USING INQUIRY-BASED APPROACHES IN TRADITIONAL PRACTICAL ACTIVITIES

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1.1 INTRODUCTION: DEFINITION OF INQUIRY-BASED SCIENCE EDUCATION (IBSE)

- Uno (1990): „*a pedagogical method that combines hands-on activities with student-centred discussion and discovery of concepts*".
- National Research Council of the United States of America in the Inquiry and the National Science Education Standards (Olson, Loucks-Horsley, 2000): "*an activity that involves*
  - *making observations*
  - *posing questions*
  - *examining books and other sources of information to see what is already known*
  - *planning investigations*
  - *reviewing what is already known in light of experimental evidence*
  - *using tools to gather, analyze, and interpret data*
  - *proposing answers, explanations, and predictions*
  - *communicating the result"*.

1.2 POSSIBLE ADVANTAGES OF IBSE

- Hofstein, Kempa (1985): increase motivation, at least among the „*curious*” and the „*socially motivated”* students
- Minner *at al.* (2010):
  - *„…student active thinking and drawing conclusions from data… increase conceptual understanding”*
- Tomperi and Aksela (2014): develops higher order cognitive skills

- Better understanding of
  - the nature of science
  - the importance of collaboration and communication in science →
  - the nature of pseudoscience.

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1.3 POSSIBLE DISADVANTAGES OF IBSE

- Kirschner, Sweller, and Clark (2006): “*minimally guided instruction is*
  - *less effective*
  - *less efficient*
  - costs more
  - *may have negative results when students acquire*
    - *misconceptions*
    - *incomplete or disorganized knowledge*”
- Bolte, Streller and Hofstein (2013): „*suitable for students with ‘curiosity’-type motivational pattern, but… disliked by the ‘achievers’ and the ‘conscientious’ students*”
- Szalay, 2015: Hungarian chemistry teachers’ further reservations toward open ended inquiry

  - time consuming → does not fit in the lessons

2.1 RESEARCH PROBLEM

- Hmelo-Silver, Duncan and Chinn (2007):
  - *under what circumstances do these guided inquiry approaches work*
  - *what are the kinds of outcomes for which they are effective,*
  - *what kinds of valued practices do they promote*
  - *and what kinds of support and scaffolding are needed for different populations and learning goals.*
- PISA (2006): under development of skills of Hungarian students such as
  - identifying scientific issues
  - devising scientific investigations
  - using scientific evidence.

Could IBSE address these issues?

If yes, how exactly could this be achieved?

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2.2 SPECIFIC CONDITIONS – SPECIFIC PROBELM

- Conditions in Hungary → introducing IBSE only gradually
  - limited time, limited resources, lack of laboratory assistants → only a few occasions / school year
  - the experiments have to be part of the curriculum → well known practical, but partly designed by students

- …whether it makes any difference if students only a few times do partially inquiry-based activities when it comes to their
  - scientific way of thinking
  - factual knowledge
  - attitude toward chemistry.

2.3 RESEAERCH QUESTIONS

1. Is there any significant change in the ability of designing experiments as a result of the intervention? If yes, is there any correlation between the previous knowledge in chemistry measured by the pre-test and the change of ability designing the experiments measured?

2. Do students in the experimental groups achieve significantly different scores on the post-test than the students of the control groups, considering the tasks measuring other knowledge, like factual knowledge, understanding and its application obtained at the lessons?

3. Is there any significant change in the attitude of students toward chemistry in general and toward their learning environment in the experimental group and in the control group? If yes, is there any difference between the changes measured in the experimental group and in the control group?

3.1 RESEARCH METHOD - SAMPLE

- 14-15-year-old students, 2 lessons (45 min) in chemistry/week
- 12 schools
  - 15 teachers
  - 31 groups of students
    - 16 control groups
    - 15 experimental groups
  - 660 students (filled out both the pre-test and post-test)
    - N (control) = 325 (49.2%)
    - N (experimental) = 335 (50.8%)
  - gender ratio (boys/girls, the difference is not significant):
    - control: 121/204
    - experimental: 141/194
  - in school year 2014/15.

