 06	63%	32%	5%	0%

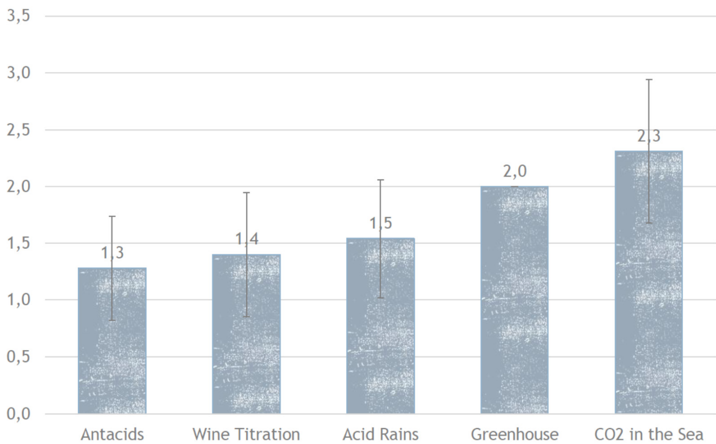

Figure 2. Mean values of teachers′ evaluation of selected activities – difficulty of the activity (Item 02), chemistry oriented activities.

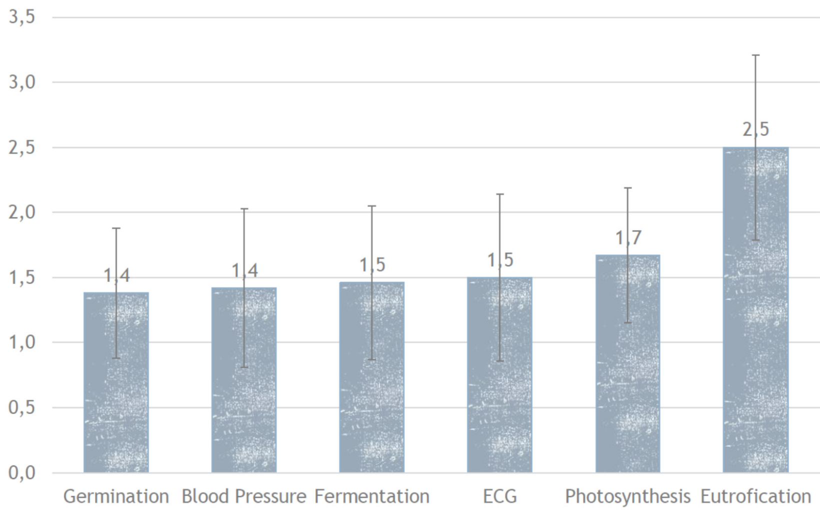

Figure 3. Mean values of teachers′ evaluation of selected activities – difficulty of the activity (Item 02), biology oriented activities.

Table 5. Comparison of the teachers′ evaluation of duration of the activity (Item 03) for the particular activities.

ACTIVITY	OPTIMAL	ADEQUATE	LONG	TOO LONG
CHEM 01	23%	69%	8%	0%
CHEM 02	60%	32%	8%	0%
CHEM 03	50%	33%	17%	0%
CHEM 04	15%	69%	15%	0%
CHEM 05	38%	38%	15%	8%
CHEM 06	23%	62%	15%	0%
CHEM 07	80%	20%	0%	0%
CHEM 12	0%	100%	0%	0%
BIO 01	58%	42%	0%	0%
BIO 02	33%	33%	33%	0%
BIO 03	0%	100%	0%	0%
BIO 04	62%	29%	10%	0%
BIO 05	67%	33%	0%	0%
BIO 06	47%	47%	0%	5%

The analysis of Item 04 shows that all the biology activities (BIO 01 – 06) and the chemistry activities CHEM 02, CHEM 05 and CHEM 07 well fit the state curriculum in both the countries. The other activities are still considered to fulfil the curriculum requirements, nevertheless, the evaluations of teachers are not so positive (see Table 6). In the case of activities CHEM 06 and CHEM 12 (Redox titration), high ratio of teachers (more than 30 %) considered that only a small part of these activities could be applied in classroom with respect to their curriculum.

Table 6. Comparison of the teachers′ evaluation of fit of the activity (Item 04) to the state (or school) educational curriculum for the particular activities.

