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NEW IBSE ORIENTED ACTIVITIES FOR BIOLOGY – DESIGN AND EVALUATION

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Abstract

The contribution presents results from testing six newly-designed biology activities developed within the European project COMBLAB that focuses on microcomputer based laboratories. Refined didactic sequence of activities follows predict-observe-explain concept and inquiry based science education approach. Students filled in four scales pre- and post-test on their motivation. The data from questionnaires were analysed according to gender, particular activity and participating school. The paper presents results from the Czech Republic, a partner that is the author of biology activities. The data show statistically differences in all three aspects: male students have higher (positive) score comparing to female students; the most favourite activity among students was measuring ECG, the least valued Seed germination. The results also differ by school, or teacher respectively. Participating students from three secondary schools (n = 278), can be divided into three clusters according to their motivation.

Keywords

Microcomputer-based laboratory (MBL). Probeware. Inquiry-Based Science Education (IBSE). Predict-Observe-Explain concept (POE). Biology education. Scientific competences. Motivation.

INTRODUCTION

Laboratories using probeware, called microcomputer based laboratories (MBL), or computer based laboratories, are showing to be very effective tool in science education as it provides a real-time measurement, illustratively demonstrates wide range of phenomena, processes, scientific procedures etc., and has a positive educational impact. For example, employment of MBL in education enhances the acquisition of scientific competencies (Tinker, 1996). Basically, probeware is a set of various sensors which enable a wide range of different measurements unified by a common way of connection of sensors, data measurement and treatment.

In this contribution, we present some results of 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: (1) Universitat Autònoma de Barcelona (Spain), (2) Charles University in Prague (Czech Republic), (3) University for Teacher Education Lower Austria, Vienna (Austria), (4) Universitat de Barcelona (Spain), (5) University of Helsinky (Finland) and (6) 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 MBL in science subjects, namely physics, chemistry and biology. In this contribution, we focused our attention on motivational orientations of Czech students participating in biology activities.

METHODS

The biology activities prepared in the framework of COMBLAB project were designed to follow guided IBSE characteristics and POE (predict-observe-explain) sequence. Each activity is introduced through motivational introduction (mostly story related to a measured/observed/studied phenomena) which explains a problem that should be solved by students. Then, students should design their experiments to solve the problem, predict results, perform the measurements and interpret the results. Important part of the activities is devoted to communication of the results and solution of the problem. In more detail, the design of activities is presented in contribution by Stratilová Urválková et al. (2014).

Two evaluating tools for motivational orientations (Pintrich et al., 1991; McAuley et al., 1989) were administered to students before and after performing of each activity. The data and results presented in this paper were obtained during the implementation of biology activities in Czech Republic. The study follows our recent work in the field – an implementation of analogous activities for chemistry, and the same biology activities in Slovakia (Skoršepa et al., 2014).

The research in Czech Republic included 278 students (177 female; mean age = 16.0 years, SD = 0.82) from three secondary schools: Masaryk Secondary School of Chemistry (n = 117), Gymnasium Třinec (n = 146) and Malostranské Gymnasium (n = 15). Some students performed more than one activity, therefore totally 327 evaluations were acquired. All the evaluations were performed in participating schools in their laboratories and by participating teachers of the particular schools.

Motivational Orientations of Students toward working with 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:

1) *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).

2) *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).

RESULTS

The presented results arose from the testing and evaluation of six newly designed biology activities: (1) The life of yeast (Yeast & Fermentation); (2) Plants and oxygen (Photosynthesis); (3) Predator plants (Eutrophication); (4) Wake up, wake up, it's time to get up! (Seed Germination); (5) What makes your heart beat? (ECG) and (6) Nursie, the pressure! (Blood Pressure).

Motivational orientations of students

Table 1 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 clear that the internal consistency of the response in the individual stages is basically acceptable in all eight cases, although two of them (Pre-test scales 2 and 4) are on the edge of acceptability.

