Experiments in teaching and learning natural sciences

the monograph edited by:
Małgorzata Nodzyńska, Paweł Cieśla, Agnieszka Kania

PEADAGOGICAL UNIVERSITY OF KRAKÓW
KRAKÓW 2014

The monograph is edited by:
Małgorzata Nodzyńska, Paweł Cieśla, Agnieszka Kania

Rewievers
Krzysztof Kruczała, Jiří Rychtera, Mariola Tracz

Cover:
Paweł Cieśla

ISBN 978-83-7271-878-5

ACTIVITIES WITH SENSORS IN LABORATORY OF BIOLOGY: STUDENTS' MOTIVATION AND UNDERSTANDING THE ACTIVITIES

Marek Skoršepa, Eva Stratilová Urválková, Petr Šmejkal, Montserrat Tortosa Moreno, Hildegard Urban-Woldron

Introduction

We present the partial study arising from a European project COMBLAB (acronym derived from COmpetency Microcomputer-Based LABoratory) titled *The acquisition of science competencies using ICT real time experiments*, where the researchers from six following universities belonging to five European countries are 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). The main aim of the project is to design and implement the research based learning materials for students and teaching materials for teachers on the background of Microcomputer-Based Laboratories (MBL). The subjects of the project interest are Physics, Chemistry and Biology.

Methods

Three evaluating tools were administered to students during the performing of each activity: (i and ii) two tests for motivational orientations [Pintrich et al., 1991; McAuley et al., 1989] and (iii) a questionnaire to gain a feedback in order to evaluate the activity and to uncover how students understand it.

The data and results presented in this paper were obtained during the implementation of Biology activities and involve only the Slovak part of the research. The study follows our recent work in the field – an implementation of analogous activities for Chemistry [Skoršepa et al., 2013].

The research in Slovak republic included 117 students (82 female; mean age = 16.9 years, SD = 0.7) from four grammar schools: (1) Gymnázium Andreja Sládkoviča, Banská Bystrica (n = 45), (2) Gymnázium Mikuláša Galandu, Turčianske Teplice (n = 25), (3) Gymnázium Spišská Nová Ves (n = 24) and (4) Gymnázium Jána Chalupku, Brezno (n = 23). None of the participating students had previous experience with MBL in their schools. However, some of them took part in testing of Chemistry activities recently [Skoršepa et al., 2013]. Most of the students performed more than one activity (usually three), therefore totally 266 evaluations were acquired. The conditions in the participating schools didn't allow testing the activities in the local schools. Due to the serious lack of necessary equipment in the schools, all students were invited to perform the activities in the university labs (Matej Bel University).

Motivational orientation of students toward working in MBL

A part of our research was to investigate the students' self-declared perception of their motivational orientations before and after performing the activity. In this study, the issues of students' motivational orientations were studied, particularly the dependence on factors such as gender, a particular activity and a specific school. The students were also clustered into the groups according to their motivational orientations.

In order to distinguish between motivational orientations before and after performing the activity, two research devices - motivational tests, were used:

Motivated Strategies for Learning Questionnaire (MSLQ) developed by Pintrich and his colleagues [Pintrich et al, 1991] for assessing student's motivational orientations and their use of

different learning strategies, which was administered to students before performing the activity (Pre-test).

Intrinsic Motivation Inventory (IMI) originally designed for assessing the subjective experience related to intrinsic motivation and self-regulation [McAuley et al., 1989] administered after realizing the activity (Post-test).

Both of the original research tools are multi-scaled. However, from each of the tools we selected four scales suitable for our purposes (Table 1) where each scale was represented by four items (declarative clauses). Answers to the items were classified on the seven-level Likert scale ranging from "I totally disagree" (1) to "I totally agree" (7).

Do students understand the activities?

In order to validate the activities and to have feedback from students on how they perceive themselves, a questionnaire including 20 items investigating several aspects related to the proposed MBL activities was designed (e.g. understanding the activity and its objectives, activity attractiveness, its difficulty, the development of students' knowledge and attitudes of students toward MBL approach). The questionnaire was administered after performing the activity. Herein, the partial data resulting from the six following items of the questionnaire are presented:
(1) I understood the objectives of the activity;
(2) List the objectives of the activity;
(3) I needed my Teacher's help to understand the activity;
(4) It was easy to collect data by means of MBL approach;
(5) MBL approach helped me to interpret the results (e.g. graphs) correctly;
(6) I think the activity could be done without MBL.

