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PRESENTATION OF LABORATORY SESSIONS FOR SCIENCE SUBJECTS IN SLOVENIAN UPPER SECONDARY SCHOOLS

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Abstract. *Among Slovenian upper secondary school science teachers a study was conducted about the implementation of laboratory work in Science teaching. One of the specific goals was to acquire preliminary data about the status of laboratory exercises in teaching Biology, Chemistry and Physics. Answers were received from 64 Biology teachers, 64 Chemistry teachers and 63 Physics teachers (about 40% of Slovene secondary school Science teachers).*

The differences in attitudes towards and performance of laboratory work among teachers of different Science subjects are small. It can be concluded that teachers of all three subjects have generally positive attitudes towards laboratory work. The differences occur in the way laboratory work is performed. Not so positive are the findings that many of the exercises are presented to the students as demonstrations, and an expository style is preferred. In the future, efforts should be made to transform expository labs into inquiry- and problem-based laboratory work.

Key words: *laboratory work, science education, upper secondary schools, teachers' attitudes.*

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Introduction

Recently two opposite processes concerning Science in human society have been witnessed. Knowledge and technology based on research in science and technology have grown progressively, but interest among students in such disciplines has declined (Osborne et al., 2003, Baram-Tsabari & Yarden, 2009; Lamanauskas & Augiene, 2009). Slovenia is no exception to this rule; in fact, attitudes towards Science are even more negative than in other parts of the world (Gabršček et al., 2005) and are worsening (Svetlik et al., 2008). Schools cannot be blamed as the sole reason for this decline but have to take their share of responsibility, which can lie both in the topics covered by the syllabus and in the way these are taught (Duggan & Gott, 2002; Hodson, 2003; Jenkins, 2003; Tranter, 2004; DiCarlo, 2009; Lamanauskas, 2009). From the science teachers' viewpoint, this should mean that if they want to stop the decline in student interest in science, they have to prepare lessons in such a way as to confirm students' interests and preferences (Chang et al., 2009; Bilek, 2010; Kubiatko et al., 2010). On the other hand, a change in teaching strategies towards popularity should not result in a lower quality of knowledge being achieved with such methods (Chalkiadaki, 2009). On the contrary, the highest educational standards should lead learners towards the development of competences for lifelong learning and solving problems unknown at the time of their education (Dean & Kuhn, 2006; Illeris, 2008).

One can hardly claim that Slovenian science teaching is oriented towards problem solving or applicability of learned content. From the results of international studies like TIMMS and PISA and a review of Slovenian studies (Glažar & Devetak, 2010; Strgar, 2010), it can be concluded that the knowledge gained by Slovenian students is more academic than practical, that they are good at reciting facts but find it difficult to apply these in new settings or to transfer knowledge between subjects or to out-of school situations. Recognized reasons for the unpopularity of science subjects and underachievement of higher educational goals include the following: topics covered in the syllabus are highly academic and fragmented among different subjects; lectures form the dominant method of school instruction, are barely connected to students' everyday experiences or interests and greatly influenced by the demands of the Matura examinations (Ivanu Grmek & Javornik Krečič, 2004, Bajd & Artač 2002, Šorgo & Kocijančič 2006, Šorgo et al., 2007, Šorgo et al., 2011).

If it is accepted that direct instruction or adding new content cannot change trends towards better achievement in making science popular, then contemporary teaching practices need to be changed. From this perspective, laboratory and experimental work should be considered as one of the cornerstones in teaching Science, because through such work it is simultaneously possible to achieve the highest cognitive levels of knowledge and to acquire many skills unlikely to be achieved with other methods (e. g., manipulative skills); moreover, students generally have positive attitudes towards laboratory work (Hofstein & Lunetta, 2004; Michael, 2001, 2006; Šorgo, 2007; Šorgo et al, 2008; Tomažič, 2008; Šorgo & Špernjak, 2009; Abrahams, 2009; Strgulc Krajšek & Vilhar, 2010).

The impetus behind the study was to survey the state of performance of laboratory work in Biology, Chemistry and Physics, and the attitudes of teachers towards such work. The results and possible differences between teachers of science subjects are planned for use in pre-service and in-service teacher training. The research questions were as follows:

1. What are the main sources of teachers' manuals used in the school laboratory?
2. Which style of laboratory work prevails?
3. How often do teachers include laboratory work in their teaching practice?
4. What are teacher's attitudes towards laboratory work?
5. Can teachers of Biology, Chemistry and Physics be recognized as part of a single teaching culture (Shuell 1992)?

