DESIGN OF RESEARCH-BASED LAB SHEETS FOR THE ACQUISITION OF SCIENCE COMPETENCIES USING ICT REAL-TIME EXPERIMENTS. DO STUDENTS GET THE POINT OF WHAT THEY ARE DOING?

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Abstract: This study is part of a European project that aims to design new microcomputer-based laboratory (MBL) activities to be used in secondary and high school to enhance on students scientific competencies. The aim of this work is to design and to implement research-based teaching materials that take advantage of the use of MBL and promote scientific competencies in students.

Researchers from six universities belonging to five EU countries have collaboratively designed a new research-based framework for MBL activities. Activities are context-based and inquiry guided. When students take experimental data, it is proposed a Predict-Observe-Explain (White & Gunstone, 1992) sequence. The main scientific competencies that the designed activities aim to enhance in students are the design of experiments, the interpretation of results and its communication. First versions of activities have been translated into national languages (German, Czech, Slovak, Finnish and Catalan) to be implemented. The study has been conducted with 865 students from five countries who have implemented the activities. Students answered a post-implementation questionnaire to elicit if they believed that they knew the objectives of the activities and if they really did. They were also asked if MBL helped them to interpret the results and if the activity could have been done without such equipment.

Results obtained in this study suggest that the research-based learning materials designed to work with MBL are useful and of quality as most students in different countries understand the point of the activities, and most of them think that these activities help them to learn and that the activities could not be done without MBL. Nevertheless, differences in results have been obtained for some activities. The results of this research will be used to refine teaching materials.

Keywords: science competencies, MBL microcomputer based laboratory, secondary school science, competencies in the laboratory

BACKGROUND

This study is part of a European project that aims to design new microcomputer-based laboratory (MBL, Thornton 1990) activities to be used in secondary and high school to enhance on students scientific competencies. Performing MBL, also called real time experiments, allows students to work out many features of science competencies, having a quick and continuous interaction with new learning that they acquire. In this technology (Figure 1) one or more sensors are connected to an interface and/or to a computer so that the results of the experiment are obtained in real time. That is students can see the graphs of the experiment at the same time that they are obtained.

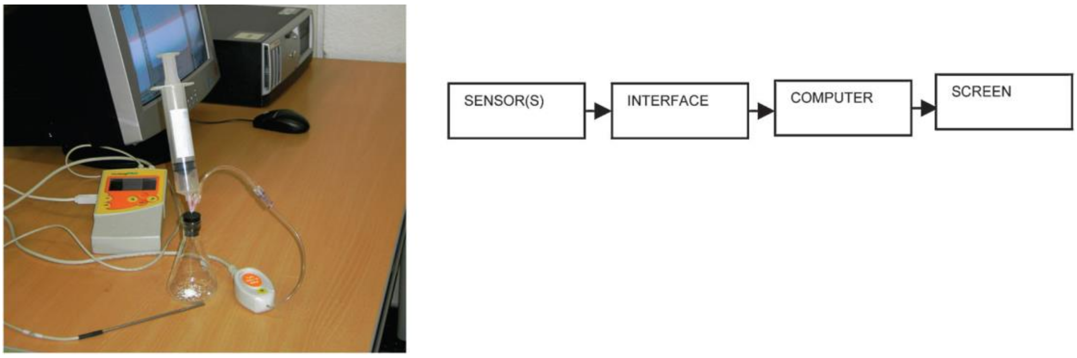

Figure 1: Example of Microcomputer Based Laboratory Technology. Students can see the results and the graph of the experiment in real time (image M. Tortosa).

This tool supports a constructivist view of education and allows working high order learning skills (Aksela, 2005). A user-friendly data logger supports a better teacher implementation (Lavonen et al, 2003). Sheppard (2006) states that MBL equipment, used with a Prediction-Observation-Explanation (POE) view is a powerful tool to evaluate students' learning in a great variety of topics.

The proposal of MBL instructions presented as an inquiry-guided activity and structured as a learning cycle has revealed to be effective in achieving significant learning. A classroom management style that promotes student verbalization and interaction is desired. It is important to minimize technical complications assuring a assuring a good experience of using the hardware and software. Previous research-based frameworks for practice in MBL activities have been suggested (Pintó et al, 2010; Espinoza & Quarless, 2010; Tortosa, 2012). Students generally express that MBL is easy-to-use technology, that motivates them and that it helps them to improve their understanding in science.

Rationale

The aim of this work is to design and to implement research-based teaching materials that take advantage of the use of MBL and promote scientific competencies in students.

The objectives of our work are twofold: (1) To obtain research-based teaching materials on real-time experiments that enhance scientific competencies in secondary and high school students, and (2) to answer the questions: “Do students understand the objectives of the research-based designed activities?”, and “Do students feel that MBL helps them learning?”