In Items 1, 3, 4, 5 and 6 as declarative clauses the answers were classified on the four-level scale: 1 – strongly agree, 2 – agree, 3 – disagree and 4 – strongly disagree. In the open Item 2, where students were asked to list the objectives of the activity, the answers were subsequently quantified as follows: 1 – correct answer; 2 – more or less correct answer; 3 – not sufficient answer and 4 – totally erroneous answer.

Results

The presented results arose from the testing and evaluation of four newly designed biology activities: (A) The life of Yeast (Yeast & Fermentation); (B) Wake up, wake up, it's time to get up? (Seed Germination); (C) What makes your heart beat? (ECG) and (D) Nursie, the pressure! (Blood Pressure).

Motivational orientations of students

Tab. 01 shows Cronbach's alpha values for all studied scales. In order to get robust variables only scales with $\alpha > 0.7$ should be considered. It is obvious that the internal consistency of answers within the individual scales is acceptable only in six of eight cases. For two scales of Pre-test (3 and 4) the internal consistency is questionable.

Tab. 01. Scales and reliability coefficients (Cronbach's alpha) for motivational orientation of students.

Scale (Pre-test)	α	Scale (Post-test)	α
1 Intrinsic Goal Orientation	.77	1 Interest/Enjoyment	.84
2 Extrinsic Goal Orientation	.80	2 Perceived Competence	.78
3 Self-Efficacy for Learning and Performance	.69	3 Effort/Importance	.82
4 Control of Learning Beliefs	.66	4 Value/Usefulness	.78

Correlation analysis show strong relationship mainly within the Post-test scales (Tab. 02) corresponding to the fact that they all relate to intrinsic motivation and self-regulation.

Tab. 02. Correlation matrix (Pearson) for motivational orientation.

	Scale	Pre1	Pre2	Pre3	Pre4	Post 1	Post 2	Post 3	Post 4
Pre1	Intrinsic Goal Orientation	1							
Pre2	Extrinsic Goal Orientation	.066	1						
Pre3	Self-Efficacy for Learning and Performance	.595**	.253**	1					
Pre4	Control of Learning Beliefs	.412**	.210**	.428**	1				
Post 1	Interest/Enjoyment	.402**	.184**	.310**	.327**	1			
Post 2	Perceived Competence	.289**	.302**	.504**	.347**	.628**	1		
Post 3	Effort/Importance	.245**	.426**	.347**	.282**	.646**	.679**	1	
Post 4	Value/Usefulness	.480**	.205**	.436**	.345**	.787**	.613**	.645**	1

**. Correlation is significant at the 0.01 level (2-tailed).

When considering different factors (gender, activity, school) as possible effectors of motivational orientations of students, the following results were found.

Motivational orientations only weakly depend on gender as the statistically significant difference was revealed only in Extrinsic goal orientation ($F(1,264) = 10.63$, $p = .001$). More specifically, female students ($M_{female} = 4.61$, $SD = 1.21$) are more extrinsically motivated than their male schoolmates ($M_{male} = 4.02$, $SD = 1.60$).

A specific activity was the second factor observed as an effector of students' motivational orientations. However, similarly to our previous study focused on activities for Chemistry [Skoršepa et al., 2013], analysis of variance (ANOVA) revealed no significant difference in variances related to the particular biology activities neither in Pre-test nor Post-test scales. The

mean values of motivational score belonging to the specific activities before and after performing the particular activity are depicted in Fig. 01 and Fig. 02.

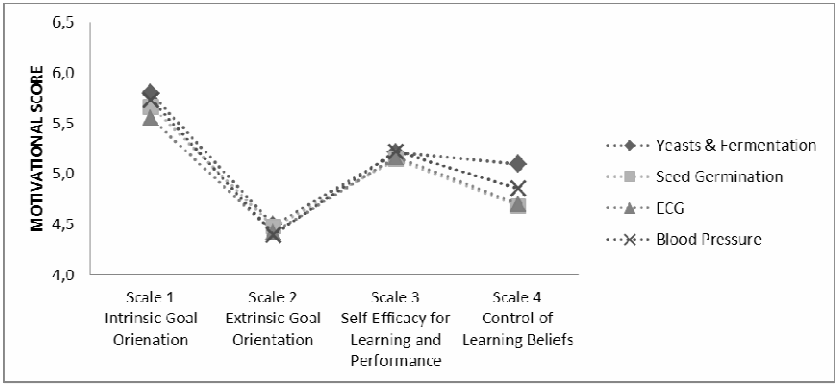

Fig. 01. Motivational orientations before performing the particular activity (mean values).

