SEEKING TO IMPROVE STUDENTS' EXPERIMENTAL DEIIGN SKILLS

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Content Pedagogy Research Program of the
Hungarian Academy of Sciences: 19 projects (2016-2020)
MTA-ELTE Research Group on Inquiry-Based Chemistry Education

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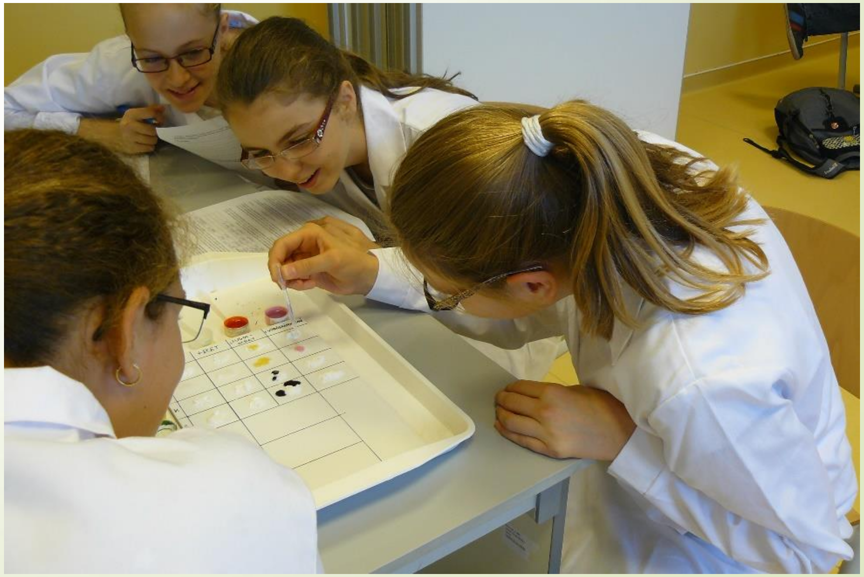
http://ttomc.elte.hu/galeria/kemias-mta-projektben-keszult-2-feladatlap-cime-hogyan-mukodik-sutopor-kiprobalasa-2016-osz (last visited: 25th June 2017)



1.1. A previous brief empirical research[1]

- in school year 2014/15, 3 lessons + pre-test and post-test
- 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. Conclusions of the brief previous research

- 1. **Experiment-designing tasks:**
  - 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 group (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 problems and questions

- Previous results built in the teacher pre-service and in-service teacher education.
- **BUT further investigations are necessary:**
  - What are the long term effects?
  - Can it be done more effectively?
  - How could this method 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:
  - factual knowledge
  - experiment designing skills
  - attitude toward chemistry

  } measuring development.
- Statistical analysis of data.

3.2. Research method: the sample

- 18 secondary schools in Hungary, 31 class/group of students (studying 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, the same structure as 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 (%)	M (%)	SD (%)		
Group 1 (control)	**41.0**	13.7	**38.7**	21.0	**-0.0561**	**non sign**
Group 2	**39.6**	13.7	**37.0**	16.6	**-0.0657**	**sign**
Group 3	**45.3**	14.3	**41.6**	21.7	**-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).**

4.2. Results – experiment-designing tasks

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

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

- **Positive significant change in each group, but 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?**
  - **Or the other events of the past school year had this positive effect?**

4.3. Results – experiment-designing 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 (%)	M (%)	SD (%)		
Group 1 (control)	**56.6**	16.3	**42.7**	22.5	-0.246	sign
Group 2	**54.7**	15.7	**41.1**	19.2	-0.249	sign
Group 3	**59.1**	17.8	**44.9**	23.9	-0.240	sign

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

- Significant negative change in each group.
- Possible reasons
  - Were the post-test tasks more difficult than the pre-test ones?
  - Did doing experiments decrease the time available to develop the knowledge in other fields?

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 questions/statement**:
  - **„How much do you like…"**
    - pre-test: „sciences" (5th and 6th grade)
    - post-test: „chemistry" (7th grade, i.e. this school year)

  showed that **students liked chemistry less than science**

  - **„How important it is in science to justify our ideas by experiments**?"

  Significantly less importance on post-test than on pre-test.

  - **„I prefer step-by-step experiments rather than that designed by myself."**

  showed that students (especially the ones who had the best results!) **definitely preferred the step-by-step experiments to the ones that they can design.**

5. Conclusions

- 12-13-year-old students: No long term positive effect of designing one or more steps of some experiments on students' experiment-designing skills.
- 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 achievement 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 project need to be discussed.
- Should we choose one important aspect of the experiment design and concentrate all efforts on teaching 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 as Group 1;
    - + learns the *ceteris paribus* principle in theory;
  - Group 3:
    - learns the *ceteris paribus* principle
    - + designs experiments where they have to apply the *ceteris paribus* principle.

Tests: Can they apply this principle while designing experiments?

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THANK YOU FOR YOUR ATTENTION!