3.2 RESEARCH METHOD - INSTRUMENTS

- Pre-test:
  - 15 items measuring conceptual understanding or factual knowledge
  - 1 item measuring the ability of designing an experiment
  - 1 item concerning the ability of finding trustworthy information about chemical problems
  - 7 items (5-point Likert scale) concerning the student‘s attitude toward chemistry and learning environment at chemistry lessons
  - marks in math, physics, chemistry, biology in the previous school year
- Post-test:
  - 13 items measuring conceptual understanding and factual knowledge
  - 2 items measuring the ability of designing an experiment
  - 7 items (5-point Likert scale) concerning the student‘s attitude toward chemistry and learning environment at chemistry lessons
- Time: 40 min to answer the questions of each test
- No specific reward or punishment for achievments on the tests

3.2. RESEARCH METHOD – DESIGNING EXPERIMENTS TASKS

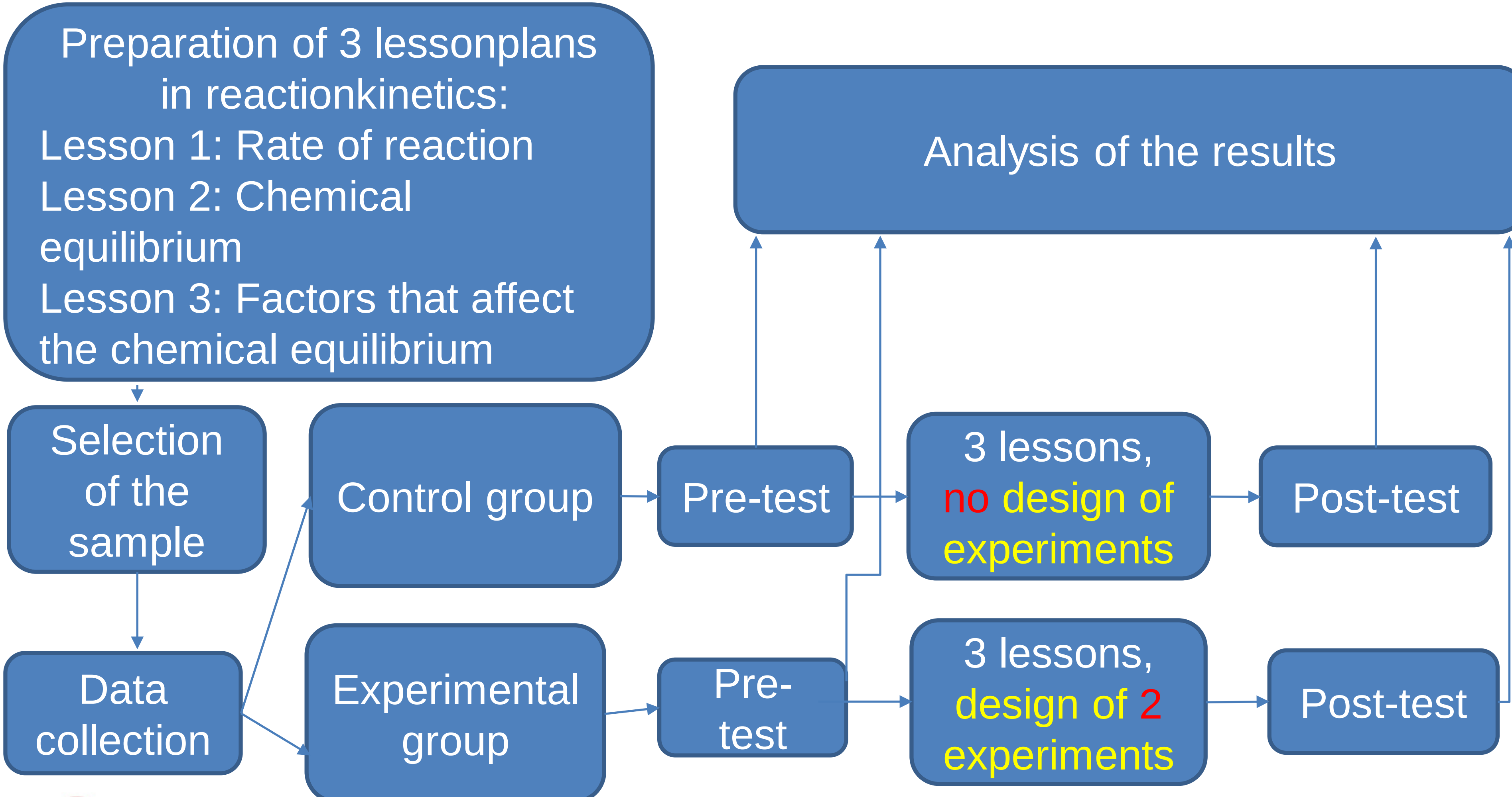
- Pre-test:
- Choose one of the conditions necessary for a chemical reaction to occur and design an experiment to prove that it is required indeed for the reaction.