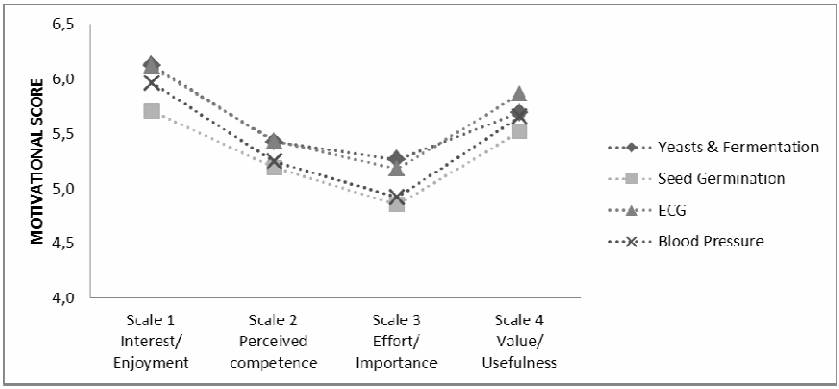

Fig. 02. Motivational orientations after performing the particular activity (mean values).

In Fig. 01 it can be seen that the motivational scores of students before experimentation are almost the same for all activities in the first three scales. We presume that it is not surprising to obtain the data with no significant differences in Pre-test because before experimentation students don't know the content of activities (their specifics and backgrounds) in detail. As apparent from Fig. 02, the differences in mean values in Post-test scales are more notable but their variances are still not significantly different (ANOVA). However it is important to note that in general students reported relatively high level of motivation in each of the Post-test scales for all activities as in most cases their mean motivational scores are not lower than five.

A particular school seems to be the most influencing factor of motivational orientation of students. The findings from ANOVA revealed a main effect of the particular school on students' perceptions of Intrinsic Goal Orientation ($F(3,262) = 12.60$, $p = .000$), Self-Efficacy for Learning ($F(3,262) = 6.70$, $p = .000$) and Control of Learning Beliefs ($F(3,262) = 6.95$, $p = .000$). The mean values of Pre-test motivational scores related to the particular schools are depicted in Fig. 03. According to the results the students of School 4 reported higher motivational orientations for Intrinsic Goal Orientation, Self-Efficacy for Learning and Control of Learning Beliefs than students from the other three schools.

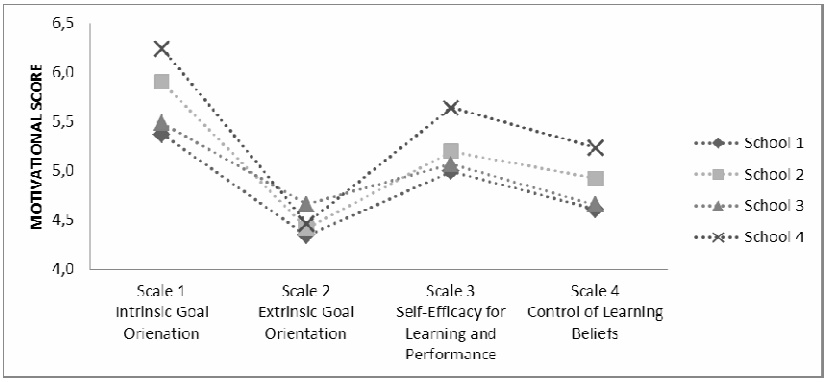

Fig. 03. Pre-test motivational orientations of students related to the particular school (mean values).

When analysed the Post-test data, the statistically significant difference was found only in one of four cases: Interest/Enjoyment ($F(3,262) = 2.79$, $p < .05$). Fig. 04 shows the mean values of Post-test motivational scores when affected by the particular school.

