Chemical education research paper

Students' Hands-on Experimental Work vs Lecture Demonstration in Teaching Elementary School Chemistry

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Received: 21-03-2011

Abstract

Science educators have suggested many benefits that accrue from engaging students in experimental activities, therefore, experimental work has a long and distinctive role in chemistry curriculum since.

The presented empirical study focuses on the valuation of effectiveness of different forms of experimental work – students' hands-on experimental work vs teacher's lecture demonstration – from the viewpoint of the quality of content knowledge acquisition and knowledge retention in teaching primary school chemistry.

106 primary school students (age 14–15 years) participated in the study. The data was collected via pre- and post- test protocol and two delayed post tests. Additionally 16 students selected from the sample were interviewed.

The results indicate that students' content knowledge gained through teacher's demonstration of experiment is better and better knowledge retention takes place in comparison to students' knowledge gained through students' hands-on experimental work. However, most of the inteviewed students stated that they prefered conducting of experiments by themselves in comparison to observation of teacher's demonstration.

Keywords: Primary school chemistry, hands-on experimental work, lecture demonstration

1. Introduction

In their wish to make the lessons most effective, teachers often wonder how they should instruct certain topic in order that students learn most and that good knowledge retention takes place. This is a very complex issue and there are many view points to think about; e.g. what is students' age group, what are students' specifics with regard to their abilities and interests, what knowledge do students already have and how the new knowledge will be related with it, which teaching methods could be used in teaching certain topic and what are their potential benefits, etc. The aim of this study focuses on the effect of different methods of instruction with regard to experimental work – students' hands-on experimental work vs teacher's lecture demonstration – on the knowledge acquisition and its durability in teaching primary school chemistry topics, namely, chromatography.

1. 1. Role of Experimental Work in Teaching and Learning of Chemistry

Most educators would agree that in learning chemistry, chemical experimental work has a very important role. For this reason chemical experimental work and laboratory activities have long had a distinctive and central role in the science curriculum and science educators have suggested that many benefits accrue from engaging students in science laboratory activities.[1–10] Experimental work stimulates students' understanding of the nature of science, as the outcomes have yet to be revealed, otherwise students could be mislead in assumption that science is about a great amount of facts to be learned by heart and not as a dynamic process of finding various ways for explanation of natural phenomena.[3] Chiappetta et al.[6] pointed out that chemical experiments can be used to introduce or reinforce a topic in lecture by illustrating a concept, principle, or point. Thereby, students develop a scientific way of thinking, observational skills, skills for systematic writing-down of the results, problem solving skills, analytical skills, and abilities to draw conclusions based on empirical results. Vrtacnik[7] described chemical experiment on one hand, as a source of information, whereby the data collected enables the pattern recognition process and generalisation; on the other hand, chemical experiments provide the opportunity for examination of theoretical hypotheses. White[5] stated that understanding of science depends on the degree of implementation of experiments in science teaching at all levels, from the very beginning up to the professional level. He indicated that a teacher demonstration can be as well affective as hands-on experimental work, but the students have to be actively involved while having their duties performed (i.e. observation and writing of results, solving tasks related to the experiment, etc.).

Researches[9,11–13] confirm that laboratory based learning quality is increased as students have an active role in the process of gaining knowledge. For that there are various learning methods, e.g. class research seminars, problem based learning, case studies, project-based learning, role playing, cooperative and cooperation learning, group debate, development of mind maps, experience based learning, etc. In regard to these methods, evaluation and valuing of knowledge are not related only to tests, but there is a need to include innovative methods of evaluation such as peer assessment, self-evaluation, the usage of portfolio, etc.[7,14]

However, Millar[15] thinks that there is need to focus on basic purpose of experimental work in knowledge acquiring, development of experimental skills, the development of natural science thinking among students.

Hofstein and Lunetta[9] found out that laboratory experiences are a key goal of natural science education in order to increase students' understanding of natural science concepts, interests and motivation, development of practical skills and capability of resolving problems, naturalistic way of thinking and understanding nature of science.

Abrahams[16] summarise that, teachers, when performing experimental work, are aware only of gaining new knowledge, but not also of basic purpose of performing experimental work for understanding natural science generally and also for the development of experimental skills. As experimental work combines very different activities and different goals, there is no need to ask ourselves about effectiveness of experimental work on teaching and learning on generally, rather than that, we should ask ourselves about effectiveness of particular examples of learning and teaching with experimental work.[15,16]

1. 2. Evaluation of Effectiveness of Different Forms of Experimental Work

For many years natural science teachers confess that traditional way of performing laboratory practices is limited because of methods that makes students follow instructions step-by-step. Students focus their thoughts on finishing one step after another and many times they do not develop deeper understanding of experiment. For many students laboratory work means just working, managing laboratory equipment that in many cases does not include development and understanding of scientific thinking.[9]

Efficiency of experimental activities were researched in a way,[17] that students were separated in three groups. Students from first group carried out experiments. The teacher demonstrated experiments for students in the second group. Students from the third group were lectured without experiments. Knowing facts, concepts and ability of problem solving were examined. Results showed that lowest scores were achieved by students from a control group and the best results were scored by students from the second group, where experiments were demonstrated by the teacher. These students showed great capability of knowledge transfer and solving problems. Students that conducted experiments by themselves were very enthusiastic about work and more motivated for subject.