- Post-test:
- Task 1: Consider the following reaction: $Br_2 + HCOOH = 2\ HBr + CO_2$
  Bromine water is yellow, but the other reactant and the products are colourless. Choose a factor that influences the rate of reaction. Design an experiment to prove that the factor chosen by yourself does influence the rate of reaction.
- Task 2: Consider the following reaction leading to a chemical equilibrium:

$$2\ NO_2 \rightleftharpoons N_2O_4$$

  The NO_2 is brown and the N_2O_4 is colourless. Using this information design an experiment by that it could be determined whether the forming of N_2O_4 is an exothermic or an endothermic reaction.

3.3 RESEARCH METHOD - DESIGN



3.4 RESEARCH METHOD: SPECIAL PARACTICAL TASKS OF THE EXPERIMENTAL GROUPS

Lesson 1: The students have to…

- perform an experiment following a step-by-step description to form colloidal sulfur by mixing $Na_2S_2O_3$ and H_2SO_4 (previous knowledge!)
- design an experiment to investigate the effect of the following factors on the rate of reaction:
  - Group 1: temperature of the starting materials
  - Group 2 and Group 3: concentrations of the $Na_2S_2O_3$ / H_2SO_4

Lesson 3: The students have to…

- add distilled water drop-by-drop to $BiCl_3$ solution until they experience a change and have to balance the given equation:

  $BiCl_3 + H_2O \rightleftharpoons \underline{BiOCl} + HCl$ (previous knowledge!)
- using materials and equipment provided design a series of experiments to prove the following: in case of chemical equilibrium, an increase in concentration drives the reaction to the opposite side:
  - adding products favours reactants
  - adding reactants favours products

4.1 RESULTS: RELIABILITY

Cronbach's alfa

	control	experimental
pre-test	0.618	0.675
post-test	0.532	0.694

Note: items of the pre-test and post-test varied in the cognitive domain of Bloom's taxonomy.

4.2 RESULTS: ACCORDING TO TYPES OF TASKS

Type of tasks Experimental/control	$M_{pre\text{-}test}$ (%)	$SD_{pre\text{-}test}$ (%)	$M_{post\text{-}test}$ (%)	$SD_{post\text{-}test}$ (%)	Δ (%)	p (sign: p<0,05)
All tasks, control	26.4	15.4	25.0	12.5	-1.4(!)	non sign
All tasks, experimental	26.8	16.4	30.0	16.0	+3.2	sign
p (sign: p<0,05)	non sign		sign			
Design tasks, control	7.2	21.5	13.4	21.3	+6.2	sign
Design tasks, experimental	6.6	19.6	23.2	26.9	+16.6	sign
p (sign: p<0,05)	non sign		sign			
Other tasks, control	29.6	16.8	27.7	13.5	-1.9(!)	non sign
Other tasks, experimental	30.2	6.6	31.6	16.2	+1.4	non sign
p (sign: p<0,05)	non sign		sign			

- Small, but significant effect in the experimental group
- Step-by-step experiments helped to develop designing skills /pre-test effect?
- Designing experiments helped to develop other knowledge/skills?
- High standard deviation (very heterogeneous sample!)