We want to know if students see the point of these new designed learning materials that have been implemented by teachers in different European countries both at schools and in workshops at university. This will give us data on the quality of the preliminary version of the activities. We agree with previous studies (Lijnse, 2004) in the fact that it is necessary that students see the point of what they are doing, so that the process of teaching and learning probably makes more sense to them.

METHOD

An exhaustive review on literature related to the topic has been made. The authors of this work, from six universities belonging to five EU countries have collaboratively designed a new research-based framework for MBL activities (Figure 2).

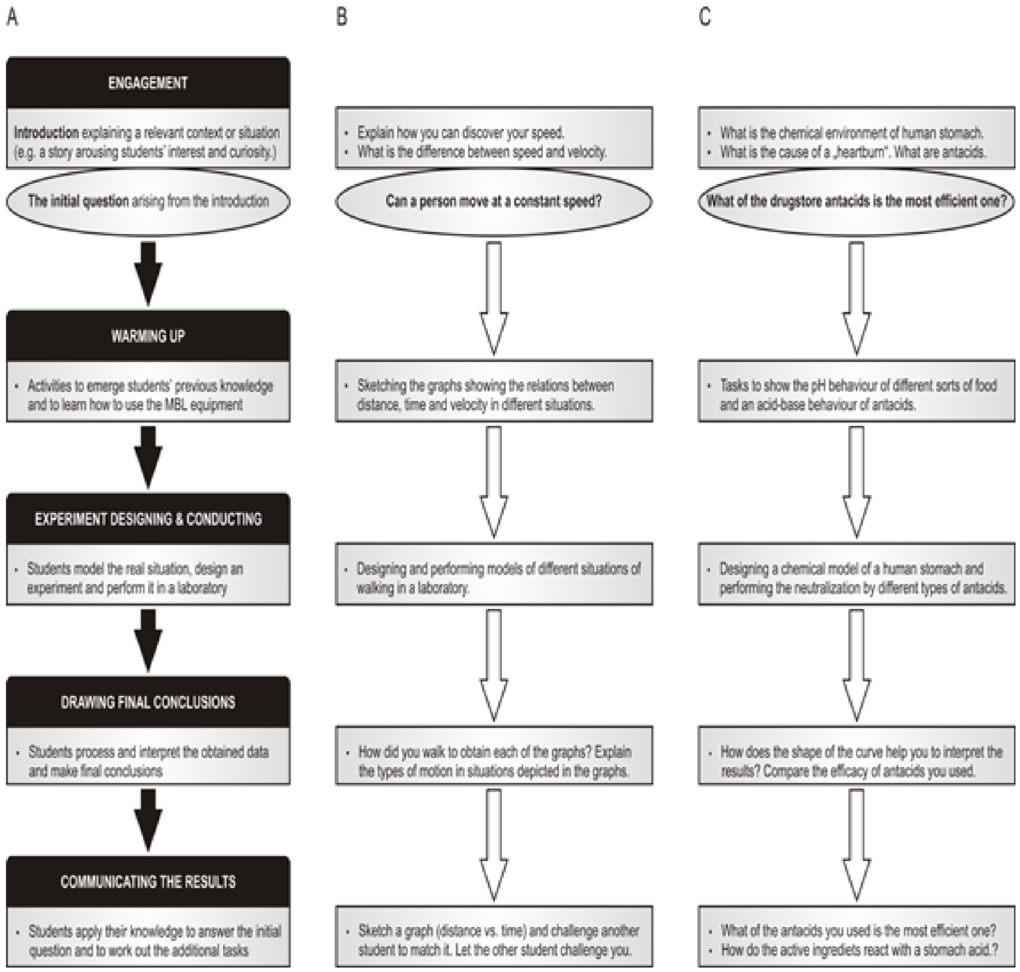

Figure 2: Research-based framework for MBL activities and examples. A) general framework, B) a specific framework for „Body motion" activity (Physics), C) a specific framework for „Antacids" activity (Chemistry)

The framework proposes that each activity has five parts: (i) an *engagement*, in which a relevant problem is exposed and a question intended to solve the problem emerges. The storyline of the whole activity consists on activities that lead pupils to answer the question to solve the problem; (ii) a *warming up* phase, which aims at making the MBL equipment needed familiar to students and to emerging students' previous ideas on the scientific concepts worked during the activity; part of this warming up phase can be skipped depending on the skills of students; (iii) a *design and conducting the experiment* phase in which students are guided so that the experiment they design is valid and reliable, students are asked to predict their expected results; (iv) in the *drawing conclusions* phase, pupils are directed to interpret the results that they obtained, to compare them with their predictions and with the theoretical model and to make conclusions; (v) in the last part *communicating the results*, students are asked to communicate their conclusions in a variety of ways.