ACTIVITY	VERY ADEQUATE	ADEQUATE	ONLY SMALL PART	NOT SUTABLE
CHEM 01	15%	69%	15%	0%
CHEM 02	63%	38%	0%	0%
CHEM 03	0%	83%	17%	0%
CHEM 04	8%	85%	8%	0%
CHEM 05	46%	54%	0%	0%
CHEM 06	8%	54%	38%	0%
CHEM 07	40%	60%	0%	0%
CHEM 12	34%	33%	33%	0%
BIO 01	58%	38%	4%	0%
BIO 02	60%	40%	0%	0%
BIO 03	50%	50%	0%	0%
BIO 04	57%	43%	0%	0%
BIO 05	58%	38%	4%	0%
BIO 06	58%	42%	0%	0%

ITEM 05: The objectives of the activity are well designed.

ITEM 06: Instructions for students are clear and have logical structure.

Majority of teachers participating in evaluation also stated that the objectives of the activities are well designed (average mark was 1.3 on 4-point scale, 99 % voted mark 1 or 2) and have clear and logical structure (1.5, 95 %). There is no statistically significant difference between Czech and Slovak teachers (Item 05: $U = 4\,949.500$; $z = 1.221$; $\boldsymbol{p = .222}$; $MR_{Czech} = 93.62$, $MR_{Slovak} = 102.24$; Item 06: $U = 4\,438.000$; $z = -.332$; $\boldsymbol{p = .740}$; $MR_{Czech} = 100.53$, $MR_{Slovak} = 98.08$), however, there is statistically significant difference among the activities (Item 05: $\chi2(4) = 40.798$; ***p = .001***; Item 05: $\chi2(4) = 38.895$; ***p = .002***). As very well designed, the activities CHEM 02 (Antacids), CHEM 07 (Wine titration), CHEM 03 (Greenhouse), CHEM 04 (Fire extinguisher), BIO 01 (Yeast fermentation), BIO 04 (Germination), BIO 05 (EKG) and BIO 06 (Blood pressure) can be considered, as majority of teachers (> 50 %) evaluated them by highest mark and no teachers attributed them bad design. On the tail of this ranking, the CHEM 06 (Cleaning liquid) and BIO 02 (Photosynthesis) can be placed as some small number of teachers (ca 5 %) reported bad design or they had high ratio of "just good" design (mark 2 on the 4-point scale; BIO 02 – more than 80 %). The activities with clear and logical structure, by opinion of participating teachers, are especially the activities CHEM 02, CHEM 05 (Acid rains), CHEM 07 and BIO 04 – BIO 06 as all of these activities were rated by highest mark by majority of teachers. In contrary, activities CHEM 01, CHEM 06, and BIO 02 (Photosynthesis) would deserve some refining with respect to the instructions provided to students, because more than 10 % of teachers evaluated them as not very clear (see Table 7). If we compare the clarity of the instructions reported by teachers and by students, we can find that both the groups evaluated the activities almost identically, with an average mark of 1.5 or 1.6, respectively.

Table 7. Comparison of the teachers' evaluation of clarity and logical structure of the instructions for students (Item 06) for the particular activities.

ACTIVITY	VERY CLEAR	CLEAR	NOT VERY CLEAR	CONFUSING
CHEM 01	23%	62%	15%	0%
CHEM 02	80%	20%	0%	0%
CHEM 03	50%	50%	0%	0%
CHEM 04	46%	54%	0%	0%
CHEM 05	62%	31%	8%	0%
CHEM 06	31%	54%	15%	0%
CHEM 07	80%	20%	0%	0%
CHEM 12	0%	100%	0%	0%
BIO 01	42%	50%	8%	0%
BIO 02	17%	50%	33%	0%
BIO 03	0%	100%	0%	0%
BIO 04	67%	33%	0%	0%
BIO 05	67%	29%	4%	0%
BIO 06	74%	26%	0%	0%

On the basis of the evaluation of the activities presented above, we can sort the activities into three groups. Simple activities with very appropriate duration time, well reproducible, and very suitable for beginners (in MBL and/or IBSE fields). The second group are the activities well evaluated, but little bit more difficult or taking longer. These activities can be still considered as suitable for regular class, nevertheless, an attention to good preparation and organization of the class must be taken into account, the participation of better experienced teacher and/or students in the course is also recommended. Finally, the third group of activities contains the activities with long duration and/or difficulty and/or more open IBSE activities. Hence, the activities of this pool can be recommended only to experienced teachers or, especially, for talented students or students with interest in science as higher autonomy of student is necessary. The distribution of the activities into the groups is summarized in Table 8.

Table 8. Distribution of the particular activities into groups on the basis of their implementation potential.