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4.3 RESULTS: ACHIEVEMENTS – ALL TASKS

Group	Control / Experimental	$M_{pre\text{-}test}$ (%)	$M_{post\text{-}test}$ (%)	Δ (%)	p (sign: p<0,05)
Boys	control	27.7	25.1	-2.6 (!)	sign
	experimental	27.1	29.8	+2.7	sign
	(sign: p<0,05)	non sign	sign		
Girls	control	25.6	25.0	-0.6 (!)	non sign
	experimental	26.6	30.2	+3.6	sign
	(sign: p<0,05)	non sign	sign		
Lowest achievement on pre-test	control	10.4	18.9	+8.5	sign
	experimental	9.65	20.2	**+10.5**	sign
Medium achievement on pre-test	control	24.7	25.3	0.0	non sign
	experimental	24.7	28.4	+3.1	sign
Highest achievement on pre-test	control	44.1	31.5	**-12.6 (!)**	sign
	experimental	45.5	41.5	-4.0 (!)	sign

4.4 RESULTS: ACHIEVEMENTS – DESIGN TASKS

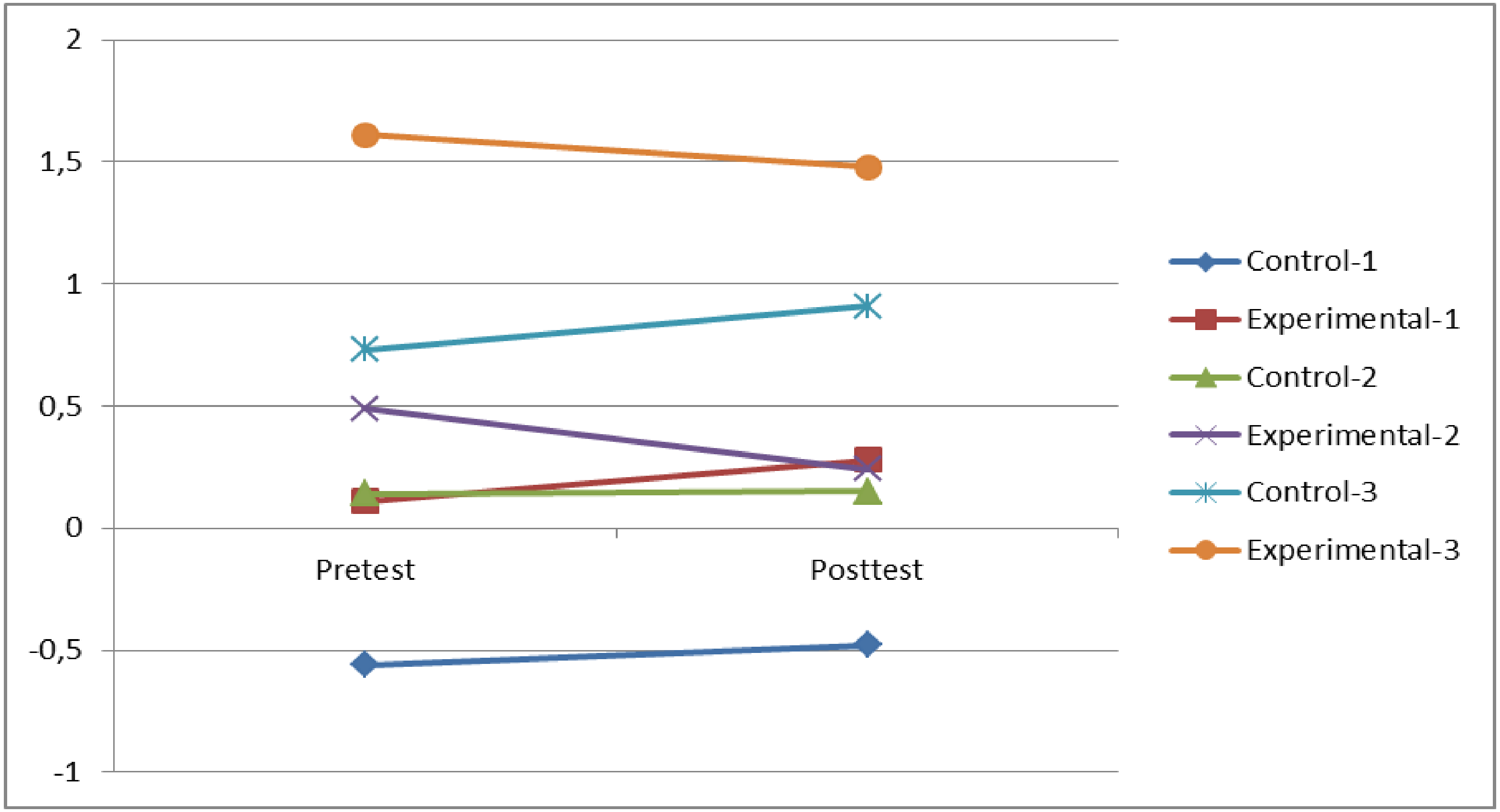
Group	Control / Experimental	$M_{pre\text{-}test}$ (%)	$M_{post\text{-}test}$ (%)	Δ (%)	p (sign: p<0,05)
Boys	control	9.1	16.5	+7.4	sign
	experimental	7.3	24.0	+16.7	sign
	(sign: p<0,05)	non sign	sign		
Girls	control	6.1	11.6	+5.5	sign
	experimental	6.0	22.6	+16.6	sign
	(sign: p<0,05)	non sign	sign		
Lowest achievement on pre-test	control	0.3	6.6	+6.3	sign
	experimental	0.0	10.0	**+10.0**	sign
	(sign: p<0,05)	non sign	non sign		
Medium achievement on pre-test	control	4.6	11.2	+6.6	sign
	experimental	1.2	20.7	**+19.5**	sign
	(sign: p<0,05)	sign	sign		
Highest achievement on pre-test	control	16.7	22.5	+5.8	non sign
	experimental	18.5	38.8	**+20.3**	sign
	(sign: p<0,05)	non sign	sign		

