SEEKING TO IMPROVE STUDENTS' EXPERIMENTAL DESIGN SKILLS

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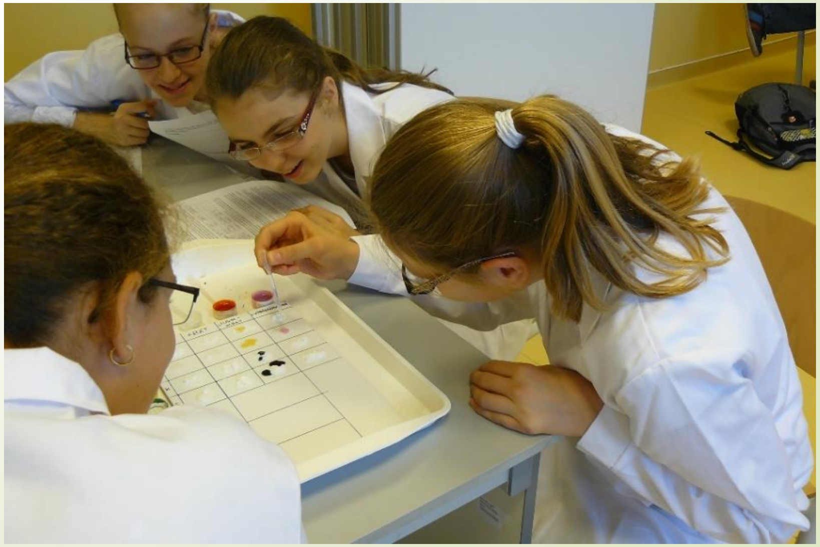
Content

1. Introduction: Results of a previous brief empirical research
2. Research problems and questions
3. Research method
4. Results
5. Conclusions
6. Further plans

http://ttomc.elte.hu/galeria/kemias-mta-projektben-keszult-2-feladatlap-cime-hogyan-mukodik-sutopor-kiprobalasa-2016-osz
(last visited: 25th June 2017)



1.1. A previous brief empirical research[1]

- 3 lessons + pre-test and post-test in school year 2014/15
- 12 Hungarian schools, 15 teachers
- 31 groups of 14-15-year-old students
    - 16 **control** groups: **following ‚step-by-step' recipes** while doing student experiments
    - 15 **experimental** groups: partly **designing and doing** the same student experiments as the control groups
- 660 students completed 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

[1]Financed by TÁMOP 4.1.2.B.2-13/1-2013-0007"NATIONWIDE COORDINATION FOR THE RENEWAL OF TEACHER EDUCATION"

1.2. Results: designing experiments 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		

1.3. Results: 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		

1.4. Conclusion of the brief previous research

- 1. **Designing experiments:**
  - Significant positive change in each group.
  - The change was even greater in the experimental group than in the control group.
- **2. Other tasks**:
  - The lowest achievement groups had better results on the post-test than on the pre-test.
  - The highest achievement groups, especially boys, had worse results on the post-test than on the pre-test, but the experimental group's results were still significantly better than their control counterpart's.
- 3. **It might be worthwhile to change some traditional ‚step-by-step' student experiments to ‚inquiries' partly designed by the students.**

[1] Szalay, L., Tóth, Z., An inquiry-based approach of traditional 'step-by-step' experiments, *Chemistry Education Research and Practice*, 2016, **17**, 923-961.

2. Research problem and questions

- Previous results were built in the pre-service and in-service chemistry teacher education.
- **BUT further investigations are necessary:**
  - What are the long term effects?
  - Can it be done more effectively?
  - How could it be widely and regularly used?
- **Research questions:**
  - 1. Would the difference in the ability of designing experiments between the groups grow in a longitudinal research?
  - 2. Does the intervention change the students' attitudes and motivation?
  - 3. Does it matter if the students actually carry out the designed experiments, or designing the experiments in theory has got similar effect?

3.1. Research method: the project

- **Content Pedagogy Research Program of the Hungarian Academy of Sciences:** 19 projects (2016-2020)
- **MTA-ELTE Research Group on Inquiry-Based Chemistry Education** – members:
  - 24 chemistry teachers and 5 university chemistry lecturers
  - pre-service chemistry teacher students.
- **4 school years:** 4x6=**24** students sheets and teacher guides
- 2016 autumn: pre-test, end of 4 school years: 4 post-tests:
  - experiment designing skills
  - „other" knowledge (e.g. factual)
  - attitude toward chemistry

  measuring development.
- Test questions structured according to Bloom's taxonomy
- Statistical analysis of data.

3.2. Research method: the sample

- 18 secondary school in Hungary, 31 class/group of students (study chemistry for 4 years)
- **883 students,** 7th grade (12-13 years), divided randomly:
  - Group 1: following **‚step-by-step' experiments** (‚control');
  - Group 2: following the same **‚step-by-step' recipes** + **theoretical experiment designing tasks;**
  - Group 3: **designing and doing** the same student experiments as Group 1 and Group 2.
- September 2016**:** **pre-test** **(18 items)**
- September 2016 – May 2017:

  6 practical activities (students sheets with experiments)
- May 2017: **1st post-test** (18 items, same structure than the pre-test), **853 students**, Group 1: 289; .Group 2: 277; Group 3: 287

4.1. Results – all tasks

Group	Pre-test			Post-test			Relative change*	p (sign: p<0,05)
	M (%)	SD (%)	p (sign: p<0,05)	M (%)	SD (%)	p (sign: p<0,05)		
Group 1 (control)	41.0	13.7	Group 3	38.7	21.0	-	-0.0561	non sign
Group 2	39.6	13.7	Group 3	37.0	16.6	Group 3	-0.0657	sign
Group 3	45.3	14.3	Group 1 Group 2	41.6	21.7	Group 2	-0.0817	sign

*Relative change = $(M_{post\text{-}test} - M_{pre\text{-}test}) / M_{pre\text{-}test}$

- Negative change in each group, but only significant in the experimental groups (Group 2 and Group 3).
- Group 3 had significantly better scores on the pre-test than the other two groups → matched pair design method will be necessary.