No. of group	Description of the group	Activities
1	Simple activities with very appropriate duration time, well reproducible, and very suitable for beginners (in MBL and/or IBSE fields)	CHEM 02, CHEM 05, CHEM 07, BIO 04, BIO 05, BIO 06
2	Activities well evaluated, but little bit more difficult or taking longer. Attention to good preparation and organization of the class must be taken into account.	CHEM 03, CHEM 04, CHEM 06, CHEM 12
3	Long duration and/or difficulty and/or more open IBSE activities. They can be recommended only to experienced teachers or, especially, for talented students or students with interest in science as higher autonomy of student is necessary.	CHEM 01, BIO 02, BIO 03

Issues in working with MBL system

ITEM 07: It was easy for students to work with the computer system.

ITEM 08: Students needed teacher's help to comprehend the principle and the objectives of this activity.

ITEM 09: Students needed teacher's help to design and perform the experiments in this activity.

Majority of teachers (97 %) participating in the evaluation indicated that it was easy for students to work with the MBL system. There was no statistically significant difference between Czech and Slovak teachers ($U = 4\ 627.500$; $z = .601$;

***p* = .548**; MR_{Czech} = 95.23, MR_{Slovak} = 99.62). Interestingly, teachers′ evaluation well corresponded with students′ evaluations, as both the groups rated simplicity of work with MBL system with the same average mark of 1.6. The results indicate that school MBL systems can be really considered as well designed systems for school use and the fears of teachers as well as students, if system works well, will not be drawback in implementation of MBL into schools.

Despite the positive evaluation of work with MBL system by students as well as teachers, the Items 08 and 09 revealed still high amount of help provided by teachers to the students. In both of the items, the Czech teachers report similar portion of help provided by teachers as Slovak teachers (Item 08: U = 4 855.000; z = 1.252; ***p* = .210**; MR_{Czech} = 92.07, MR_{Slovak} = 101.47; U = 4 444.000; z = .050; ***p* = .960**; MR_{Czech} = 97.78, MR_{Slovak} = 98.13). In overall, teachers reported amount of help provided to students as 99 %, which indicates, that in any performed activity, some help provided by teacher is required. The results also show that about 20 % of help is a principal and important help (continuous help necessary to finish the objectives of the activity – mark 1 at the 4-point scale), 60 % are attributed to occasional help with some particular issues, small amount of help (once or twice per course) is about 18 % and only 2 % of teachers reported that no help was necessary during the MBL course. The comments in the questionnaire and experience of researches from the courses indicate that majority of the amount of help (ca 55 %) can be attributed to usage of MBL system (set-up of the system, technical problems, software and hardware issues, questions related to control of the system, …), and the smaller portion only to other problems (preparation of solutions, how to use a burette, theoretical problems, …). Although the help provided to students by teachers is mostly occasional, the total amount of help and also a portion attributed to work with MBL system are relatively high. Comparing to the “regular” laboratory course without MBL, the course with MBL seems to be ca 2 times more demanding for teachers. 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 organization 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. If we compare the results of analysis of answers to Item 09 provided by teachers with results provided by students, in the case of the Czech Republic, the patterns of the answers are very similar and also well comparable to answers of Slovak teachers. In particular, ca 20 % of both of the group reported principal help, ca 50 % occasional help and 20 % rare help. No provided help was reported by roughly 10 % of students as well as teachers (see Chart 3). In contrast, the reports of Slovak teachers and students are different (see Chart 4). It seems that Slovak students underestimated the amount of help provided by teachers, probably due to their higher motivation (Smejkal et al. 2017), as there is no reason for different portions of help in the individual categories. Despite that, Slovak students still report high portion of help needed which, again, stress attention to good preparation and organization of the MBL courses.

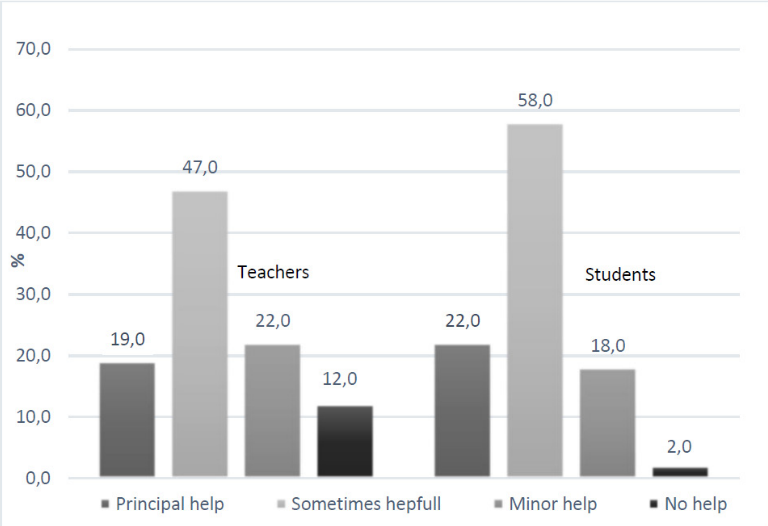

Figure 4. Comparison of "amount" of help provided by teachers to students during MBL laboratory course reported by **Czech** *teachers (left) and students (right).*