Skvarč[18] researched capability of students for independent planning and performing experiments, and also how experimental strategy influences the capability of correct experiment purpose defining, precision of experimental observation, correct results explanation and knowledge gained. The control group students were working by the instructions; experimental group students were given problem based task (open experimental work type). Result analysis showed that students from the control group described their observation more precisely, experimental group students were more successful with experiment result explanation and achieved on average 4,8% better knowledge test results.

Režek Donev[19] researched understanding two experiments that were carried out in four different ways: (1) as multi-media presentation, which students observed two by two on the computer, (2) as laboratory experiment carried out in pairs, (3) as multimedia presentation shown on LCD monitor and (4) as teacher's demonstration followed by explanation. Results showed that, elementary school students understood experiments from teacher's demonstration with explanation. With secondary school students, the best results were achieved with after-test for the group which carried out experiment in a laboratory.

Logar[20,21] investigated which method of experimental work (demonstration experiment or experimental work in pairs) leads toward qualitative and long-term knowledge. Students in control group have experimented in pairs while students in experimental group only observed a demonstration experiment. Research results showed that students which participated in demonstration experiment achieved better results in tests on knowledge. The research also showed that both groups were equal at examining long-term knowledge.

Pirečnik[22] has studied which one out of three methods of practicing experimental work in primary school is more suitable for learning about polymers from the point of view of student's successfulness in following experimental observations, gaining new subject knowledge and their long-term knowledge. Three methods mentioned were demonstration experiment, students experimenting in groups where each group worked on all steps of experiment and and the third method, where each group worked only on one part of experimental work and then reported to others about the results.

Research results showed that in quality knowledge tests all three groups students were equal, while long-lasting knowledge tests showed better results with students that were participating in demonstration experiment.

Different studies showed different results in student's cognitive achievements by experimental work. Some of them[23,24] showed better student's cognitive achievements when student-centred experimental work lessons were practiced in comparison to teaching-centred working method. Others[25] have showed better student's cognitive achievements when learning activities did not include experimental work, compared to those where experimental work was included in learning activities.

Researchers[26] focused on: (1) observing the activities of students during their experimental work outside school and (2) relations between factors such as the students group size and cognitive achievements. During the analysis of the students' video-recordings at their laboratory activities, nine categories were made. These categories focused on four major students' activities and finally four clusters were formed, according to the duration of the activities i.e. dominant activities of the students. These four clusters were: (a) *all-rounders*, whose members distributed their time equally over all relevant activities, (b) *observers*, whose members were focused mainly on observing the experimental work, (c) *high-experimenters*, whose members were conducting the experimental work itself and (d) *passive students*, whose members were involved into activities that were not directly connected with the experimental work. The students of all clusters achieved better cognitive achievements both in its long and short-term knowledge; the interesting point is that the level of knowledge of the group »a« students did not decrease over the time.

2. Problem Definition and the Scope of the Study

Experimental work has an important role in school curriculum for chemistry in Slovenia and abroad, as it represents one of the foundations for scientific literacy confirmed by numerous studies.[9,27–32] On the other hand, sceptics warn,[7,33] that experimental work that is not sufficiently integrated into the educational process does not develop intended scientific competencies; according to them, it also represents additional costs for the system.

In order to improve the discussed circumstances, our major goal of the research has been set to evaluate specific forms of experimental work, its quality and sustenance of acquired knowledge. Within the research, we have examined closely which of the suggested forms of experimental work (demonstration experiment or learners' experimental work in pairs) is more suitable for chosen topics in teaching and education in primary school: (1) students' efficiency while attending the experimental work, (2) acquiring new knowledge and skills and (3) the sustainability of acquired knowledge. The research also wanted to show what are the *pros* and *cons* of specific forms of experimental work through the eyes of learners.

We posed the following research questions:

1. When do students acquire better experimental data from observation of chemical experiments: if they conduct experiments by themselves through following instructions in working sheets or if they observe the teacher demonstrating experiments?
2. When do students learn more (in the sense of the cognitive domain) from experiments: if they conduct experiments by themselves through following instructions in working sheets or if they observe the teacher demonstrating experiments?
3. Do students better remember what they have learned (in the sense of the cognitive domain): if they do the experiments themselves or if they observe the teacher demonstrating experiments?

