How can we teach the experiment design skills?

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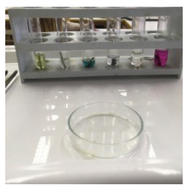
One aspect of the knowledge areas of scientific literacy is **evaluating and designing a scientific enquiry**[1]

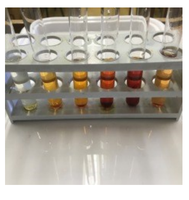
Therefore, **the development of experiment design skills is important**.

- Positive results of our earlier research[2]**.** The control group did 'step-by-step' experiments. The experimental group designed one or more of the experiments before doing them. All students were 14-15 year olds.
- Investigations are necessary to answer these **research questions**:
  1. Would the difference between in the ability of control and experimental groups to design experiments increase over a 4 year period (longitudinal study)?
  2. Does taking responsibility for designing experiments change students' attitude and motivation to chemistry?
  3. Are students' experiment design skills affected by whether or not they do the designed experiments?

[1] PISA 2015 Assessment and Analytical Framework: Science, Reading, Mathematic and Financial Literacy, PISA, OECD Publishing, Paris.

[2] Szalay, L., Tóth, Z., (2016), An inquiry-based approach of traditional 'step-by-step' experiments, *Chem. Educ. Res. Pract.*, **17**, 923-961.





Research group:

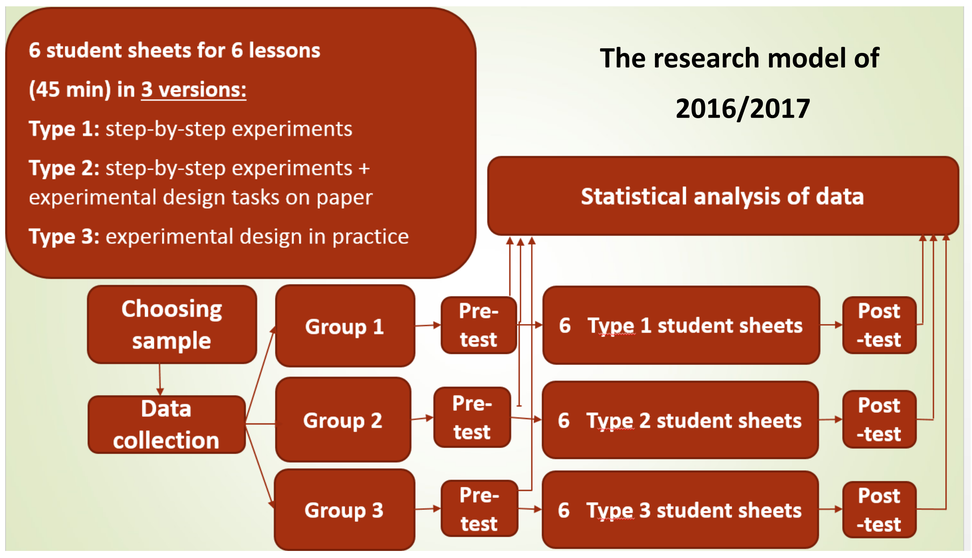
- 25 chemistry teachers, 5 university chemistry lecturers and presently 4 pre-service chemistry teacher students

Research method:

- **4 school years** (2016-2020); **6 students sheets + teacher guides / school year** (altogether: 4x6=**24**)
- **5 tests** (pre-test: September 2016; 4 post-tests in the end of the school years; each consists of 18 items: 3 items for recall, 3 items for understanding, 3 items for application, 9 items for experiment design skills)

Sample:

- 18 secondary schools in Hungary, 31 classes of students (they study chemistry for 4 years)
- **920 students,** 7th grade in 2016/2017 (12-13 years), divided randomly into three groups described below



1st year: school year 2016/2017

Activities of the 3 groups of students:

- Group 1 ('control'): follow **'step-by-step' recipes when doing the experiments**
- Group 2: follow the same **'step-by-step' recipes and design other experiments 'on paper'**
- Group 3: doing the same student experiments as Group 1 and Group 2 , but **design one or more experiments before doing them**.

Statistical methods: calculation of mean, standard deviation, relative change, g-factor, correlation coefficient, analysis of variance (ANOVA), independent-samples T-test (F-test)

(Note: Group 3 had significantly better scores on the pre-test than the other two groups, therefore matched pair design method was necessary.)

Most important test result: Group 3 students got lower scores for the experiment designing tasks on the first post-test than Group 2 students.