Table 1: 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	.87
2 Extrinsic Goal Orientation	.70	2 Perceived Competence	.82
3 Self-Efficacy for Learning and Performance	.73	3 Effort/Importance	.80
4 Control of Learning Beliefs	.69	4 Value/Usefulness	.79

Correlation analysis shows strong relationship mainly within the post-test scales (Table 2) corresponding to the fact that they all relate to intrinsic motivation and self-regulation.

Table 2: Correlation matrix (Spearman) for motivational orientation

	Scale	Pre1	Pre2	Pre3	Pre4	Post1	Post2	Post3	Post4
Pre1	Intrinsic Goal Orientation	1							
Pre2	Extrinsic Goal Orientation	.186**	1						
Pre3	Self-Efficacy for Learning and Performance	.551**	.297**	1					
Pre4	Control of Learning Beliefs	.524**	.238**	.369**	1				
Post1	Interest/Enjoyment	.442**	.187**	.320**	.311**	1			
Post2	Perceived Competence	.373**	.291**	.422**	.268**	.653**	1		
Post3	Effort/Importance	.475**	.314**	.347**	.258**	.622**	.616**	1	
Post4	Value/Usefulness	.510**	.241**	.363**	.377**	.785**	.629**	.628**	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 on the basis of analysis of variance (ANOVA).

Motivational orientations showed to be dependent on gender and partially on particular school/teacher (see Table 3). In the case of gender, strong statistically significant difference was found in the pre-test scales, except the *extrinsic goal orientation*. In other three scales males reached statistically significant higher scores: scale of *Intrinsic Goal Orientation* ($F(1,325) = 11.381$, $p = .001$; $M_{male} = 4.92$, $SD = 1.10$, $M_{female} = 4.50$, $SD = 1.22$), the most significant difference was in scale *Self-Efficacy for Learning and Performance* ($F(1,325) = 23.973$, $p = .000$; $M_{male} = 4.61$, $SD = 1.11$, $M_{female} = 4.06$, $SD = .92$), and *Control of Learning Beliefs* ($F(1,325) = 8.348$, $p = .004$; $M_{male} = 4.69$, $SD = 1.06$, $M_{female} = 4.36$, $SD = .99$). This difference can be probably attributed to technical preferences of boys, who can be motivated by work with probeware. In the case of post questionnaires, strong statistically significant difference was revealed in all studied scales: *Interest/Enjoyment* ($F(1,325) = 14.017$, $p = .000$; $M_{male} = 4.31$, $SD = 1.30$, $M_{female} = 4.77$, $SD = 1.27$), *Perceived Competence* ($F(1,325) = 13.631$, $p = .000$; $M_{male} = 5.15$, $SD = 1.27$, $M_{female} = 4.65$, $SD = 1.16$), *Effort/Importance* ($F(1,325) = 4.477$, $p = .035$; $M_{male} = 5.17$, $SD = 1.12$, $M_{female} = 4.91$, $SD = 1.10$), and *Value/Usefulness* ($F(1,325) = 9.309$, $p = .002$; $M_{male} = 5.27$, $SD = 1.11$, $M_{female} = 4.88$, $SD = 1.19$). Mean values of boys were more positive that of girls which, similarly to pre-test, can be attributed to higher technical preference of boys.

Table 3: Statistical significances generated by three different factors (pre- and post-test)

	Scale	Gender	School	Activity
Pre1	Intrinsic Goal Orientation	.001	.000	.204
Pre2	Extrinsic Goal Orientation	.152	.413	.487
Pre3	Self-Efficacy for Learning and Performance	.000	.491	.648
Pre4	Control of Learning Beliefs	.004	.018	.893
Post1	Interest/Enjoyment	.000	.000	.000
Post2	Perceived Competence	.000	.274	.004
Post3	Effort/Importance	.035	.001	.010
Post4	Value/Usefulness	.002	.000	.000

Difference between groups is significant at the 0.05 level.

Second studied aspect was particular activity. No significant differences evinced the pre-test analysis. Although not confirmed by the analysis, in Figure 1 can be seen some differences in the extrinsic goal orientation and self-efficacy for learning and performance, where mean values for Blood pressure activity reach higher values, which indicates higher expectation in the case of this activity. We presume that it is not surprising to obtain the data with no significant differences in pre-test because before experiment

students don't know the content of activities (their specifics and backgrounds) in detail.