3. Methods

The research proceeded through several phases. An outline of the main phases of the investigation is brefly presented in Advance Organiser Section.

3. 1. Advance Organiser

For the research, a measuring instrument and one lesson from chromatography were taken into consideration. All the students that participated in the research, on the topic of chromatography, and before the lesson started, had to write a Pre-test which was assessed. According to their results they were divided into a control and an experimental group, so that they were equal in their level of knowledge.

A lesson on chromatography, in the continuation of the research, was performed in two ways and in accordance with the teacher's preparatory worksheet. Both ways of teaching included the same introductory part and an abstract on the theory of the new content, with instructions on how to fill learners' worksheet properly; the difference between the ways of teaching was in the form of conducting the experimental work of the school lesson. *An experimental group* consisted of the students that observed a demonstration experiment, whereas *a control* *group* consisted of students who conducted the experiment in pairs, following the instructions on the worksheet and direction of the teacher. Both groups, while attending the experiment, filled the (same) worksheet, and handed it on to the teacher at the end of the class. After the learning unit finished, all the students wrote a Post-test 1 which evaluated the quality of their learners' knowledge and after 14 days they were given Post-test 2 which assessed their sustenance knowledge in regard to the chosen method of work. After 5 months passed, the students had to do the Post-test 3 where we wanted to evaluate their long-term retention knowledge in regard to the chosen method of work.

The collected data were analysed. On the basis of results for a pretest, Post-test 1 and Post-test 2, some students (N = 16) were chosen and a structured interview was taken with them. The aim of the interview was to obtain certain explanations and detailed data, e.g., to enquire about students' opinion of pros and cons of working in pairs, i.e. of attending the demonstration experiment. The structured interview was taken orally, each student was interviewed for 8 minutes. Sixteen students participated in the interview, eight from the experimental group who observed the experiment, and eight from the control group who conducted the experiment in pairs.

A lesson on Paper Chromatography consisted of three operational goals that were assessed with Post-tests. From the lesson, the students have learnt and understood chromatography theory, made the difference between mobile and stationary phase, and they know how to use paper chromatography as a method of separating mixtures. You can obtain the details of the work on request to the authors of the work.

3. 2. Instruments

The following measuring instruments were taken into account:

– Pretests (seven tasks: six tasks of the choosing type, one task requiring explanation) ;
– Learners' worksheet with instruction and a chart for writing their observation remarks and experiment results (eight tasks: 4 tasks of filling-in the data, two short-answer tasks, three tasks that included a short answer with an explanation);
– Post-test 1, Post-test 2, Post-test 3 (tests are the same content-wise; numerals 1, 2, and 3 represent the time period the pupils took a test: 1 – immediately after the lesson unit finished; 2 – after 14 days, 3 – after 5 months), (seven tasks: 2 tasks of a choosing type, one task of filling-in the data, three short-answer tasks and one task where the learners had to explain things);
– A structured interview (seven open-type questions, short answers, each question consisting of two subquestions that required studentss to explain and interpret a short answer).

3. 3. Sample

106 primary school students from Primary School Metlika, Primary Schol Črnomelj and Primary School Semič participated in the research. 54 students formed the experimental group, while the control group consisted of 52 students. The students were equally divided into both groups according to their pre-knowledge. The classification of the students according to sex was also equal, the experimental group consisting of both 27 girls and 27 boys respectively; the control group had 26 boys and 26 girls. An average age of the pupils was 14.5 years. The division according to their learning success was also a usual one (Gaussian curve) for both groups.

3. 4. Data Collection

Students were divided into two equally assessed Pre-test groups; the Pre-test was taken in November 2007. A Paper Chromatography lesson was performed in the experimental and control group during December 2007; at that time, the learners took a Post-test 1, after 14 days a Post-test 2 and after 5 months a Post-test 3.

3. 5. Data Analysis

Pre-test and all the Post-tests and worksheets were processed by using qualitative and quantitative methods of data processing. A statistical data processing used so called t-test. The calculation of the t-test was made by using SPSS.S 16.0 version of a computer software.

The tasks of an open type in the pretest, in all three Post-tests and on a worksheet were content-wise analysed. All the learners' answers in the structured interview were also semantically analysed. We have chosen 10% of tests, searched categories in the text, developed a categorization chart, and checked the whole pattern using the chart.

4. Results and Discussion

The results are presented with regard to stated research questions.

First research question:

When do students acquire better experimental data from observation of chemical experiments: if they conduct experiments by themselves through following instructions in working sheets or if they observe the teacher demonstrating experiments?