Methodology of Research

Science Education in Slovenian Schools

In Slovenian 9-year compulsory basic school (two 3-year primary cycles and one 3-year lower secondary cycle), Science topics are integrated into various subjects until the 6th and 7th year of schooling, where they are taught as a subject called Science. In the last two years of lower secondary schooling, Biology, Physics, and Chemistry are taught as separate subjects. In upper secondary schools the destiny of Science subjects largely depends on the type of school. In the general upper secondary programme (a 4–year academic programme), Biology, Physics, and Chemistry are compulsory, each occupying 210-academic hours in the first three years for all students. If a student chooses such a subject as one of their Matura subjects, then they have to take an additional 140-hour course. In technical (4-year programmes) and vocational schools (3-year programmes), the diversity (both in topics and number of academic hours) in Science teaching is greater. In some schools the topics are again integrated into various Science and Technology subjects, but in some schools (nursery, biotechnology or food science, machinery, etc.) these are taught as Biology, Physics or Chemistry with differing numbers of lesson hours. More detailed information about the school system of Slovenia is available online (Education in Slovenia).

Sample Selection

The community of Slovenian upper secondary school science teachers is rather small (about 500 teachers), with about 150 teachers teaching each of the major science subjects (Biology, Chemistry, Physics). Questionnaires were addressed to all Slovenian secondary schools, and 207 respondents answered: 64 Biology teachers; 64 Chemistry teachers, 63 Physics teachers, and 16 from teachers of other subjects, teaching assistants, or ICT support staff (Šorgo et. al. 2007). Owing to its heterogeneity, the

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last group was omitted from further analysis. Exact numbers are not available, so the estimation is that questionnaires were collected from about 40% of Slovenian upper secondary school science teachers. The teachers from the sample taught in general secondary schools (107; 56%), technical schools (72; 37.7%), and vocational schools (12; 6.3%). The type of school was later not used as a dividing criterion for the statisical analyses because there was an insufficient number of respondents from each subject falling into each category to allow appropriate statistical analysis.

Statistically significant differences among teachers of different subjects were not found by age, or number of working years in school, although gender was an exception ($\chi^2 = 53.37$, df = 2, p = 0.000) (Table 1).

Table 1. Gender structure of the sample.

		Subject			
		Biology	Chemistry	Physics	Total
Gender	Male	6	8	39	53
	Female	57	54	24	135
Total		63	62	63	188

On average, the teachers had 17 years of teaching experience, and were 44 years old. About 90 % of Biology and 87 % of Chemistry teachers in our sample are women, and it seems that Physics is the last general high school Science subject where women are outnumbered by men (61 %) (Table 1).

Instrument and Procedures

In order to establish secondary school Science teachers' perspectives on and attitudes towards laboratory work in Biology, Chemistry and Physics, a questionnaire was constructed. The questionnaire was divided into four parts and was completed anonymously.

The first part of the instrument was based on the assumption that teachers in Slovenia are not autonomous in choosing teaching content but are autonomous in choosing the methods and sources of information to achieve the intended curricular goals. The intention of this part was to discover the dominant sources for manuals used in the school laboratory; it consisted of a single question: 'How often do you use different sources of manuals for laboratory exercises?', followed by the 7 items listed in Table 2. Teachers were asked to answer using a six-point scale (1 – do not use; 2– rarely; 3 – up to a quarter; 4 – between one quarter and a half; 5 – between a half and three quarters; 6 – more than three quarters). The six-point scale was constructed to allow quantification of results and make comparison easier between teachers of different subjects using means and standard deviations to show a tendency.

The second part of the instrument was about instructional styles of laboratory work. The intention was to identify the dominant instructional styles used in laboratory practice because achievement, especially in the higher cognitive domains (Krahtwohl, 2001), can depend on the style used. The categories employed were as follows (Table 3):

1. Step-by-step manuals with defined goals, lists of materials, pictures of the apparatus, and defined forms (tables, graphs, etc.) for presentation and analysis of results.
2. Step-by-step manuals with defined goals, lists of materials, pictures of the apparatus, without defined forms (tables, graphs, etc.) for presentation and analysis of results.
3. Short manuals with defined goals and a list of materials.
4. Problem-based laboratory work, where students are involved in planning the experiment.
5. As a demonstration. Students get information about the experiment; the experiment is demonstrated by a teacher. Students are obliged to write down results and make an analysis.

Teachers were asked to answer using a similar six-point scale (1 – do not use; 2– rarely; 3 – up to a quarter; 4 – between one quarter and a half; 5 – between a half and three quarters; 6 – more than three quarters) as used in the first part of the instrument.

In the third part of the instrument, interest lay in establishing the share of laboratory exercises among all lessons performed by teachers. Slovenian teachers are autonomous in choosing methods, and the titles of laboratory exercises are more often suggested than prescribed by their syllabi, with a lower limit of 30 % of lessons to be performed as laboratory work. To allow comparison between different subjects, a relative seven-point scale was constructed (Table 4), and teachers answered by circling one option. The options were as follows:

1. More exercises are performed than prescribed by the syllabus.
2. All prescribed exercises are performed.
3. More than three-quarters of prescribed exercises are performed.
4. Between three-quarters and half of the prescribed exercises are performed.
5. Between half and a quarter of prescribed exercises are performed.
6. Less than a quarter of the prescribed exercises are performed.
7. I do not perform laboratory exercises.