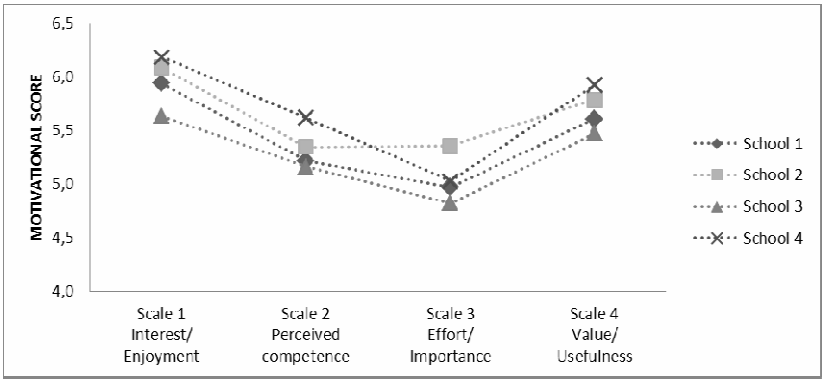

Fig. 04.Post-test motivational orientations of students related to the particular school (mean values).

A hierarchical cluster analysis of Pre-test and Post-test motivational scores (using Ward's method of clustering) revealed that participants can be grouped into three reasonable clusters in both Pre- and Post-cases. A subsequent non-hierarchical cluster analysis (K-means) on the Pre-test data provided the final cluster centers that can be seen in Fig. 05. Interestingly, 79% of participants (38% of Cluster 1 plus 41% of Cluster 3) reporting high motivational scores in Intrinsic Goal Orientation, Self-Efficacy and Control of Learning Beliefs can be divided into two subgroups according to their different Extrinsic Goal Orientations: (i) highly extrinsically motivated (Cluster 3) and (ii) weakly extrinsically motivated (Cluster 1). The last group (Cluster 2) comprises students with plain specific preferences for all Pre-test scales.

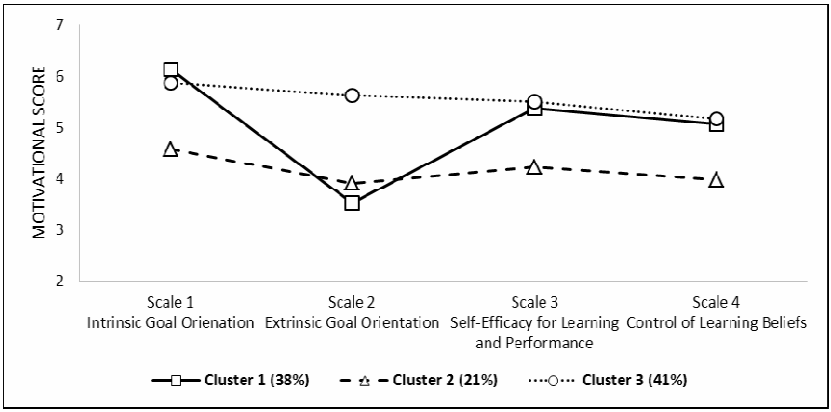

Fig. 05. Cluster analysis of Pre-test data (final cluster centers).

Fig. 06 shows that the cluster layering of the Post-test data is more distinct and the three groups of students can be clearly distinguished. The most participants reported high (Cluster 3) or medium (Cluster 1) preferences for all of the Post-test scales. Only 3% of them (Cluster 2) reported almost none specific preference for all scales.

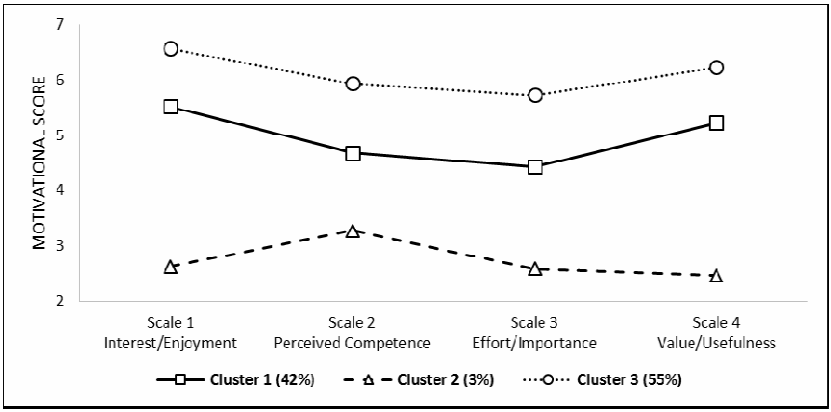

Fig. 06. Cluster analysis of Post-test data (final cluster centers).