2nd year: school year 2017/2018

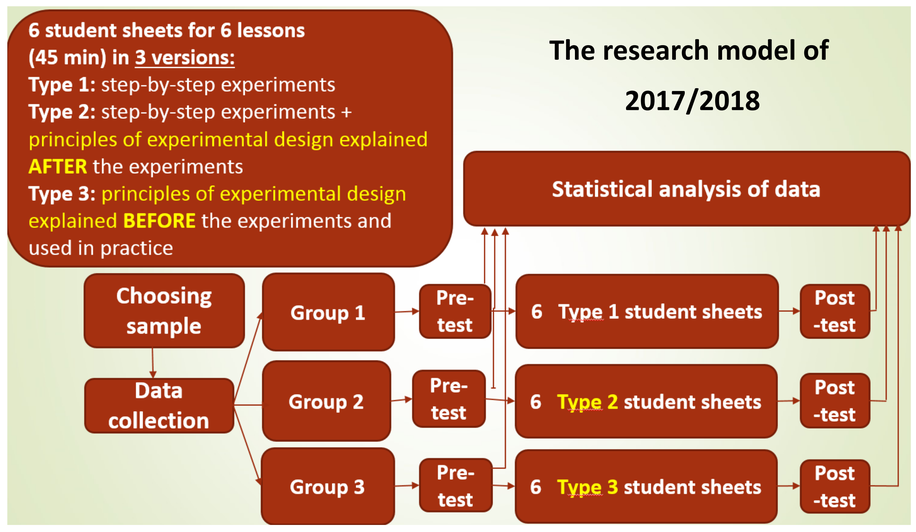
After discussions with experts of psychology and assessment it was concluded that **the important aspects of the experimental design has to be taught** and different methods of statistical analysis are needed.

Activities of the 3 groups of students:

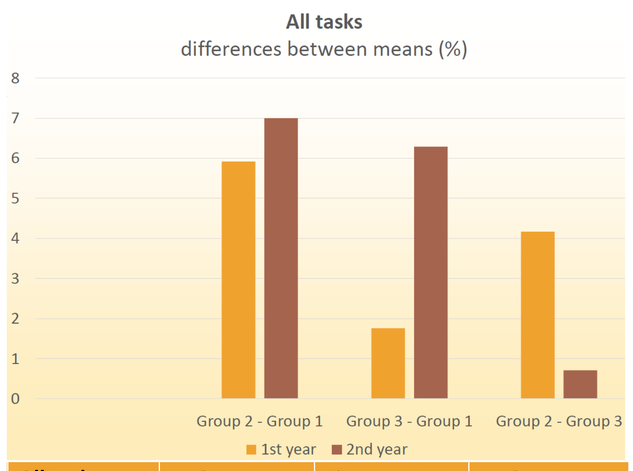
- Group 1 (,control'): follow **'step-by-step' recipes** when doing the **experiments**
- Group 2: follow the same 'step-by-step' recipes and **are then given explanations of the experimental design of these recipes**
- Group 3: do the same student experiments as Groups 1 and 2 , but **with guidance about experimental design before planning and carrying out some of the experiments .**

Statistical methods: calculation of mean, standard deviation, correlation coefficient, **difference between means** (measured at the same time), **Cohen's d** (between two measurements).

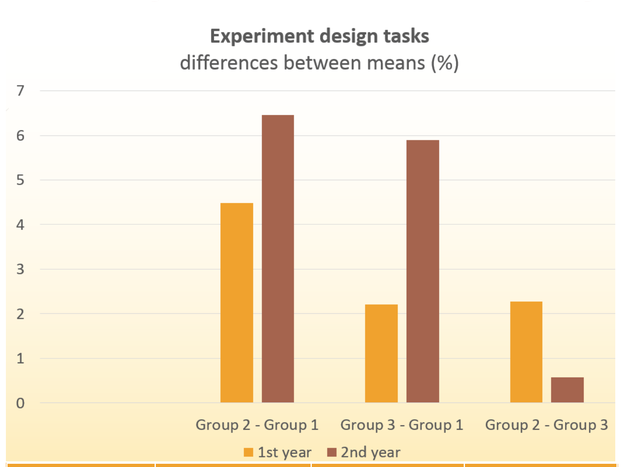
Aspects of the experimental design taught e.g. dependent and independent variables; significant features of a modelling experiment; main principles of qualitative and quantitative analysis.



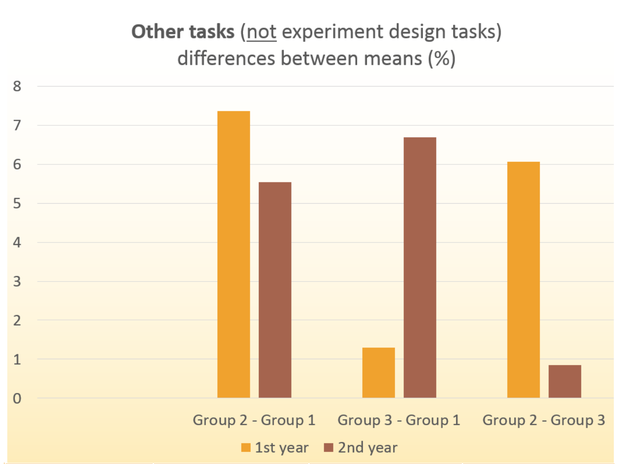
Statistical analysis of the 1st and 2nd year tests