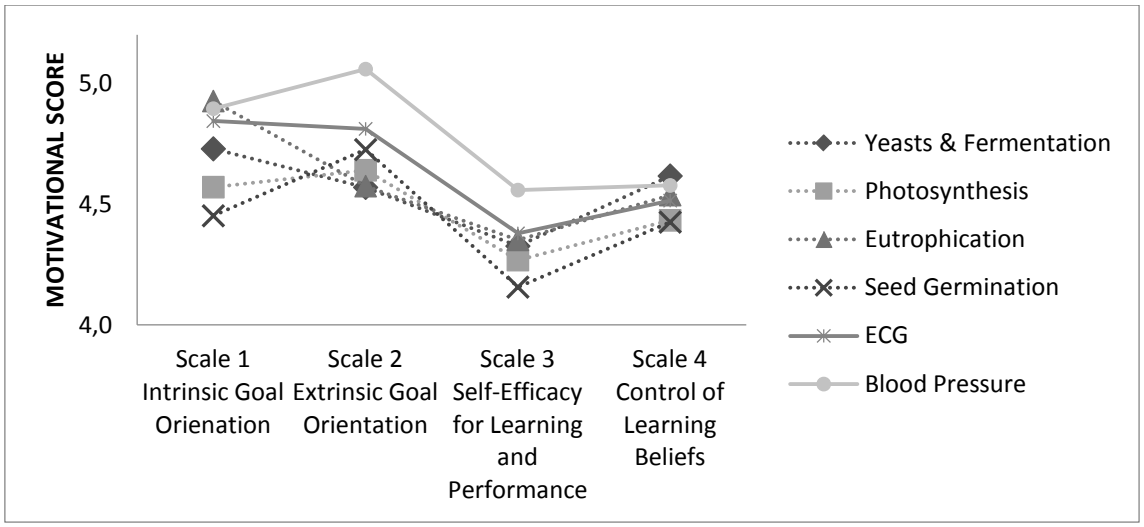

Figure 1: Motivational orientations before performing the particular activity (mean values)

On the contrary, the differences in mean values in post-test scales are more notable, their variances are also significantly different (ANOVA), as apparent from Figure 2. The analysed data show differences in all four scales: *Interest/Enjoyment* ($F(5,322) = 5.888$, $p = .000$; $M_{1yeast} = 5.34$, $SD = 1.23$, $M_{2photo} = 4.75$, $SD = 1.42$, $M_{3eutro} = 4.67$, $SD = 1.11$, $M_{4germi} = 4.55$, $SD = 1.24$, $M_{5ECG} = 5.51$, $SD = 1.05$, $M_{6press} = 5.08$, $SD = 1.68$), *Perceived Competence* ($F(5,322) = 3.501$, $p = .004$; $M_{1yeast} = 4.94$, $SD = 1.12$, $M_{2photo} = 4.84$, $SD = 1.22$, $M_{3eutro} = 4.88$, $SD = 1.03$, $M_{4germi} = 4.46$, $SD = 1.32$, $M_{5ECG} = 5.32$, $SD = 1.15$, $M_{6press} = 4.75$, $SD = 1.42$), *Effort/Importance* ($F(5,322) = 3.059$, $p = .010$; $M_{1yeast} = 5.17$, $SD = 1.10$, $M_{2photo} = 4.67$, $SD = 1.23$, $M_{3eutro} = 5.06$, $SD = 1.03$, $M_{4germi} = 4.89$, $SD = 1.01$, $M_{5ECG} = 5.35$, $SD = 1.10$, $M_{6press} = 4.98$, $SD = .99$), and *Value/Usefulness* ($F(5,322) = 5.564$, $p = .000$; $M_{1yeast} = 5.54$, $SD = .94$, $M_{2photo} = 4.71$, $SD = 1.40$, $M_{3eutro} = 4.85$, $SD = .88$, $M_{4germi} = 4.78$, $SD = 1.11$, $M_{5ECG} = 5.31$, $SD = 1.00$, $M_{6press} = 4.89$, $SD = 1.35$). Studying the visualized data in Figure 2, we can declare, not all the activities were attractive for all the students at the same level. ECG activity was evaluated as the most attractive, together with Yeast and fermentation activity. We speculate that the reason can be that these activities are relatively simple, comprehensible and not very complicated to design. The ECG activity is also oriented to physiological states of body, which can be a motivational factor. On the other hand, the activity on Germination was not very interesting for students. This activity is more demanding for students to design the experiment, to estimate the factors influencing the experiment and relatively