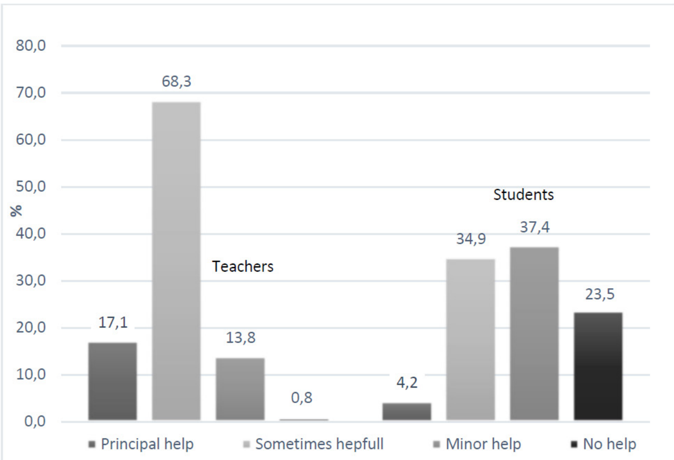

Figure 5. Comparison of "amount" of help provided by teachers to students during MBL laboratory course reported by **Czech** *teachers (left) and students (right).*

The result is further supported by analysis of the last selected item in the questionnaire, which evaluated comments of teachers on “Most stressed parts to work with MBL system”. Although only few teachers commented this Item, the analysis showed that “fears” of teachers are mostly oriented to technical aspects and issues (how to use the MBL system?, problems with hardware and/or software, what to do if … - 46 %) and to methodology and organization aspects (30 %). Also, the lack of appropriate worksheets and materials which can be employed in MBL courses can be a source of “fears” of teachers implementing MBL courses and, hence, an existence of well prepared and tested and evaluated worksheets would be appreciated (ca 23 %). These results rationalize again organization of appropriate courses on MBL 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 and also preparation of new activities which employ the MBL systems.

Conclusions

A new research-based framework for computer based laboratory activities in science education has been proposed and implemented. The activities were evaluated by teachers very positively and in the case of majority of activities, teachers considered their duration, difficulty and content (with respect to the state and school curriculum) as optimal. The teachers also considered the objectives to be defined adequately and instructions as clear.

In all the analysed items of the questionnaire, there was no difference between the Czech and Slovak teachers, probably due to their similar conditions of their professional preparation as majority of them started their professional career (or life) in former Czechoslovakia or soon after the splitting of the country. Although, there was no difference between the Czech and Slovak teachers, there was difference between Czech teachers and students as teachers evaluated the activities more positively than students, probably due to longer experience with MBL systems. On the other hand, all the students as well as teachers of both of the countries rated the instructions of the activities very similarly as clear with a logical structure.

The analysis showed significant differences among the particular activities. On the basis of the analysis, the activities were sorted into three groups with respect to a purpose of application and/or implementation potential: *a)* Simple activities with very appropriate duration time, well reproducible, and very suitable for beginners (in MBL and/or IBSE fields). *b)* Activities well evaluated, but little bit more difficult or taking longer. These activities can be still considered as suitable for regular class, nevertheless, an attention to good preparation and organization of the class must be taken into account, the participation of better experienced teacher and/or students in the course is also recommended. *c)* Activities with longer duration and/or difficulty and/or more open IBSE character. Hence, the activities of this pool can be recommended only to experienced teachers or, especially, for talented students or students with interest in science as higher autonomy of student is necessary.

Despite very positive evaluation of the activities as well as of set-up and work with MBL systems by teachers as well as students, 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 and which require teacher´s attention and help provided to students, give still relatively high portion 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.

The analysis of teachers´ opinions related to the "fears" of teachers implementing MBL courses, and, hence, the most appreciated parts of MBL course for teachers, revealed that these "fears" are mostly oriented to technical aspects and issues, methodology and organization aspects and lack of availability of tested and evaluated worksheets. These results rationalize again organization of appropriate courses on MBL 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 and also preparation of new activities and materials (worksheets, tutorials) which employ the MBL systems.

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