4.2. Results – designing experiments tasks

Group	Pre-test			Post-test			g-factor*	p (sign: p<0,05)
	M (%)	SD (%)	p (sign: p<0,05)	M (%)	SD (%)	p (sign: p<0,05)		
Group 1 (control)	25.6	17.7	Group 3	34.7	24.9	-	0.122	sign
Group 2	24.6	17.7	Group 3	33.0	20.9	Group 3	0.112	sign
Group 3	31.6	19.4	Group 1 Group 2	38.3	25.8	Group 2	0.099	sign

*g-factor = $(M_{post\text{-}test} - M_{pre\text{-}test}) / (100 - M_{pre\text{-}test})$

- Positive and significant change in each group, but it is the smallest in the case of Group 3.
- Possible reasons
  - Was the method counterproductive for 12-13 years old?
  - Did doing experiments help to learn how to design an experiment and/or the other events of the past school year had this positive effect?

4.3. Results – designing experiments tasks according to the achievement on pre-test*

Group	Pre-test		Post-test		Relative change/ g-factor	p (sign: p<0,05)
	M (%)	SD (%)	**M (%)**	SD (%)		
Group 1 – Lowest achievement	**8.9**	9.3	**22,2**	20.6	0.146	sign
Group 1 – Medium achievement	**22.1**	10.1	**35.7**	26.5	0.175	sign
Group 1 – Highest achievement	**43.8**	16.3	**42.4**	21.4	-0.032	non sign
Group 2 – Lowest achievement	**6.9**	8.3	**21.9**	20.4	0.161	sign
Group 2 – Medium achievement	**21.8**	9.9	**34.1**	20.2	0.157	sign
Group 2 – Highest achievement	**45.0**	13.8	**40.9**	18.3	-0.091	non sign
Group 3 – Lowest achievement	**8.3**	10.7	**19.4**	20.65	0.121	sign
Group 3 – Medium achievement	**25.3**	13.5	**35.0**	2.3	0.130	sign
Group 3 – Highest achievement	**45.2**	15.5	**47.9**	24.3	0.049	non sign

*Groups divided into 3 equal size sub-groups (lowest, medium, highest achivement)

Significant positive change in the lowest and medium achievement sub-groups. – the effect of doing experiments?

4.4. Results – other tasks

Group	Pre-test			Post-test			Relative change*	p (sign: p<0,05)
	M (%)	SD (%)	p (sign: p<0,05)	M (%)	SD (%)	p (sign: p<0,05)		
Group 1 (control)	**56.6**	16.3	-	**42.7**	22.5	-	-0.246	sign
Group 2	**54.7**	15.7	Group 3	**41.1**	19.2	Group 3	-0.249	sign
Group 3	**59.1**	17.8	Group 2	**44.9**	23.9	Group 2	-0.240	sign

*Relative change = $(M_{post\text{-}test} - M_{pre\text{-}test}) / M_{pre\text{-}test}$

- Negative and significant change in each group.
- Possible reasons
  - Were the post-test tasks more difficult than pre-test?
  - Did doing experiments decrease the time available to develop the knowledge of the other territories?

4.5. Results – gender and attitude

- Same trends among the boys' and girls' achievements regardless of their groups or sub-groups.
- Answers to 5 point Likert scale qestions „how much do you like…"
  - pre-test: „sciences" (5th and 6th grade)
  - post-test: „chemistry" (7th grade, i.e. this schoolyear)

  showed that **students liked chemistry less than science**.
- 5 point Likert scale ansvers to qestion: „**How important it is in science to justify our ideas by experiments**?"
  - **Significantly less importance on post-test than on pre-test**.
  - Group 3 had smaller decrease than the Group 1 (control).
- Answers to 5 point Likert scale question in post-test showed students (especially the ones who had the best results!) **definitely preferred the step-by-step expements to the ones that they can design**.

5. Conclusion

- No long term positive effect of designing one or more steps of some experiments on students’ experiment design skills in the case of 12-13 years students.
- Doing **any type** of experiments
  - develop the experimental design skills of the lowest and medium achievment students;
  - do not cause any significant changes in the experiment design skills of the highest achievment students;
  - probably reduce the development of other (e.g. factual) knowledge;
- Chemistry curriculum in Hungary is over-crowded and this de-motivates students.

6. Further plans

- Further steps of this 4-year projects need to be discussed.
- Choose one important aspect of the experiment design and concentrate all efforts on teaching/learning and testing that?
- E.g. „*ceteris paribus*”, i.e.” “holding other things constant”:
  - Group 1: keeps doing only step-by-step experiments;
  - Group 2:
    - does the same step-by-step experiments than Group 1;
    - + learns the *ceteris paribus* principle in theory;
  - Group 3:
    - learns the *ceteris paribus* principle
    - + designs experiments when they have to apply the *ceteris paribus* principle.

Tests: Can they apply this principle while designing experiments?

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