By using specific types of worksheet we wanted to find out the influence of the experimental work forms on the learners' ability to observe and note changes and record events that take place during the experiment. From Table 1 can be devoted, that there are no statistically significant differences in the efficiency of solving working

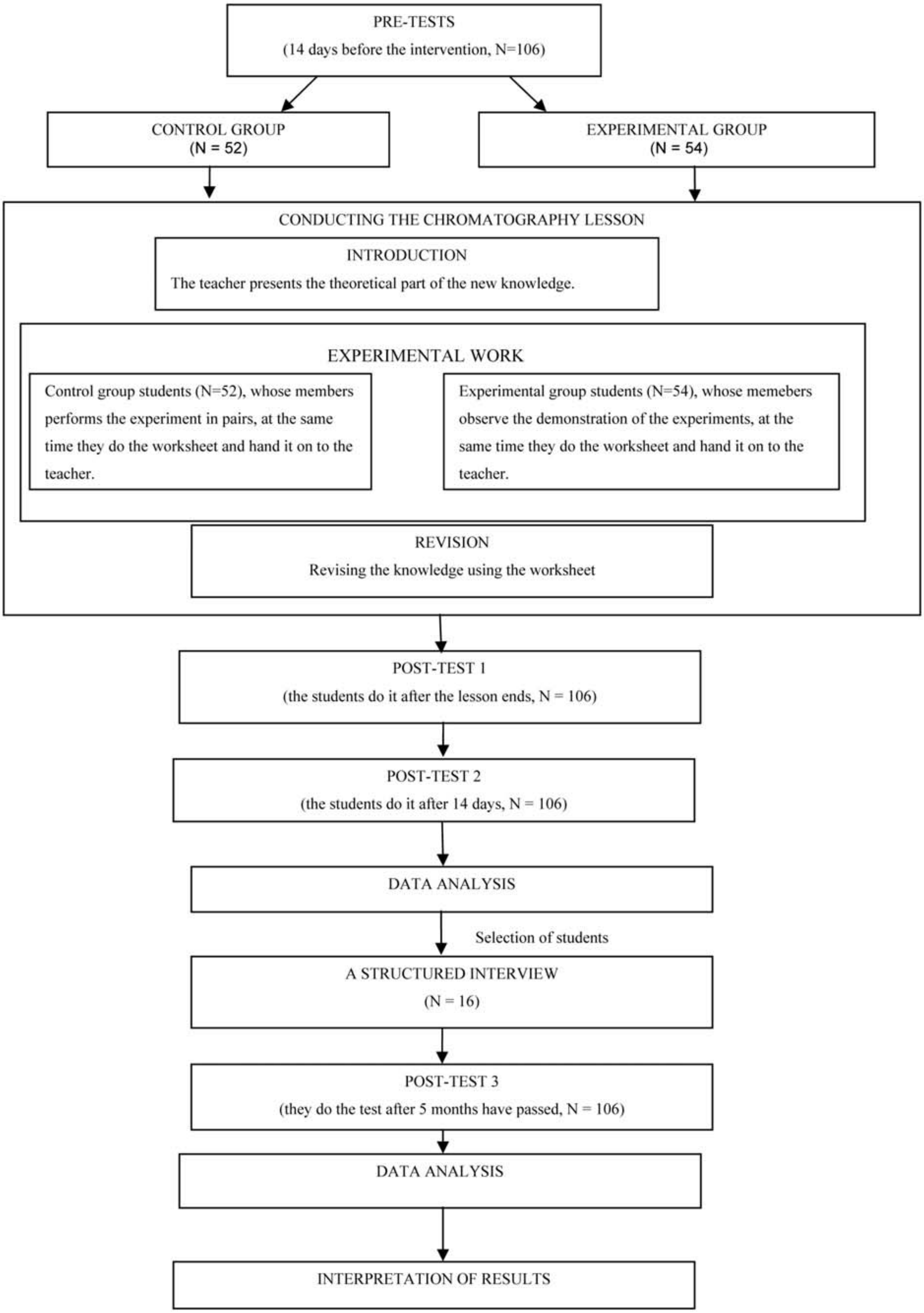

Figure 1: A scheme of the research process

sheet as a whole between control and experimental group ($t = 0{,}32$; $p > 0{,}05$).

Table 1: Comparing the achievement of experimental and control group while doing the worksheet

	Experimental group		Control group		t	p
	Means	SD	Means	SD		
Worksheet	17,28	2,74	17,09	3,01	0,32	0,75

Although there were no significantly important differences between groups that were filling on the work sheet as a whole and on some of its tasks (Task 3, Task 4, Task 5, Task 7), however, we found out some significantly important differences in several specific tasks, which are described in detail further on in the article (Task 1, Task 2, Task 6, Task 8).