The fourth part of the instrument was a twenty-item (Table 5) closed questionnaire using a five-point Likert scale (5 – strongly agree, 4 – agree, 3 – neutral, 2 – disagree, 1 –strongly disagree). The intention of the questionnaire was to measure attitudes towards laboratory activities and compare differences between Biology, Chemistry and Physics teachers. The questionnaire has a reliability of 0.806 measured as Cronbach's alpha. The questionnaire was assembled in such a way that disagreement with the statement reflects a positive attitude towards it. To prevent automatism, four statements (marked with an asterisk in Table 5) were posted and later coded in the opposite direction.

Data Analysis

The data analysis was carried out with the statistical software SPSS® 17.0. The Mann-Whitney and Kruskall-Wallis non-parametric tests were used to identify differences in frequencies of answers. To make parallel comparisons of the differences in means among different groups of teachers, the F –test was performed, showing generally the same pattern as the nonparametric tests. Data were tested for normal distribution with the Kolmogorov-Smirnov test and showed that all the variables did not follow normal distribution at the level of $p<0.01$. Owing to the distribution of data, only means and outcomes of the non-parametric test are reported in the tables. Correlations between groups of teachers are reported as Pearson's correlation coefficient. Exploratory factor analysis was performed using Principal Component Analysis as the extraction method and Varimax with Kaiser Normalisation as the rotation method (Lavonen et al.2003). Cronbach's alpha was used to test the reliability of the questionnaire. The Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO = 0.798) and Bartlett's Test of Sphericity (Sig = 0.000) were performed to test the adequacy of the data for factor analysis. From the calculated means and the highly correlated answers concerning attitudes, it was concluded that teachers of all three subjects can be treated as single group.

Results of Research

Source of Manuals for Laboratory Exercises

The intention was to establish the level of usage of manuals from different sources in laboratory work. Seven items were offered to the teachers, and they answered on a six-point scale (Table 2).

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Table 2. Source of manuals for laboratory exercises.

Source of manuals	Subject	N	Mean	Stand. Dev.	Mean Rank	Chi-Square	p
From recent textbooks	Biology	61	4.3	1.6	118.47	48.123	0.000
	Chemistry	63	3.2	1.7	88.77		
	Physics	52	2.0	1.2	53.02		
	Total	176	3.2	1.8			
From old textbooks	Biology	60	2.9	1.5	106.53	14.847	0.001
	Chemistry	62	2.2	1.0	84.98		
	Physics	54	2.0	1.0	72.50		
	Total	176	2.4	1.3			
From the Internet	Biology	60	1.7	1.0	78.48	3.163	0.206
	Chemistry	57	2.0	1.8	93.54		
	Physics	54	1.8	1.0	86.40		
	Total	171	1.8	1.0			
From textbooks written in foreign languages	Biology	60	1.9	1.0	87.80	4.216	0.121
	Chemistry	61	2.0	0.9	95.69		
	Physics	53	1.7	0.8	77.74		
	Total	174	1.9	0.9			
From teacher-to-teacher study groups	Biology	61	2.0	0.9	82.13	1.631	0.443
	Chemistry	61	2.1	0.9	92.68		
	Physics	53	2.2	1.2	89.37		
	Total	175	2.1	1.0			
I prepare them myself	Biology	59	2.1	1.1	62.01	25.487	0.000
	Chemistry	59	3	1.5	93.53		
	Physics	55	3.6	1.7	106.81		
	Total	173	2.9	1.5			

From Table 2, it can be recognized that differences are statistically significant in three of seven items. The most important source of laboratory manuals for Biology and Chemistry teachers comprises recent and old textbooks, while Physics teachers prefer to prepare their own manuals.

Instructional Style of Laboratory Work

The aim was to discover the instructional style of laboratory work that dominates in science teaching. Five items were offered to the teachers, and they answered on a six-point scale (Table 3).

Table 3. Instructional styles of laboratory work.

Instructional style	Subject	N	Mean	Stand. Dev.	Mean Rank	Chi-Square	p
Detailed manuals with forms for data analysis	Biology	59	4.4	1.7	99.79	15.943	0.000
	Chemistry	63	4.3	1.8	98.41		
	Physics	55	3.2	1.8	66.65		
	Total	177	4.0	1.8			