All tasks	Pre-test 1st post-test	1st post-test 2nd post-test	Pre-test 2nd post-test
	Cohen's *d**		
Group 2	**0,28**	0,04	**0,33**
Group 3	0,08	0,16	**0,28**

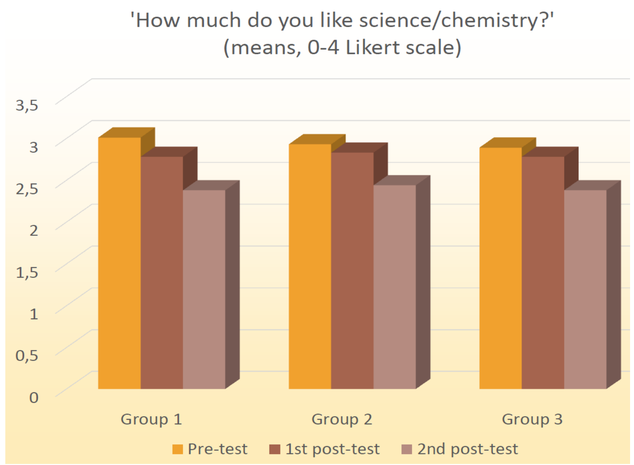


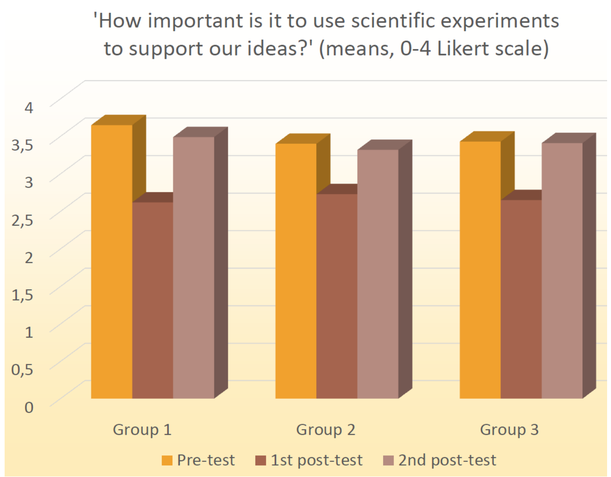
Experimental design tasks	Pre-test 1st post-test	1st post-test 2nd post-test	Pre-test 2nd post-test
	Cohen's *d**		
Group 2	0,14	0,06	**0,22**
Group 3	0,05	0,10	0,11

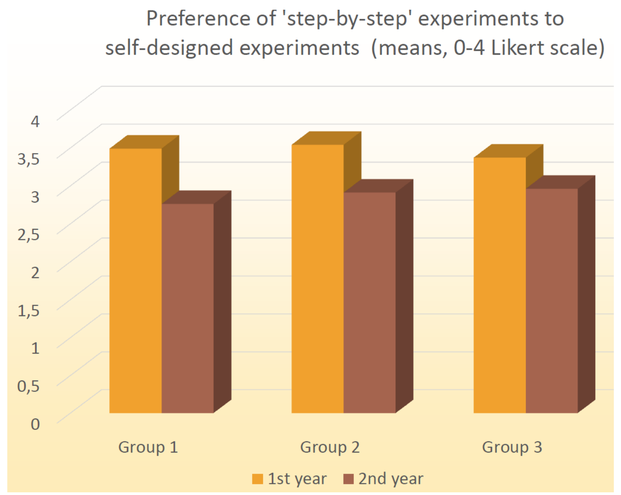


Other tasks	Pre-test 1st post-test	1st post-test 2nd post-test	Pre-test 2nd post-test
	Cohen's *d**		
Group 2	**0,33**	0,01	**0,31**
Group 3	0,14	0,19	**0,34**

Cohen's *d is an effect size used to indicate the standardised difference between two means. The values in **bold** show significance at the 0.05 probability level.







Some positive changes in attitude toward chemistry:

- Group 2 boys: mainly in the 1st year
- Group 3 girls: mainly in the 2nd year

Group 3 boys very strongly favour the 'step-by-step' experiments to the ones they have to design.

The intervention had a positive influence on the achievements and the attitude of students who either had the lowest or the highest marks on the pre-tests.

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Many thanks for all the colleagues' work.

Summary of the results

- Experiment design tasks: weak positive development for Groups 2 and 3, but it is only statistically significant for Group 2 students' in the 2nd year.
- Other tasks: moderate positive development in case of Group 2 students in the 1st year and for both Groups 2 and 3 by the end of the 2nd year.

Conclusion

- The Group 2 interventions appear more successful at this age and in long term.
- It seems advantageous to teach experimental design skills.

New questions

- Were Group 3 students affected by cognitive overload?
- Can we confirm our belief that it is beneficial to teach the principles of experimental design skills prior to students designing an experiment?

THE 2nd YEAR RESEARCH MODEL WILL BE USED FOR THE FINAL 2 YEARS OF THE PROJECT.