Understanding the activities and students' perception of their MBL performing

The complete set of data related to this sub-topic can be seen in Tab. 03. After each of the performed activities most of the students declared that they understood the activity objectives (A: 95.7%, B: 98.6%, D: 100.0%, D: 100.0%). The students usually answered that they strongly agree (1) or agree (2) with the declarative clause in the Item 1. However, after listing the objectives (Item 2), the differences between the particular activities appeared and not all of them were satisfying. In activities C and D more than 80% of respondents listed the correct or more or less correct answers. On the other hand, the objectives of the other two activities (A and B) are probably not so clear for students as only about half of them reported correct or more or less correct answers. Furthermore, in these activities there is an anxious number of students reporting totally erroneous answers (A: 31.8% and B: 44.8%).

Tab. 03. Students' answers to the selected items of the questionnaire administered after performing the activities (M - mean value; S – score; T – total; V% - valid percent; C% - cumulative percent).

Item \ Activity	A (Yeast & Fermentation) N = 47				B (Seed Germination) N = 73				C (ECG) N = 73				D (Blood Pressure) N = 73			
	M	S	V%	C%	M	S	V%	C%	M	S	V%	C%	M	S	V%	C%
1. I understood the objectives of the activity	1.32	1	74.5	74.5	1.30	1	71.2	71.2	1.25	1	75.3	75.3	1.26	1	74.0	74.0
	± .62	2	21.3	95.7	± .50	2	27.4	98.6	± .43	2	24.7	100.0	± .44	2	26.0	100.0
		3	2.1	97.9		3				3				3	100.0	
		4	2.1	100.0		4	1.4	100.0		4				4		
		T	100.0			T	100.0			T	100.0			T		
2. List the objectives of the activity	2.19	1	45.5	45.5	2.63	1	16.4	16.4	1.96	1	37.0	37.0	1.26	1	80.6	80.6
	±1.41	2	6.8	52.3	±1.36	2	25.4	41.8	±1.00	2	45.2	82.2	± .89	2	7.5	88.1
		3	15.9	68.2		3	13.4	55.2		3	2.7	84.9		3	6.0	94.0
		4	31.8	100.0		4	44.8	100.0		4	15.1	100.0		4	6.0	100.0
		T	100.0			T	100.0			T	100.0			T	100.0	
3. I needed my Teacher's help to understand the activity	2.74	1	10.6	10.6	2.89	1	4.1	4.1	3.11	1	4.1	4.1	3.01	1	5.5	5.5
	± .91	2	25.5	36.2	± .84	2	28.8	32.9	± .77	2	12.3	16.4	± .80	2	15.1	20.5
		3	42.6	78.7		3	41.1	74.0		3	52.1	68.5		3	52.1	72.6
		4	21.3	100.0		4	26.0	100.0		4	31.5	100.0		4	27.4	100.0
		T	100.0			T	100.0			T	100.0			T	100.0	
4. It was easy to collect data by means of MBL approach	1.38	1	63.8	63.8	1.30	1	71.2	71.2	1.33	1	69.9	69.9	1.32	1	68.5	68.5
	± .53	2	34.0	97.9	± .49	2	27.4	98.6	± .52	2	27.4	97.3	± .46	2	31.5	100.0
		3	2.1	100.0		3	1.4	100.0		3	2.7	100.0		3		
		4	100.0			4	100.0			4				4		
		T				T				T	100.0			T	100.0	
5. MBL approach helped me to interpret the results (e.g. graphs) correctly	1.21	1	78.7	78.7	1.37	1	63.0	63.0	1.51	1	50.7	50.7	1.49	1	56.2	56.2
	± .41	2	21.3	100.0	± .48	2	37.0	100.0	± .53	2	47.9	98.6	± .60	2	38.4	94.5
		3				3				3	1.4	100.0		3	5.5	100.0
		4				4				4				4		
		T	100.0			T	100.0			T	100.0			T	100.0	
6. I think the activity could be done without MBL	2.55	1	10.6	10.6	3.00	1	5.5	5.5	2.64	1	15.1	15.1	1.26	1	24.7	24.7
	± .87	2	38.3	48.9	± .79	2	15.1	20.5	± .96	2	24.7	39.7	± .44	2	37.0	61.6
		3	36.2	85.1		3	53.4	74.0		3	41.1	80.8		3	27.4	89.0
		4	14.9	100.0		4	26.0	100.0		4	19.2	100.0		4	11.0	100.0
		T	100.0			T	100.0			T	100.0			T	100.0	

At least 16.4% of the students reported a need of their tutor's help (Item 3). However, the level of such help is different for particular activities. From this point of view, it seems that activities A and B needed to be led by a tutor more frequently than the other two activities (notice a probable relation to the results of Item 2). On the other hand, about 60 to 80% of students didn't need their teacher's help.