Activities for Chemistry, Physics and Biology have been created. They are context-based and inquiry guided. When students take experimental data, it is proposed a Predict-Observe-Explain sequence. First versions of activities have been revised (Figure 3), and translated into national languages (German, Czech, Slovak, Finnish and Catalan), before being implemented with secondary school students.

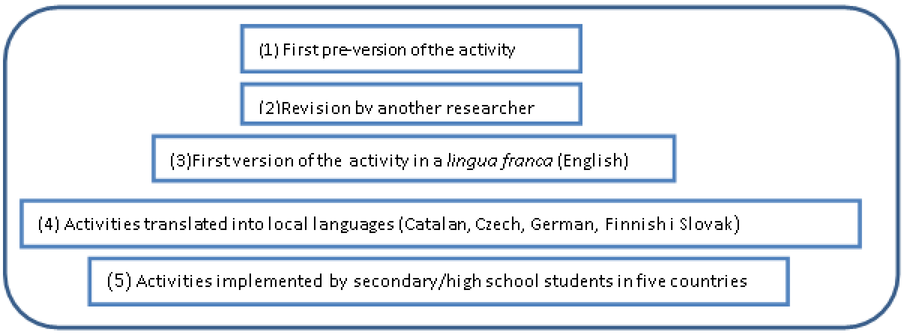

Figure 3: Process before the first implementation of the activities designed

In order to validate the framework created in this research, activities have been implemented with 865 students from five countries (Table 1). In Austria, Czech Republic and Slovakia students went to university to be taught by one of the researchers as teachers in the session; in Finland in some cases the researcher went to schools to implement the activities and in some other the implementation was done at university. In Catalonia (Spain) activities have been implemented at current schools with their current teachers, who had a two-session training course before implementation. Students answered a post-implementation questionnaire; their answers to four questions are presented:

1. Do you understand the objectives of the activity?
2. List the objectives of the activity.
3. MBL approach helped me to interpret the results correctly.
4. The activity could have been done without MBL equipment.

Table 1

Number of students who implemented the activities. S: at school; U: at university

Partner	**Country**	**Physics**		**Chemistry**		**Biology**		**Total**
UAB	Spain	46	S	186	S	--		**232**
CU	Czech Rep	--		126	U	76	S	**202**
UW	Austria	40	S/U	--		--		**40**
UB	Spain	98	S	83	S	--		**181**
UH	Finland	--		168	S/U	--		**168**
UMB	Slovakia	--		42	U	--		**42**
Total		**184**		**605**		**76**		**865**

In questions 1, 2, and 4 students choose from a four-level Likert scale ranging from 1 (strongly agree) to 4 (strongly disagree); question 2 is open, answers have been classified ranging from 1 (very good answer) to 4 (totally erroneous answer).

Data were analysed in different ways: descriptive analyses, statistical analyses of mean, analysis of frequencies and comparative analysis (subject, country, age, gender). Significance was determined based on Kurskal-Wallis test or based on Mann-Whitney U test (significant level 0.05).

RESULTS

In table 2a can be seen that most of students (91.6% of answers) say that they understand the objectives of the activity (most frequent answers 1: totally agree and 2: agree). That is students think that they understand what they are doing. When students are asked to list the activities, we have obtained (table 2b) that more than half of the answers (54.7%), are good or very good, although the highest frequencies are for 2 (good answer) and 3 (bad answer).

In summary 9 out of 10 students think that they understand the objectives of the activities, but only 5 out of 10 do. This is a crucial result to be taken into account with the objective of improving them when we obtain the new version of the activities, and the didactic guides supporting teachers. Significant differences (Kruskal-Wallis test, significant level lower than 0.05) have been found between understanding the objectives in Physics and Chemistry activities (Figure 4), and between the places of of implementation: students claim better understanding of the objectives when the activities are implemented at University. No significant differences were found between countries (table 3), except in one case that can be attributed to the subject implemented.

Students say that MBL helps them to interpret the results (91.4% of answers), and that the activity could not have been done without MBL (Table 4). We consider these a very positive result, because the objective of the research is to obtain activities that take advantage of the use of MBL, but not classical (no research-based) activities that use sensors.

Table 2

Frequencies and percentages to the questions (a) I understand the objectives of the activities and (b) List the objectives of the activity. 1. Totally agree/totally correct. 4. Totally disagree/totally erroneous answer

(a) I understand the objectives of the activity					
Valid		Frequency	Percent	Valid percent	Cumulative percent
	1	387	44.7	45.9	**45.9**
	2	386	44.6	45.7	**91.6**
	3	58	6.7	6.9	98.5
	4	13	1.5	1.5	100.0
	Total	844	97.6	100.0	
Missing	0	21	2.4		
Total		865	100.0		