The first and second task on the worksheet consisted of filling-in the data type that required from students answers on level *knowledge* of Bloom's taxonomic scale of cognitive learning aims. The students of both groups listened to the same introduction and were asked to fill in the missing words. The learners of the experimental group filled better the task number 1 on the worksheet than the control group; the difference is statistically important, ($t = 3{,}16$; $p < 0{,}05$) and the task number 2 ($t = 2{,}52$; $p < 0{,}05$); the data point to the fact that the learners of the experimental group seem to listen better what the teacher had to say.

At task 6 students had to think about and answer an open-ended question related to their experimental results on the level *analysis* of Bloom's taxonomic scale. Results in experimental group were below the results of the control group and the difference was statistically important ($t = –3{,}04$; $p < 0{,}05$). We assume, that students that conducted experimental work on their own were more interested in solving the task in comparison to students who were involved just as observers of a demonstration experiment, because the task is directly related to their hands-on activity. This assumption is supported by results from the structured interview – presented later on in the article.

Also, the 8th task required from students to answer an open-ended question, this time on the *synthesis* level of Bloom's taxonomic scale; it was predicted that students would be able to devote a rule based on their experimental results and apply it in a new, hypothetical situation. There are statistically significant differences between the experimental and control group in favor of the students of the experimental group ($t = 2{,}13$; $p < 0{,}05$). Because this task is not directly related to students' own hands-on activity, we propose, that the advantage of students in experimental group can be ascribed to the same issues as their better success on the post tests, which is discussed in the framework of 2nd research question of this article.

In the structured interview we asked students some questions to get deeper understanding of the described results. The specific question and students' answers are presented bellow.

Interviewer's question: What was your experience of experiments' observation and collection of experimental results?

Students answers showed that qualitive preparation and structured worksheet (N = 14) is of great help while observing experiments. Students (N = 2) that observed demonstration of the experiment warned of problems that occured during simultaneous observation of the experiment and writing notes. There were no such problems reported by students in the control group, as individual experiment offers opportunity that students adapt their speed of conducting the expertiment and writing notes.

Example of experimental group student's answer:

Student 3: »When I observe the experiment, I am disturbed if I have to fill out worksheet, as I look all the time what I am going to write down, instead of observing an experiment and that is why I overlook something important.«

Example of control group student's answer:

Student 15: »Worksheet has helped me at work, as I knew what is important and what I have to observe, so I could fill out worksheet.«

Student's answers are in accordance with literature[9] which quotes that working instruments such as working instructions, exercise book and worksheets have an important role in forming and improving student's laboratory skills and learning in the laboratory. The learning material helps students to focus on questions they have to answer and orient them to the things that have to be done so that they come to a right solution (observation, interpretation, report). Students quote, as in literature,[33] some disadvantages while using worksheets, for example: in their work, students follow directions not thinking about purpose of the experiment, students are not searching for a connection between experiment itself and concepts learned in classroom, because of insufficient pre-knowledge they do not know what they have to be focused on at experiment and do not know how to explain their observations; students do not see how to make the connection between planning an experimental procedure and a purpose of research.

Second research question:

When do students learn more (in the sense of the cognitive domain) from experiments: if they conduct experiments by themselves through following instructions in worksheets or if they observe the teacher demonstrating experiments?

Although there were no statistically important differences in pre-knowledge between the experimental and control group in the Pre-test ($t = 0{,}57$; $p > 0{,}05$), statistically important differences between the groups were observed in the Post-test1 ($t = 2{,}36$; $p < 0{,}05$) in favour of students who observed teachers' demonstration of chemical experiment (Table 2).

Table 2. Students' results on tests with regard to the method of experimental work

	Experimental group		Control group		t	p
	Means	SD	Means	SD		
re-test	2,98	1,56	3,13	1,65	0,57	0,57
Post-test1	8,33	2,01	7,32	2,39	2,36	0,02

To better understand Post-test 1 for the results mentioned above, we gave a few questions to students using a structured interview. Answers are written here:

Interviewer's question: What are the pros and cons of teacher's demonstrations?

Give your opinion.

Students (N = 10) in both groups were disturbed by low visibility of teacher's experiment, they like that teacher pointed out important changes during the experiment and wrote down important data (N = 5) and also that they are sure the experiment will be successful (N = 3).

Example of experimental group student's answer:

Student 4: »At the demonstration I like the fact that experiment will be carried out right and I am disturbed because I sit too far away to see well.«

Example of control group student's answer:

Student 11: »I like demonstration because I do not touch dangerous chemicals, but classmates cover my sight so I do not see well from my seat, so I have to move all the time if I want to see something.«

Interviewer's question: What do you consider to be good sides and bad sides of experimenting, when your students carry it out by yourselves under teacher's tutelage?