4.5 RESULTS: ACHIEVEMENTS – OTHER TASKS

Group	Control / Experimental	$M_{pre\text{-}test}$ (%)	$M_{post\text{-}test}$ (%)	Δ (%)	p (sign: p<0,05)
Boys	control	30.9	27.0	-3.9 (!)	sign
	experimental	30.3	31.1	+0.8	non sign
	(sign: p<0,05)	non sign	sign		
Girls	control	28.8	28.1	-0.7(!)	non sign
	experimental	30.1	32.0	+1.9	non sign
	(sign: p<0,05)	non sign	sign		
Lowest achievement on pre-test	control	12.0	21.7	**+9.7**	**sign**
	experimental	11.3	22.6	**+11.3**	**sign**
	(sign: p<0,05)	non sign	non sign		
Medium achievement on pre-test	control	28.0	27.8	-0.2	non sign
	experimental	29.3	30.1	+0.8	non sign
	(sign: p<0,05)	non sign	non sign		
Highest achievement on pre-test	control	48.7	33.5	**-15.2 (!)**	sign
	experimental	50.0	42.1	-7.9 (!)	sign
	(sign: p<0,05)	non sign	sign		

4.6 RESULTS: ATTITUDE TOWARD CHEMISTRY

1: lowest achievement; 2: medium achievement; 3: highest achievement



Attitude toward chemistry was not much influenced by the intervention.