time consuming. Also, this activity is more open IBSE oriented than the others. This is probably the main reason of low scores for this activity in post-tests. The Czech students do not use the IBSE approach very much in schools and they are more familiar with instructed laboratories and teacher oriented education. However, post-test scales for all activities as in most cases their mean motivational scores are not lower than four.

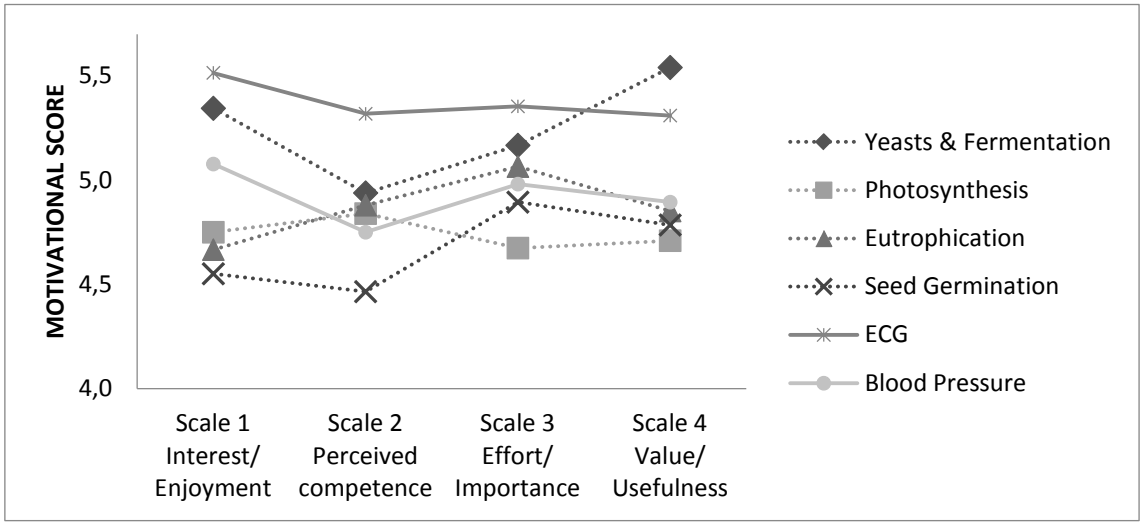

Figure 2: Motivational orientations after performing the particular activity (mean values)

The significant difference was revealed also in third aspect of particular school (or teacher). In pre-test the differences were found in scale of *Intrinsic Goal Orientation* ($F(2,324) = 9.803$, $p = .000$; $M_{sch1} = 4.86$, $SD = 1.10$, $M_{sch2} = 4.60$, $SD = 1.00$, $M_{sch3} = 3.62$, $SD = 1.74$) and *Control of Learning Beliefs* ($F(2,324) = 4.094$, $p = .018$; $M_{sch1} = 4.63$, $SD = 1.04$, $M_{sch2} = 4.42$, $SD = 1.04$, $M_{sch3} = 3.94$, $SD = 1.20$). Figure 3 further shows that students from school 1 and 2 have similar mean score (school 1 a bit higher) in all four scales, but students from school 3 had a quite small intrinsic goal orientation before performing the activity; they had in opposite the highest mean value in scale of extrinsic goal orientation.