Instructional style	Subject	N	Mean	Stand. Dev.	Mean Rank	Chi-Square	p
Detailed manuals without forms for data analysis	Biology	58	2.6	1.4	79.83	14.379	0.001
	Chemistry	58	2.4	1.4	73.22		
	Physics	55	3.6	1.7	105.98		
	Total	171	2.9	1.6			
Short manuals	Biology	58	2.0	1.0	84.33	0.104	0.949
	Chemistry	59	2.0	1.1	85.21		
	Physics	53	2.1	1.2	87.10		
	Total	170	2.0	1.1			
Problem-based experiment	Biology	59	1.6	0.6	90.26	2.535	0.282
	Chemistry	58	1.6	0.7	86.47		
	Physics	52	1.4	0.5	77.38		
	Total	169	1.6	0.6			
Demonstration	Biology	57	2.1	0.8	80.40	21.565	0.000
	Chemistry	58	2.7	1.2	102.72		
	Physics	50	1.8	0.9	63.09		
	Total	165	2.2	1.1			

From Table 3, it can be recognized that differences are statistically significant in half the items. Biology and Chemistry teachers prefer detailed manuals with forms for data analysis and Physics teachers detailed manuals without forms for data analysis. Problem-based experiments are the least frequently scheduled by teachers of all three subjects.

Share of Laboratory Exercises among Lessons

The aim was to establish the quantity of lessons performed as laboratory exercises. Teachers were offered seven items, and they answered on a six-point scale (Table 4).

Table 4. Share of laboratory exercises among lessons.

	Biology		Chemistry		Physics	
	N	%	N	%	N	%
More exercises are performed than prescribed by the syllabus.	12	19.7	10	15.9	5	8.6
All prescribed exercises are performed.	24	39.3	38	60.3	27	46.6
More than three-quarters of the prescribed exercises are performed.	23	37.7	12	19.0	20	34.5
Between three-quarters and half of the prescribed exercises are performed.	1	1.6	2	3.2	4	6.9
Between half and a quarter of the prescribed exercises are performed.					2	3.4
Less than a quarter of the prescribed exercises are performed.			1	1.6		
I do not perform laboratory exercises.	1	1.6				

The differences between Biology, Chemistry and Physics teachers are not statistically significant at the five percent level ($\chi^2 = 19.9$; df = 2, p = 0.07).

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Attitudes of Science Teachers towards Laboratory Activities

The instrument aimed to identify teachers' attitudes towards laboratory work (Table 5, Table 6, Appendices), and whether teachers of Biology, Chemistry and Physics can be recognized as part of a single teaching culture (Shuell 1992).

Table 5. Statistics from the questionnaire about teachers' attitudes towards laboratory work in Biology, Chemistry and Physics.

Statement	Subject	N	Mean	Stand. Dev.	Mean Rank	Chi-Square	p
V 1: Laboratory exercises should only be a supplement to instruction.	Biology	62	3.1	1.0	91.44	0.423	0.809
	Chemistry	61	3.1	0.8	91.79		
	Physics	56	3.0	1.1	86.46		
	Total	179	3.1	1.0			
V 2*: Skills gained through laboratory activities are not important for students' further work and study success.	Biology	62	4.2	0.5	95.54	0.921	0.631
	Chemistry	62	4.1	0.5	87.74		
	Physics	58	4.1	0.7	91.20		
	Total	182	4.1	0.7			
V 3: I do not like laboratory activities because of the danger of potential injury.	Biology	62	4.7	0.5	100.35	4.156	0.125
	Chemistry	62	4.6	0.6	84.75		
	Physics	60	4.7	0.6	92.40		
	Total	184	4.7	0.6			
V 4: Laboratory exercises need a lot of precious time which could be used more beneficially for other types of instruction.	Biology	62	4.3	0.7	92.70	1.980	0.372
	Chemistry	63	4.4	0.6	99.17		
	Physics	60	4.1	0.8	86.83		
	Total	185	4.3	07			
V 5: Knowledge gained through laboratory activities is not systematic.	Biology	62	4.2	0.8	103.09	5.004	0.082
	Chemistry	63	4.1	0.7	92.25		
	Physics	60	3.9	1.0	83.37		
	Total	185	4.1	0.8			
V 6: All goals suggested in the syllabus to be achieved through laboratory activities can be achieved with other instructional methods.	Biology	62	4.1	0.8	92.48	0.076	0.963
	Chemistry	63	4.2	0.6	92.19		
	Physics	60	4.1	0.8	94.39		
	Total	185	4.1	0.8			
V 7: The positive effects of the feedback from correction of laboratory reports do not justify the quantity of work.	Biology	61	3.5	1.1	95.42	0.908	0.635
	Chemistry	61	3.5	1.0	92.,24		
	Physics	60	3.3	1.0	86.77		
	Total	182	3.4	1.0			
V 8: Money spent on laboratory equipment could be better used for other instructional materials.	Biology	62	4.4	0.6	86.97	2.448	0.294
	Chemistry	63	4.4	0.6	91.98		
	Physics	60	4.5	0.8	100.31		
	Total	185	4.4	0.7			
V 9: Manuals for laboratory exercises should be very detailed.	Biology	62	3.6	0.9	104.55	16.056	0.000
	Chemistry	63	2.8	0.9	7218		
	Physics	60	3.4	0.9	102.93		
	Total	185	3.2	1.1			
V 10: I would feel uncomfortable if I didn't know the end results of the laboratory activities.	Biology	62	2.9	1.0	84.20	4.848	0.089
	Chemistry	63	3.1	1.1	90.75		
	Physics	60	3.4	1.2	104.45		
	Total	185	3.1	1.2			