Express your opinion.

Students in both groups (N = 5) think that, if they experiment on their own, they remember experiment for longer period and they cooperate with classmates (N = 4). Many students are not sure if experiment is carried out properly (N = 7).

Example of experimental group student's answer:

Student 7: »I prefer to do experiment on my own because I like experimental work and I can discus it with my classmates.«

Example of control group student's answer:

Student 14: »If we experiment in pairs we can divide our work. I am unhappy if teacher puts me next to a student of a poorer knowledge and then I have to do everything on my own; I hardly interchange views with someone about experiment and I don't know if experiment is carried out right.«

Interviewer's question: Do you think that the methods previously described (demonstrational experiment, the student doing the experiment on his own) are equal, i.e., do you gain the same knowledge using these two methods?

Express your opinion.

The control group students are in favour of conduction of experimental work by students' pairs (N = 8), while the other group thinks that both methods are equal (N = 6). For both groups it is important that any kind of experimental work is supported by teacher's explanation.

Example of control group student's answer:

Student 9: »It's very good, if we work alone, and then the teacher explains the theoretical side of it.«

Example of experimental group student's answer:

Student 7: »In my opinion I learn same, if I do experiment by myself or if I look teacher demonstration.«

Students' answers gave us similar results as found in literature,[9] where it is stated out that laboratory experiences are a basic goal of science education for student's understanding of natural concepts, interest and motivation, development of practical skills and ability solving problems, for the scientific way of thinking and understanding nature of science. Due to important role of experimental work in science class and chemistry class, many researchers[11,16,34] tried to evaluate understanding of experimental work as students see it and found out that experimental work in class is the most pleasant way of teaching science, it is the most useful and effective method of teaching.[35] They also affirm that experimental work is necessary to stimulate enthusiasm for science among young people.[28] Students think that experimental is reasonable, no matter what method of experimental work was used. The experiment makes them possible to remember lesson easier and to learn lesson easier, school instruction is more diverse and when they do the experiment themselves they see well what happens during the experiment.[22]

Third research question:

Do students remember better what they have learned (in the sense of the cognitive domain): if they do the experiments themselves or if they observe the teacher demonstrating experiments?

With knowledge Post-tests (Post-test 1, Post-test 2 and Post-test 3) we have checked knowledge retention of experimental and control group.

As mentioned before, experimental group students that observed demonstration experiment, were more successful at solving test at the end of lesson (Post-test 1), the difference is statistically significant ($t = 2{,}36$; $p < 0{,}05$, Table 3).

Post-test 2 was carried out 14 days after realisation of lesson in class. Similar as Post-test 1 results we can see differences in favour for experimental group also in Post-test 2 ($t = 2{,}04$, $p < 0{,}05$, Table 3).

Post-test 3, which content was identical as in Post-test 1 and in Post-test 2, was carried out after five months. Again, there occurred significant differences. Students that observed teacher's demonstration scored better result in Post-test 3 than students that experimented in pairs. Difference is statistically significant ($t = 2{,}72$; $p < 0{,}05$, Table 3).

Table 3: Experimental group and control group students achievement comparison in doing the Post-test 1, Post-test 2 and Post-test 3

	Experimental group		Control group		t	p
	Means	SD	Means	SD		
Post-test1	8,33	2,01	7,32	2,39	2,36	0,02
Post-test2	7,78	2,65	6,96	2,43	2,04	0,05
Post-test3	6,04	2,56	4,69	2,44	2,72	0,01

Results of knowledge retention tests after 14 days and five months showed us decreased knowledge in both groups. Better results of experimental group speak in favour of teacher's demonstration and as well indicates that long-term knowledge is connected with a teaching method. We assume that pupils who conduct experimental work on their own experience higher cognitive load due to their hands-on activities in comparison to pupils who are guided through experimental work just as observes of a demonstration experiment conducted by their teacher. This is supported by theory of cognitive load work memory,[36] which has limitied information capacity.

Researchers have marked cognitive load with three characteristics: (1) actual load that is the result of interactivity of presented contents and influences on individually expert knowledge of students, (2) external load refers on teaching method and does not contribute or even hinder student's learning and (3) relative load, which is necessary for individual data processing and transfer to long-term memory, so it activates learning. These components are treated as an additional part, where direct connection and/or external load is reduced; they also have the potential for the increase of the relative component which is of significance in learning.[37] With regard to students' hand-on experimental work in comparison to teachers' demonstration we believe that reasons for overtaxing students may be simultaneous performing of more tasks: following teacher's verbal instructions, using experimental skills of students (for example: what to do, how and when), working with laboratory equipement and materials, use of laboratory manuals, use of theoretical basics of experimental work, terms, symbols, representations, working with classmates in groups, which has been confirmed also by other researchers.[38,39]

5. Conclusions and Implications

The basic goal of the research was to find out, which of selected experimental work methods in primary school is more suitable for teaching and learning defined contents from student's successfulness at observing experiment course, gaining new knowledge and knowledge durability. We wanted to find out advantages and disadvantages of specific experimental work methods from the student's point of view.