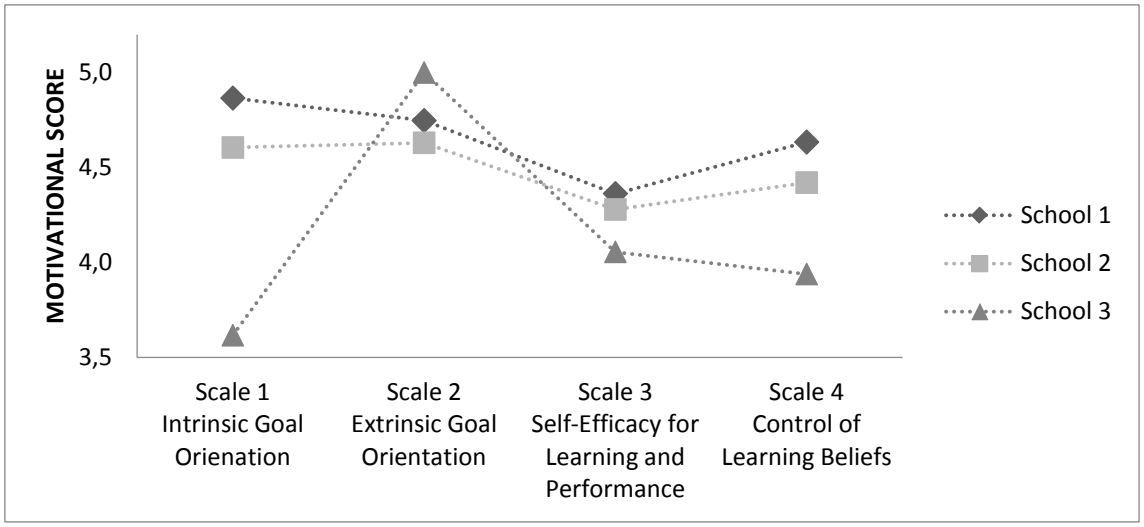

Figure 3: Pre-test motivational orientations of students related to the particular school (mean values)

The post-test analysis showed significant differences in all scales except *Perceived Competence* (Figure 4). The strong differences can be found in evaluating value and usefulness by students from different schools: *Interest/Enjoyment* ($F(2,324) = 9.276$, $p = .000$; $M_{sch1} = 5.28$, $SD = 1.29$, $M_{sch2} = 4.81$, $SD = 1.27$, $M_{sch3} = 4.10$, $SD = 1.37$), *Effort/Importance* ($F(2,324) = 7.118$, $p = .001$; $M_{sch1} = 5.1$, $SD = 1.04$, $M_{sch2} = 5.04$, $SD = 1.13$, $M_{sch3} = 3.99$, $SD = 1.39$), and *Value/Usefulness* ($F(2,324) = 17.705$, $p = .000$; $M_{sch1} = 5.31$, $SD = 1.04$, $M_{sch2} = 4.90$, $SD = 1.14$, $M_{sch3} = 3.65$, $SD = 1.58$). Still, the school 3 reached the lowest score, below indifferent value 4.