Statement	Subject	N	Mean	Stand. Dev.	Mean Rank	Chi-Square	p
V 11: Manuals for laboratory work should be prepared only by experts.	Biology	62	3.0	0.9	82.44	9.662	0.008
	Chemistry	62	3.1	1.1	86.45		
	Physics	60	3.6	0.9	109.14		
	Total	184	3.2	1.0			
V 12*: There should be more problem-based laboratory activities.	Biology	62	3.9	0.6	105.66	9.950	0.007
	Chemistry	63	3.8	0.6	93.75		
	Physics	60	3.5	0.8	79.13		
	Total	185	3.7	0.7			
V 13: There is no need for teachers to know how to handle a part of the equipment, because (s) he has a lab assistant.	Biology	62	3.7	0.9	84.92	2.534	0.282
	Chemistry	63	3.8	1.0	95.18		
	Physics	60	3.9	1.0	99.06		
	Total	185	3.8	1.0			
V 14*: Knowledge achieved during laboratory activities in one subject can be later used in laboratory activities in other subjects.	Biology	62	3.8	0.8	104.79	5.608	0.061
	Chemistry	63	3.5	0.7	88.92		
	Physics	60	3.5	0.8	85.10		
	Total	185	3.6	0.8			
V 15: During laboratory work, it is hard to control the students' work.	Biology	62	3.2	1.0	91.17	0.040	0.980
	Chemistry	61	3.2	1.0	92.95		
	Physics	60	3.3	0.9	91.89		
	Total	183	3.2	1.0			
V 16: Because of expense, I perform most of the laboratory work as demonstrations.	Biology	62	4.2	0.6	95.78	1.604	0.449
	Chemistry	63	4.1	0.7	86.95		
	Physics	60	4.2	0.8	96.48		
	Total	185	4.2	0.7			
V 17: Through the teacher's demonstration of the experiment, students can achieve the same level of knowledge as when the experiment is performed by the students.	Biology	62	3.9	0.9	99.44	4.569	0.102
	Chemistry	63	3.7	0.7	81.97		
	Physics	59	3.9	0.9	96.45		
	Total	184	3.8	0.8			
V 18: When I have to decide, I prefer demonstration of an experiment.	Biology	62	4.1	0.7	107.85	11.635	0.003
	Chemistry	62	3.8	0.6	85.34		
	Physics	58	3.7	0.9	80.60		
	Total	182	3.9	0.8			
V 19*: Students should participate in the planning of laboratory work.	Biology	62	3.5	0.7	109.04	11.224	0.004
	Chemistry	63	3.1	0.8	86.86		
	Physics	59	3.0	0.7	81.14		
	Total	184	3.2	0.8			
V 20: Laboratory work is a waste of time because we must explain everything that was done once again through direct instruction.	Biology	62	4.3	0.7	92.80	0.422	0.810
	Chemistry	62	4.3	0.8	94.30		
	Physics	59	4.2	0.9	88.75		
	Total	183	4.3	0.8			

The answers on the attitudes questionnaire (Table 5) among all three groups of teachers are highly correlated at the significance level $p < 0.01$. The correlation between Biology and Chemistry teachers is $r(20) = 0.91$, $p < 0.01$, followed by the correlation between Chemistry and Physics teachers $r(20) = 0.90$, $p < 0.01$. The lowest value relates to the correlation between Biology and Physics teachers $r(20) = 0.84$, $p < 0.01$.

It can be recognized from the results in Table 5 that differences among teachers of all three subjects are statistically significant at the $p < 0.05$ level for only a quarter of the answers (V 9, V 11, V 12, V

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18 and V 19), showing that Science teachers of all three subjects on average share essentially the same opinions concerning laboratory work.

Among these variables, there are only two statements where the calculated means lie in the opposite direction. The first one is the statement that "Manuals for laboratory exercises should be very detailed", where Chemistry teachers mildly agree with this statement, while Biology and Physics teachers disagree with it. The second statement is, "I would feel uncomfortable if I didn't know the end results of the laboratory activities", where it seems that Biology teachers are less confident than teachers of the other two subjects. For all other statements, the reported means are on the same side of the attitude scale, and the differences lie only in the strength of the teachers' opinions.

Nevertheless, a deeper insight into these differences emerges when differences in pairs of teachers of different subjects were compared (Appendix 1). From the number of statistically significant differences, it was possible to recognize that the differences of Biology teachers as compared to Chemistry (6 answers) and Physics teachers (7 answers) greatly outnumbered differences between Chemistry and Physics teachers (1 answer). No statistically significant differences were found among teachers of different subjects in eight answers.