The analyses of tests conducted immediately after pedagogical process showed that students in experimental group gained more knowledge than students in control group and there is a statistically significant difference ($t = 2{,}36$; $p < 0{,}05$). Also, results of tests after 14 days and after five months showed that there is still statistically significant difference in favour of teacher's demonstration of experiment.

According to pupils statements they have problems in simultanious observation of experiments performed by teachers and writing down observations. We can deduce that teachers' role in conduction of demonstration experiment is double – besides conduction of demonstration experiment, it is very important that teacher guides pupils and directs their attention to what and when they should observe, and on the other hand what and when they should write down.

Results from the interviews also indicate that influence of experimental work on students' interest for learning chemistry is significant, therefore it is crucial to combine demonstration experiments with students' work in order to support learning.

6. References

1. K. Tobin, *School Science and Mathematics* **1990**, *90*, 403–418.
2. R. F. Gunstone, A. B. Champagne, in: E. Hegarty-Hazel (Ed.): The student laboratory and the science curriculum, Routledge, London, **1990**, pp. 159–182.
3. D. Hodson, *Studies in Science Education* **1993**, *22*, 85–142.
4. R. Lazarowitz, P. Tamir, in: D. L. Gabel (Ed.): Handbook of research on science teaching and learning, Macmillan, New York, **1994**, pp. 94–130.
5. R. T. White, *International Journal of Science Education* **1996**, *18*, 761–774.
6. E. L. Chiappetta, T. R. Koballa, Science instruction in the middle and secondary schools, Upper Saddle River, NJ: Pearson Education, **2002**, pp. 337.
7. M. Vrtačnik, S. A. Glažar, V. Ferk Savec, V. Pahor, Z. Keuc, V. Sodja, (Eds.). Kako uspešneje poučevati in se učiti kemijo?: monografija za učitelje kemije – mentorje, **2005**, Faculty and Schools Partnership, Faculty of Chemistry and Che-

mical Technology, Department of Chemistry, Ljubljana.