Students clearly claimed that it was easy to collect data by means of MBL (Item 4) and MBL helped them in interpreting the results (Item 5). In the first three activities more than half of participants think that they couldn't be done without MBL (A: 51.1%; B: 79.4% and C: 60.3%). Reversely, in the last activity students probably know from their home or a hospital experience that for blood pressure measuring an MBL approach is not necessary.

Conclusion

In conclusion, recognizing the level of students' motivational orientation is needed not only to know the student's interest in performing the MBL activities but also to find out whether the students are competent in filling in the questionnaires used to evaluate the activity tasks (chapter 2.2). We presumed that adequately motivated students are more engaged to the entire process and put more effort to complete the experimental tasks but also to complete the questionnaires. Their answers can be then considered more relevant and valuable for subsequent revision of the activities.

We found out that mainly initial motivational orientations strongly depend on particular school attended by a student and only weakly depend on gender. Moreover, similarly to study devoted to activities for Chemistry [Skoršepa et al., 2013] we didn't reveal a significant effect of particular activity on the motivational orientations. This is in contradiction with our previous study [Urban-Woldron at al., 2013] where Chemistry and Physics activities were processed together. However, we suppose that such dependence is more related to variance disparities between the subjects than inside them. According to our separate findings from Chemistry and Biology, we believe that when a single subject is taken into account, no significant evidence of relationship between the particular activity and motivational orientation appears.

The most of the students reported that they understood the activities. However, after deeper investigation diverse level of understanding was confirmed. Knowing that the revision of activities needs to make them comprehensible for the majority of students, it is our task to pay attention mainly to the activities calling for improvement (activity A and B).

The data from our research is still in progress and needs further processing. It will also be important to compare the Slovak data to the results of the other countries participating in the project. However, the partial results suggest the acquisition of MBL approach to the education with experimental background.

References:

McAuley, E., Duncan, T., Tammen, V. V. (1989). Psychometric properties of the Intrinsic Motivation Inventory in a competitive sport setting: A confirmatory factor analysis. Research Quarterly for Exercise and Sport, 60, 48-58.

Pintrich, P. R. et al. (1991). A manual for the use of the Motivated Strategies for Learning Questionnaire (MSLQ). Michigan (US): Ann Arbor, National Centre for Research to Improve Postsecondary Teaching and Learning, 76 p.

Skoršepa, M., Tortosa Moreno, M., Urban-Woldron, H., Stratilová Urválková, E. (2013). Implementácia aktivít do vyučovania v počítačom podporovanom laboratóriu na stredných školách. In: Proceedings of the Conference "Súčasnosť a perspektívy didaktiky chémie III, Donovaly 2013". Banská Bystrica: Fakulta prírodných vied UMB, 78-83.

Urban-Woldron, H., Tortosa Moreno, M., Skoršepa, M. (2013). Implementing learning with sensors in science education: Students' motivational orientations toward using MBL. In C. P. Constantinou, N. Papadouris & A. Hadjigeorgiou (Eds.), E-Book Proceedings of the ESERA 2013 Conference: Science Education

Research For Evidence-based Teaching and Coherence in Learning. Part 4. Nicosia, Cyprus: European Science Education Research Association, 165-171. ISBN: 978-9963-700-77-6.

White, R. T., Gunstone, R. F. (1992). Probing Understanding. Great Britain: Falmer Press.

Acknowledgement:

We thank students and teachers who have implemented the activities. This work has been supported by 517587-LLP-1-2011-1-ES-COMENIUS-CMP.

Marek Skoršepa[1], Eva Stratilová Urválková[2], Petr Šmejkal[2],

Montserrat Tortosa Moreno[3], Hildegard Urban-Woldron[4]

[1] - *Matej Bel University, Banská Bystrica (Slovakia),*

[2] - *Charles University, Prague (Czech Republic),*

[3] - *Universitat Autònoma de Barcelona (Spain),*

[4] - *University for Teacher Education Lower Austria, Vienna (Austria)*

Marek.Skorsepa@umb.sk