Exploratory factor analysis was performed, and six factors were extracted, explaining 60% of variance (Table 6).

Table 6. Total variance explained in the questionnaire about teachers' attitudes towards laboratory work in Biology, Chemistry and Physics.

Component	Initial Eigenvalues			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	5.092	25.458	25.458	3.761	18.803	18.803
2	1.733	8.666	34.124	1.881	9.406	28.209
3	1.549	7.746	41.870	1.733	8.665	36.874
4	1.486	7.432	49.302	1.725	8.627	45.501
5	1.139	5.694	54.996	1.507	7.535	53.036
6	1.081	5.407	60.402	1.473	7.366	60.402

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.

The first factor (Appendix 2) was designated Perceived Importance. From the factor loadings, it can be concluded that teachers value laboratory work highly and do not see it as a waste of time or as something useless that can be replaced by other methods or forms of instruction.

The second factor was designated Control of the Environment. From the factor loadings, it can be concluded that teachers do not fear potential injury and involvement of students in such work, nor did they see demonstrations as a substitute for hands-on activities in the interest of preventing potential damage.

The third factor was designated Importance of Hands-on Activities. From the factor loadings, it can be concluded that teachers place a higher value on students' hands-on activities than on demonstrations.

The fourth factor was designated Transferability, and it can be concluded from the factor loadings that teachers believe that skills and knowledge gained through laboratory work are important for both transfer among subjects and to the situation beyond school.

The fifth factor was designated Involvement in Preparation. According to the means, it seems that teachers are ambivalent concerning involvement of students in the preparation of laboratory manuals or the idea of writing manuals by themselves. It seems that they are quite happy with manuals prepared by others, and that concerning this item, differences within the group of teachers of one subject are greater than differences among teachers of different subjects.

The sixth factor was designated Confidence, and here it can be recognized that teachers, as in the fifth factor, are separated into two groups. One group of teachers, regardless of subject, consisted of those who prefer the well-established pathways of manuals prepared by experts, while there are others who do not fear exposure when something unexpected arises during laboratory work.

Discussion

According to the results of the survey, it can be concluded that Slovenian teachers of Biology, Chemistry and Physics value laboratory work highly, do not fear potential injury and involvement of students in such work and value hands-on activities more than demonstrations. All these can be recognized as positive factors for the introduction of such work into active teaching practice (Ingram et al., 2001), where 'active processing of information, not passive reception of information, leads to learning' (Lujan & DiCarlo, 2005).

From the results presented in Table 4, it can be recognized that half the teachers perform all or even more than the activities, suggested in their syllabi, and almost all teachers perform at least three-quarters of such laboratory exercises, a level which can be recognized as satisfactory. Because not all teachers perform all suggested laboratory activities caution is necessary. It has been well documented by many scholarly studies (Abell & Lederman, 2007; Michael, 2006) that laboratory work is one of the most promising methods in achieving higher order knowledge (Hofstein & Lunetta, 2004; Hofstein & Mamlok-Naaman, 2007), but there is always a possibility that teachers will abandon it and replace it with lectures, in order to transfer as much content as possible when syllabi are overloaded with content (Lujan & DiCarlo, 2005). The trend toward expending the content to be covered at the expense of the suggested quantity of laboratory work in the Biology syllabus can already be observed in Slovenia (Šorgo & Špernjak, *in press*).

Differences between teachers of the three subjects are not so great as to allow for recognition of completely different teaching cultures (Shuell 1992) among subjects in the performance of laboratory work; nevertheless, differences do exist. These differences can be recognized in the preferred method by which laboratory work is performed. Physics teachers prefer more freedom in the preparation of manuals by themselves, and chemistry teachers value demonstrations more highly than teachers of the other two subjects. It is assumed that these differences are topic dependent. In Physics and Chemistry the end results of the experiments, when following the manuals in school settings, are highly predictable; this is not always the case in Biology, especially when dealing with living organisms. The other possible reason involves the hazards and safety of experimental work. The risks are greatest in Chemistry, especially when dealing with aggressive or toxic chemicals. Some of the differences are probably the result of their previous schooling at faculties (Supovitz & Turner, 2000) and of experience gained through laboratory work during their studies. These finding can be recognized as important in efforts to enhance the transfer of knowledge between subjects and the level of cooperation between teachers (e. g., Development of Science Competences Project, 2009-2011); a lack of these is recognized as one of the most important problems in general upper secondary school in Slovenia (Rutar Ilc, 2005).