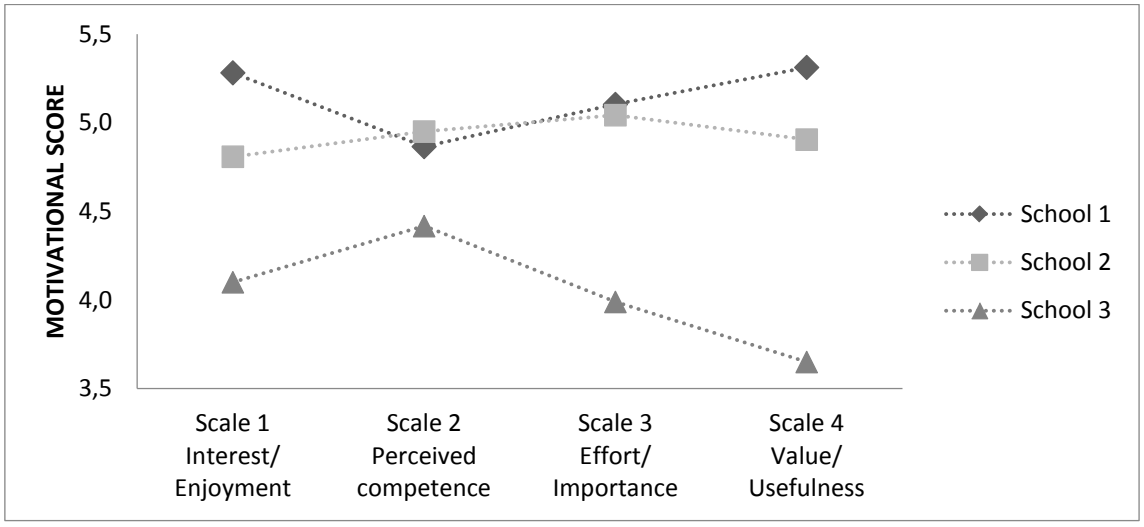

Figure 4: Post-test motivational orientations of students related to the particular school (mean values)

The differences can be explained in discussion of various aspects: first can be specialization of the school – school 1 with the highest mean values is a vocational school oriented to chemistry and two other schools in testing are general secondary schools. Second aspect is the particular activity: students from school 3, with the lowest mean score, were the youngest students from the sample (age 14) and they performed activity photosynthesis, which sometimes brings problematic results that have to be discussed with teacher. And the third important aspect is teacher him/herself who motivates and facilitates students during the activity. On the other hand, the difference between school 1 and school 2 is not as big as in the case of school 2 and 3. To evaluate an influence of the particular school deeper, higher number of schools should be taken into evaluation.

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 centres that can be seen in Figure 5. The analysis shows that 62 % of participants (23 % of Cluster 1 plus 39 % of Cluster 3) report high scores in Intrinsic Goal Orientation. The graphs of Clusters 1 and 2 are virtually identical, except that the score in the cluster 1 is of almost two points lower in average. Clusters 2 and 3 report almost identical high level of Intrinsic Goal Orientation but they differ considerably in Extrinsic Goal Orientation; the values for Self-Efficacy for Learning and Control of Learning Believes scales are comparable. The Figure 5 also shows that 23 % students in Cluster 1 has indifferent or lower score in pre-test scales, below neutral value 4, which means that a quarter of students in evaluation was not enough motivated, or may have been sceptical.

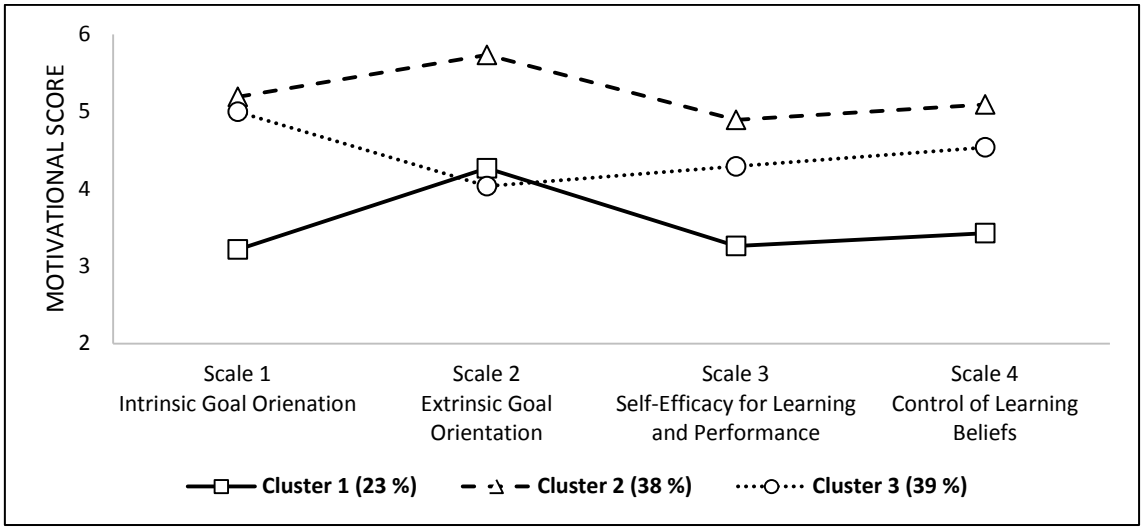

Figure 5: Cluster analysis of Pre-test data (final cluster centres)

Figure 6 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 (79 %) reported high (Cluster 2) or medium (Cluster 3) preferences for all of the post-test scales. Yet about 20 % preferences of participants are below average in all scales (Cluster 1).

