How can we teach the experiment design skills?

Edina Kiss1, Luca Szalay1, Zoltán Tóth2

1ELTE, Eötvös Loránd University, Budapest, Faculty of Science, Institute of Chemistry, Pázmány Péter sétány 1/A, H-1117 Budapest, Hungary, dr.kissed@gmail.com
2University of Debrecen, Faculty of Science and Technology, Institute of Chemistry, Egyetem tér 1., H-4010 Debrecen, Hungary

One aspect of the knowledge areas of scientific literacy is evaluating and designing a scientific inquiry1 Therefore, the development of experiment design skills is important.

1. We got positive results in 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 years old.

2. Further investigations were necessary to answer the following research questions:
   1. Would the difference between 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 did the designed experiments?

4. Research group: 25 chemistry teachers, 5 university chemistry lecturers and until now 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, 33 classes of students (they study chemistry for 4 years)
- 520 students, 3rd grade in 2016/2017 (12-13 years), divided randomly into three groups described below

The intervention could not stop the negative trends in the attitude of students to chemistry.

The research model of 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 experiments as Group 1 and Group 2, but design one or more experiments before doing them.

Statistical methods: calculation of mean, standard deviation, analysis of covariance (ANCOVA).

The development of the experimental groups (Group 2 and Group 3) was shown by the Cohen’s d that is an effect size to indicate the standardised difference between two means.4

(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.

Cohen’s d value of 1 indicates that the means of the two groups differ by 1 standard deviation. Values around 0.4-0.5 medium and 0.2 large. The Cohen’s d values were calculated taking into consideration the means and standard deviations approximated by the ANCOVA analysis.

The values in bold show significance at the 0.05 probability level.

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Students in each group thought the role of science experiments significantly less important when they had studied chemistry for a year than they did when they had studied science. (The previous two school years). This negative trend turned back in the second year of the project.

Student very strongly favour the ‘step-by-step’ experiments to the ones they have to design.

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The 2nd year research model is used for the final 2 years of the project.

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