From the results dealing with the source of manuals for laboratory exercises (Table 2), can conclude that teachers of all three subjects combine manuals from different sources, but that there are differences between Biology, Chemistry and Physics teachers in their preference for one or another source. The greatest differences are in the use of manuals from textbooks. Such manuals (from both new and old textbooks) are the most important source for Biology teachers and the least important for Physics teachers. In contrast, Physics teachers prefer to write their manuals themselves, a practice which is rarely reported by Biology teachers. In both cases the values reported for Chemistry teachers lie between those for teachers of the other two subjects but are closer to those for the Biology teachers. Knowing that published manuals lack creativity, and are rarely written in an inquiry- and problem-based fashion, Physics teachers have a greater tendency to construct such manuals, which would lead to development of creativity, as one of the highest goals of education (Dobrowolska, 2010; McWilliam & Dawson, 2008).

The least significant differences among teachers of all three subjects involves the sharing of manuals among teachers in study groups and using sources from the Internet. One interesting finding is that the Internet is not an important source of information, even though it is known that all teachers from

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Slovenia have access to the web at least from the school library computers. The most probable reason is that laboratory manuals in the Slovene language are rarely found on the Internet. So, for use in the classroom, teachers can not simply download manuals; instead, they have at least to translate and edit such material before implementation in the classroom.

From the results presented in Table 3, it is obvious that expository, step-by-step manuals, reported by many as "cook-books", are the dominant style among Biology, Chemistry and Physics teachers. The difference is only that Biology and Chemistry teachers prepare forms for students to report their results, while Physics teachers offer students some freedom in the presentation of results. Problem based experiments are rarely or never scheduled, a feature common to all three groups. Demonstrations are a more common practice in Chemistry than in other subjects. The most probable explanation is that, for safety reasons, some experiments cannot be recommended for students at the pre-university level; moreover, there is the cost of the chemicals. These findings could be seen as alarming because it has been well documented (Domin 1999, Hoffstein & Lunetta, 2004, Michael 2001, 2006) that the contribution of expository laboratory exercises to higher cognitive levels such as analysis, evaluation and creativity (Krathwohl 2002) is minor in comparison to the knowledge gained through inquiry- and problem- based exercises. From the perspective of teacher trainers, this should mean that more emphasis needs to be placed on such teaching during both preservice and in-service training.

Conclusions

From the results of the study, it can be concluded that Slovenian upper secondary school science teachers value laboratory work highly and that most of them performed all or more of the labs suggested by the curricula. These findings can be regarded as positive and as a promising basis for students' active teaching experiences and the transfer of knowledge among disciplines. The problem identified here is that most laboratory work is being performed in a 'cook-book', expository fashion. Inquiry- and problem- based laboratory exercises are offered rarely or never, so the added value of the labs is more in confirmation of theoretical information and development of practical skills than in developing higher order knowledge and problem solving strategies or enhancing creativity. In the future, more effort must be given to in-service and pre-service teacher training to promote work which will foster the development of competences and higher order knowledge and skills and perhaps halt the decline of or even raise interest in science among students.

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Appendix 1: p-values of Mann-Whitney test. Tested pairs: Biology – Chemistry; Biology – Physics; Chemistry – Physics.

Statement	Subject	Biology	Chemistry	Physics
V 1: Laboratory exercises should only be a supplement to instruction.	Biology			0.601
	Chemistry	0.985		
	Physics		0.545	
V 2*: Skills gained through laboratory activities are important for students' further work and study success.	Biology			0.612
	Chemistry	0.334		
	Physics		0.674	
V 3: I do not like laboratory activities because of the danger of possible injury.	Biology			0.279
	Chemistry	0.042		
	Physics		0.342	
V 4: Laboratory exercises need a lot of precious time which could be used more beneficially for other types of instruction	Biology			0.498
	Chemistry	0.444		
	Physics		0.166	
V 5: Knowledge gained through laboratory activities is not systematic.	Biology			0.033
	Chemistry	0.181		
	Physics		0.283	
V 6: All goals suggested in the syllabus to be achieved through laboratory activities can be achieved with other instructional methods.	Biology			0.820
	Chemistry	0.964		
	Physics		0.808	

Statement	Subject	Biology	Chemistry	Physics
V 7: The positive effects of the feedback from correction of laboratory reports do not justify the quantity of work.	Biology			0.347
	Chemistry	0.729		
	Physics		0.551	
V 8: Money spent on laboratory equipment could be better used for other instructional materials.	Biology			0.123
	Chemistry	0.552		
	Physics		0.328	
V 9: Manuals for laboratory exercises should be very detailed.	Biology			0.827
	Chemistry	0.000		
	Physics		0.001	
V 10: I would feel uncomfortable if I didn't know the end results of the laboratory activities.	Biology			0.029
	Chemistry	0.492		
	Physics		0.151	
V 11: Manuals for laboratory work should be prepared only by experts.	Biology			0.002
	Chemistry	0.767		
	Physics		0.021	
V 12*: There should be more problem-based laboratory activities.	Biology			0.003
	Chemistry	0.108		
	Physics		0.078	
V 13: There is no need for teachers to know how to handle a part of the equipment, because they have lab assistant.	Biology			0.121
	Chemistry	0.261		
	Physics		0.681	
V 14*: Knowledge achieved during laboratory activities in one subject can be later used in laboratory activities in other subjects.	Biology			0.033
	Chemistry	0.055		
	Physics		0.622	
V 15: During laboratory work, it is hard to control the students' work.	Biology			0.955
	Chemistry	0.823		
	Physics		0.925	
V 16: Because of expense, I perform most of the laboratory work as demonstrations.	Biology			0.917
	Chemistry	0.964		
	Physics		0.273	
V 17: Through the teacher's demonstration of the experiment, students can achieve the same level of knowledge as when the experiment is performed by the students.	Biology			0.758
	Chemistry	0.041		
	Physics		0.103	
V 18: When I have to decide, I prefer demonstration of an experiment.	Biology			0.004
	Chemistry	0.003		
	Physics		0.477	
V 19*: Students should participate in the planning of laboratory work.	Biology			0.001
	Chemistry	0.013		
	Physics		0.537	
V 20: Laboratoy work is a waste of time because we must explain everything that was done once again through direct instruction.	Biology			0.645
	Chemistry	0.863		
	Physics		0.531	