(b) List the objectives of the activity					
Valid		Frequency	Percent	Valid percent	Cumulative percent
	1	118	13.6	16.3	16.3
	2	277	32.0	38.4	**54.7**
	3	240	27.7	33.2	**88.0**
	4	87	10.1	12.0	100.0
	Total	722	83.5	100.0	
Missing	0	143	16.5		
Total		865	100.0		

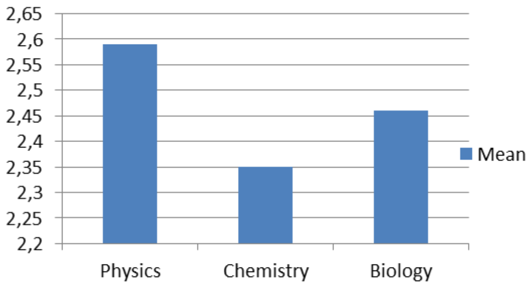

Figure 4: Answers to the question: "List the objectives of the activity". 1: totally erroneous answer. 4: Very good answer Comparison of subjects

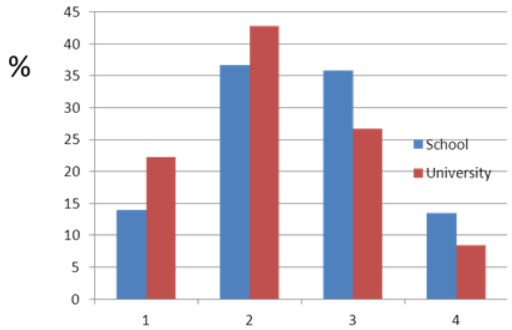

Figure 5: Answers to the question "List the objectives of the activity". 1: totally erroneous answer. 4: Very good answer. Comparison of implementations at school and at university

Table 3

Frequencies and percentages to the question "MBL helps me to interpret the results" 1: Totally agree, 4: Totally disagree.

MBL helps me to interpret the results					
Valid		Frequency	Percent	Valid percent	Cumulative percent
	1	388	44.9	45.6	**45.6**
	2	389	45.0	45.8	**91.4**
	3	58	6.7	6.8	98.2
	4	15	1.7	1.8	100.0
	Total	850	98.3	100.0	
Missing	0	15	1.7		
Total		865	100.0		

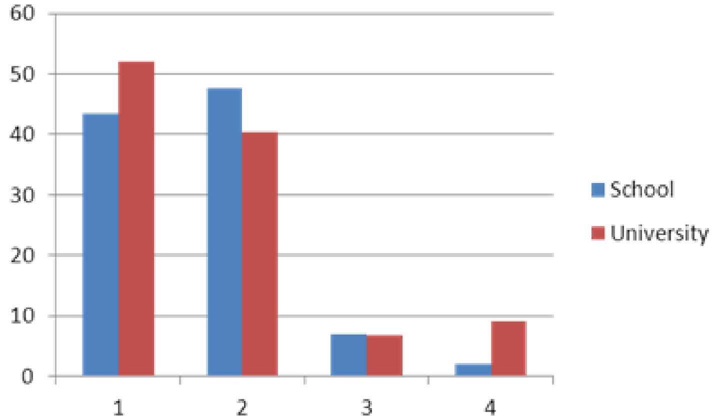

Figure 6: Answers to the question: "MBL helps me to interpret the results" 1: Totally agree; 4: Totally disagree. Students performing the activity at University have the perception that MBL helps them more

Table 4

Answers to the question: "The activity could have been done without MBL" 1: Totally agree; 4: Totally disagree.

The activity could have been done without MBL					
Valid		Frequency	Percent	Valid percent	Cumulative percent
	1	47	5.4	5.8	5.8
	2	149	17.2	18.2	24.0
	3	349	40.3	42.7	**66.7**
	4	272	31.4	33.3	**100.0**
	Total	817	94.5	100.0	
Missing	0	48	5.5		
Total		865	100.0		

CONCLUSIONS AND IMPLICATIONS

A new research-based framework for MBL activities in secondary and high school has been designed. Chemistry, Physics and Biology activities have been designed using it, and have been implemented with students. After implementing the activities most of students (91.6%) say that they understand the objectives of the activities, that MBL helps them to interpret results (91,4 %) and that the activity could not have been done without MBL (76%). Nevertheless difficulties emerge when students are asked to list the objectives and although more than half of them (54.7%) do it correctly, we think that this result, even being partly positive, being the first time that students are faced with MBL, should be improved and must be taken into account to obtain the new versions of the activities and the didactical guides for teachers.

No significant differences between countries or between boys and girls have been found. In three of the four items studied, differences have been obtained in the answers of students when the activity is performed at universities or at school. Students think that they understand better the activities at University, their answers ate better, and they even think that the MBL equipment helps them more when the activity is performed at university.

In future research we suggest to study in depth the differences between the place of implementation, also to study similarities and differences between single activities and to pay attention to the 9% of students that say that don't understand the activities and that MBL does not help them.

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