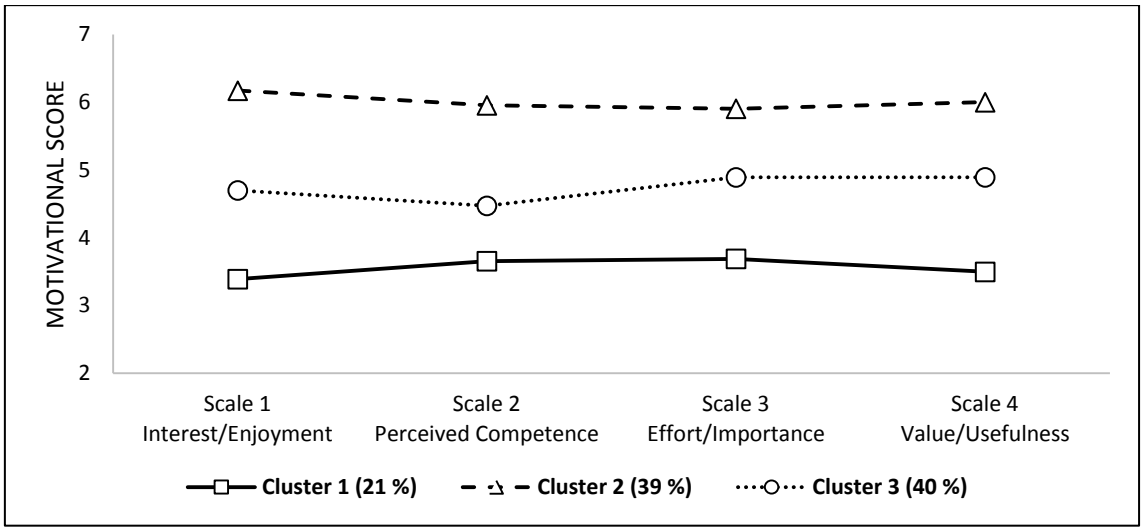

Figure 6: Cluster analysis of Post-test data (final cluster centres)

CONCLUSION

A set of six biology activities has been prepared and evaluated. The activities were prepared with respect to IBSE (inquiry based science education) and POE (predict-observe-explain) characteristics. The activities are: The life of Yeast (Yeast & Fermentation); Plants and oxygen

(Photosynthesis); Predator plants (Eutrophication); Wake up, wake up, it's time to get up! (Seed Germination); What makes your heart beat? (ECG) and Nursie, the pressure! (Blood Pressure).

We found out that motivational orientations of Czech students participating in study strongly depend on gender, particular on school attended (5 of 8 scales) and on conducted activity (all the post-test scales). This is in agreement with previous study (Urban-Woldron at al., 2013) where Chemistry and Physics activities were processed together. The higher scores in the case of boys could be attributed to their technical preferences in studied group.

The ECG activity has been recognized as the most attractive for participating students, followed by the Yeast & Fermentation activity. On the other hand, activity focused on Germination was not very attractive for students. We speculate that while the attractive activities are relatively simple with broad and clear ways of investigation, the activity on germination is more difficult to design the experiment and interpret the results, which demotivates students to solve the problem. The Czech students are also not very well trained in IBSE, which can cause problems in following learning path leading to demotivation.

We can summarize that there is quite a substantial group of participants (Cluster 2,38 %) with high motivation both intrinsic and extrinsic. In the case of intrinsic motivation alone, we found a high score even for 62 % of the participants (23 % of Cluster 1 and 39 % of Cluster 3). On the other hand, one fourth of students belong to cluster with quite low motivation before performing the activity and the number after performing the activity increases just to one fifth of the students. The reason might be weak motivation by the teachers, but this hypothesis must be supported by other study or at least research method.

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