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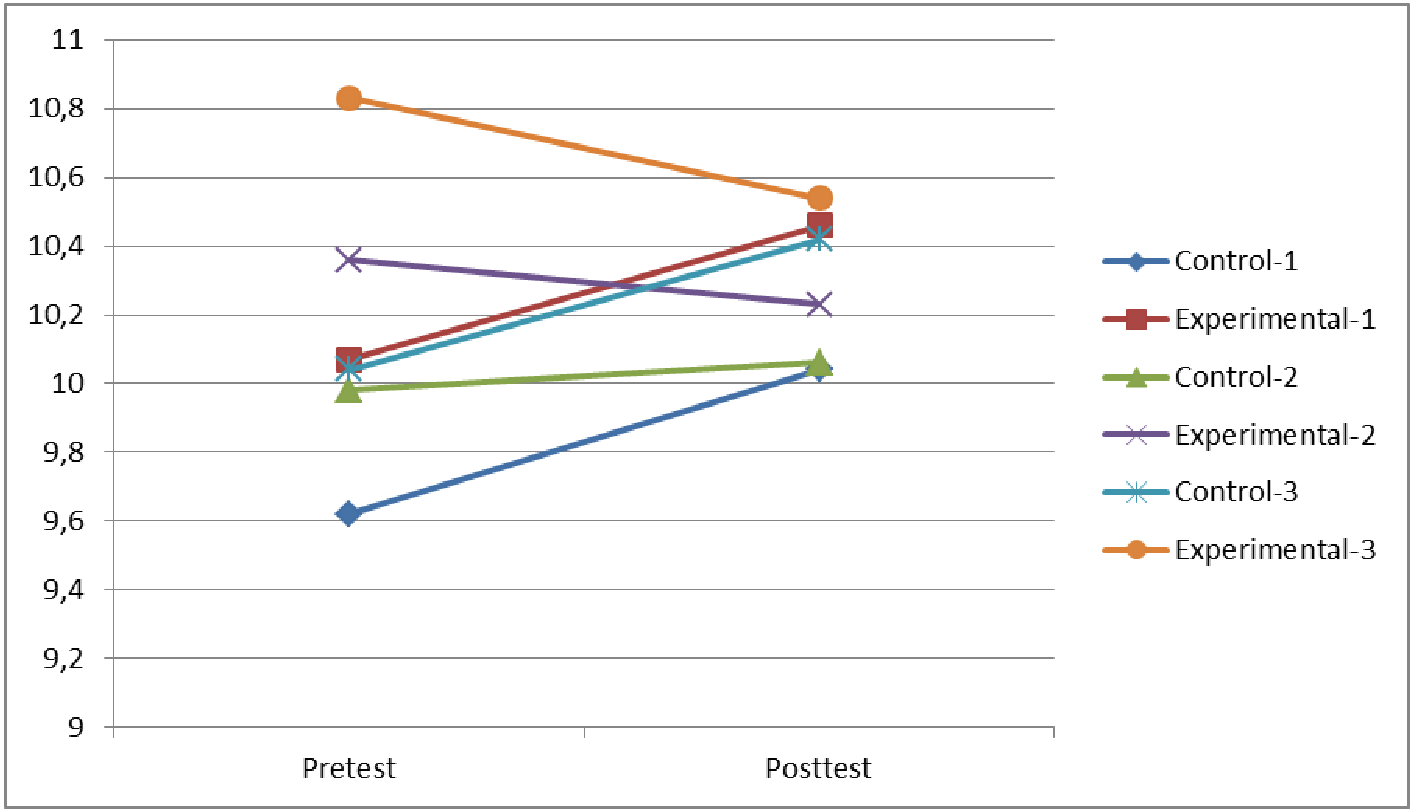
4.6 RESULTS: ATTITUDE TOWARD LEARNING ENVIRONMENT

1: lowest achievement; 2: medium achievement; 3: highest achievement



Attitude toward learning environment (experiments and working in groups) was not much influenced by the intervention either.

4.7 RESULTS: CORRELATIONS (r)

	Pre-test – post-test	Previous year marks – post-test
Control	0.482	0.273
Experimental	0.603	0.283

- There were only small changes in the order of students by their achievements between the two tests
- There were only weak correlations between the previous years marks and the achievements on the post-tests

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5.1 CONCLUSIONS: ABILITY AND KNOWLEDGE

1. Designing tasks: There was a significant positive change in the ability of designing experiments as a result of the short intervention in both the control group and the experimental group, but the change in the experimental group was significantly higher than in the control group. Medium and high achievement students' of the experimental group seemed to gain more on an absolut scale, but lower achievement students gained more on a relative scale.

2. Other tasks: Both boys and girls in the experimental group achieved significantly better scores on the post-test than the students of the control groups, considering the tasks measuring other knowledge, like factual knowledge, understanding and its application. Both the control and the experimental lowest achievement groups had better results on the post-test than on the pretest. However, both the control and the experimental highest achievement groups had worse results on the post-test than on the pretest, but the highest achievement experimental group's results were still significantly better than their control counterpart's.

5.2 CONCLUSIONS: ATTITUDE

3. Attitude: This short intervention did not influence much the students' attitude toward chemistry or their learning environment.

However, there is a significant correlation between the students' achievements on the pre-test and their attitude toward chemistry and chemical industry, whereas this correlation does not exist in the case of attitude toward the chemistry experiments and working in groups.

This is worth of further analysis…

6. IMPLICATIONS

1. It is worth changing traditional practical activities into experiments that are partially designed by students, because these seem to…
   - develop skills needed for scientific literacy
   - motivates lowest achievement group of students.

2. In case of the highest achievement group of students inquiry tasks might have a negative effect on knowledge other than designing experiments gained at the lessons.

3. These short inquiries cannot be expected to influence the students attitude a lot.

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