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Appendix 2: Means, standard deviations and component loadings.

			Component loadings					
	M	SD	1	2	3	4	5	6
Factor 1: Perceived importance								
V 8: Money spent on laboratory equipment could be better used for other instructional materials.	4.4	0.7	0.813					
V 4: Laboratory exercises need a lot of precious time which could be used more beneficially for other types of instruction	4.3	0.7	0.760					
V 20: Laboratoy work is a waste of time because we must explain everything that was done once again through direct instruction.	4.3	0.8	0.745		0.311			
V 6: All goals suggested in the syllabus to be achieved through laboratory activities can be achieved with other instructional methods.	4.1	0.8	0.727					
V 5: Knowledge gained through laboratory activities is not systematic.	3.9	1.0	0.682	0.420				
V 7: The positive effects of the feedback from correction of laboratory reports do not justify the quantity of work.	3.4	1.0	0.682					
V 1: Laboratory exercises should only be a supplement to instruction.		1.0	0.400				0.456	
Factor 2: Control of the environment								
V 3: I do not like laboratory activities because of the danger of possible injury.	4.7	0.6		0.696				
V 15: During laboratory work, it is hard to control the students' work.	3.2	1.0		0.626				
V 12*: There should be more problem-based laboratory activities.	3.7	0.7		0.486		0.551		
V 16: Because of expense, I perform most of the laboratory work as demonstrations.	4.2	0.7		0.468	0.535			
V 5: Knowledge gained through laboratory activities is not systematic.	3.9	1.0	0.682	0.420				
V 18: When I have to decide, I prefer demonstration of an experiment.	3.9	0.8		0.370	0.662			
Factor 3: Importance of hands-on activities								
V 17: Through the teacher's demonstration of the experiment, students can achieve the same level of knowledge as when the experiment is performed by the students.	3.8	0.8			0.750			
V 18: When I have to decide, I prefer demonstration of an experiment.	3.9	0.8		0.370	0.662			
V 16: Because of expense, I perform most of the laboratory work as demonstrations.	4.2	0.7		0.468	0.535			
V 9: Manuals for laboratory exercises should be very detailed.	3.2	1.1			0.313		0.624	0.322
V 20: Laboratoy work is a waste of time because we must explain everything that was done once again through direct instruction.	4.3	0.8	0.745		0.311			

			Component loadings					
	M	SD	1	2	3	4	5	6
Factor 4: Transferability								
V 14*: Knowledge achieved during laboratory activities in one subject can be later used in laboratory activities in other subjects.	3.6	0.8				0.744		
V 2*: Skills gained through laboratory activities are important for students' further work and study success.	4.1	0.7				0.635		
V 12*: There should be more problem-based laboratory activities.	3.7	0.7		0.486		0.551		
V 13: There is no need for teachers to know how to handle a part of the equipment, because they have lab assistant.	3.8	1.0				-0.417		0.344
Factor 5: Involvement in preparations								
V 19*: Students should participate in the planning of laboratory work.	3.2	0.8					0.714	
V 9: Manuals for laboratory exercises should be very detailed.	3.2	1.1			0.313		0.624	0.322
V 1: Laboratory exercises should only be a supplement to instruction.	3.1	1.0	0.400				0.456	
V 11: Manuals for laboratory work should be prepared only by experts.	3.2	1.0					0.300	0.655
Factor 6: Confidence								
V 10: I would feel uncomfortable if I didn't know the end results of the laboratory activities.	3.1	1.2						0.800
V 11: Manuals for laboratory work should be prepared only by experts.	3.2	1.0					0.300	0.655
V 13: There is no need for teachers to know how to handle a part of the equipment, because they have lab assistant.	3.8	1.0				-0.417		0.344
V 9: Manuals for laboratory exercises should be very detailed.	3.2	1.1			0.313		0.624	0.322

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