8. A. Hofstein, *Chemistry Education: Research and Practice* **2004**, *5*, 247–264.
9. A. Hofstein, V. N. Lunetta, *Science Education* **2004**, *88*, 28–54.
10. A. Hofstein, R. Mamlok-Naaman, *Chemistry Education: Research and Practice* **2007**, *8*, 105–108.
11. J. Bennett, S. Hogarth, F. Lubben, B. Campbell, A. Robinson, *International Journal of Science Education* **2010**, *32*, 69–95.
12. L. Tarhan, H. Ayar-Kayali, *Research Science Education* **2008**, *38*, 285–300.
13. D. Cheung, *International Journal of Science and Mathematics Education* **2007**, *6*, 107–130.
14. I. Gerlič, N. Golob, N. Bukovec, I. Devetak, V. Ferk Savec, S. A. Glažar, A. Godec, N. Gros, J. Majer, D. Sikošek, M. Vrtačnik, K. S. Wissiak Grm, K. Žarić, (Eds.): Kompetence naravoslovne pismenosti, skupne vsem naravoslovnim strokam. Chemistry: Project: Development of science skills, Faculty of Natural Sciences and Mathematics, Maribor, **2009.**
15. R. Millar, J-F. Le Maréchal, A. Tiberghien, in: J. Leach, A. (Ed): Paulsen Practical work in science education, Roskilde/Dordrecht: The Netherlands, Roskilde University Press/Kluwer, **1999**, pp. 33–59.
16. I. Abrahams, R. Millar, *International Journal of Science Education* **2008**, *30*, 1945–1969.
17. W. Killerman, *International Journal of Science Education* **1996**, *18*, 333–346.
18. M. Skvarč, Pomen eksperimenta pri pouku kemije. Masters Thesis, University of Ljubljana, Faculty of Natural Sciences and Engineering, Ljubljana, **1999**, 139.
19. N. Režek-Donev, Pomen multimedije za pouk kemije. Masters Thesis, University of Ljubljana, Faculty of Natural Sciences and Engineering, Ljubljana, **2000**, 120.
20. A. Logar, Vrednotenje vpliva oblike eksperimentalnega dela na kakovost in trajnost znanja. Graduation Thesis, University of Ljubljana, Faculty of Education, Ljubljana, **2008,** 91.
21. A. Logar, V. Ferk Savec, in: S. Dolinšek, T. Lyons (Eds): Evaluation of the influence of various methods of experimental work on quality and durability of chemistry knowledge: Socio-cultural and Human Values in Science and Technology Education, XIV. IOSTE Symposium, Institute for Innovation and Development of University of Ljubljana, Bled, **2010**.
22. D. Pirečnik, Vrednotenje različnih oblik eksperimentalnega dela pri pridobivanju kemijskega znanja. Graduation Thesis, University of Ljubljana, Faculty of Education Ljubljana, **2010,** 158.
23. C. Randler, M. Hulde, *Research in Science & Technological Education* **2007**, *25,* 329–338.
24. F-J. Scharfenberg, F. X. BogneR, S. Klautke, *Biochemistry and Molecular Biology Education* **2007**, *35*, 28–39.
25. H. Sturm, F. X. Bogner, *International Journal of Science Education* **2008**, *30*, 941–959.
26. F-J. Scharfenberg, F. X. BogneR, S. Klautke, *International Journal of Science Education* **2007**, *30*, 451–467.
27. J. Josephsen, *Chemistry education: Research and practice* **2003**, *4*, 205–218.
28. I. Gibson, P. Dhanda, T. Harris, D. Heath, M. Hoban, B. Iddon, T. Mcwalter, A. Murrison, G. Smith, B. Spink, D. Turner, (Eds): Science education from 14 to 19, House of Commons Science and Technology Committee, The Stationery Office, London, **2002**.
29. R. Millar, The role of practical work in the teaching and learning of science, Paper prepared for the meeting, High school science laboratories: Role and vision, Washington, DC: National Academy of Sciences, **2004**, pp. 24.
30. M. Vrtačnik, Smisel kurikularne prenove kemije, Zavod republike Slovenije za šolstvo, OE Maribor, **1998**, pp. 11–13.
31. S. A. Glažar, *Kemija v šoli* **2007**, *19*, 2–3.
32. M. Vrtačnik M. Naji, S. A. Glažar, M. Možina, T. Novak-Požek, T. Pufič, D. Sikošek, Učni načrt: program osnovnošolskega izobraževanja, Kemija, Ministrstvo za šolstvo, znanost in šport, Zavod republike Slovenije za šolstvo, Ljubljana, 2000, 47 pp.
33. D. Hodson, *International Journal of Science Education* **1996**, *18*, 761–774.
34. I. Abrahams, *International Journal of Science Education* **2009**, *31*, 2335–2353.
35. B. Cerini, I. Murray, M. Reiss, *Student review of the science curriculum*, http://www.planet-science.com/sciteach/review, (accessed: 29.8.2010).
36. A. Baddeley, *Science* **1992**, *255*, 556–559.
37. F-J. Scharfenberg, F. X. Bogner, *International Journal of Science Education* **2010**, *32*, 829–844.
38. R. Mancy, N. Reid, Aspects of Cognitive Style and Programming, 16th Workshop of the Psychology of Programming Interest Group. Ireland: Carlow, **2004**, pp. 1–9.
39. N. Reid, I. Shah, *Chemistry Education Research and Practice* **2007**, *8*, 172–185.

Povzetek

Eksperimentalno delo ima pri poučevanju naravoslovnih vsebin ključno vlogo, kar je razvidno tudi iz učnih načrtov naravoslovnih predmetov. Pričujoča raziskava se ukvarja z vrednotenjem učinkovitosti različnih oblik eksperimentalnega dela (samostojnega eksperimentalnega dela učencev, učiteljeve demonstracije eksperimenta) iz vidika pridobivanja kemijskega znanja v osnovni šoli in njegove trajnosti.
V raziskavi je sodelovalo 106 učencev (starosti 14–15 let). Podatke smo zbrali ob uporabi preizkusov znanja, ki so bili uporabljeni pred in po intervenciji v razredu ter z zapoznelimi testi znanja v določenih časovnih obdobjih po zaključeni intervenciji. S 16 učenci smo opravili strukturirani intervju, da bi pridobili dodatne informacije o njihovem dojemanju izbranih oblik eksperimentalnega dela.
Rezultati raziskave kažejo, da so učenci pridobili boljše vsebinsko znanje kemije, ko je pouk potekal ob uporabi učiteljeve demonstracije kemijskega eksperimenta v primerjavi s samostojnim delom učencev. V nasprotju s tem pa je večina učencev v intervjujih povedala, da se iz samostojnega dela po njihovem mnenju več naučijo in da eksperimentalno delo raje izvajajo sami, kakor opazujejo učiteljevo demonstracijo. Iz ugotovitev lahko zaključimo, da imata obe obliki eksperimentalnega dela pri pouku kemije pomembno vlogo in ju je potrebno ustrezno vključiti v učni proces.