SEEKING TO IMPROVE STUDENTS’ EXPERIMENTAL DESIGN 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
Content

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(last visited: 25th June 2017)
1.1. A previous brief empirical research

- 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

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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.

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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 measuring development.
  - attitude toward chemistry
- 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

<table>
<thead>
<tr>
<th>Group</th>
<th>Pre-test</th>
<th>Post-test</th>
<th>Relative change*</th>
<th>p (sign: p&lt;0.05)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M (%)</td>
<td>SD (%)</td>
<td>M (%)</td>
<td>SD (%)</td>
</tr>
<tr>
<td>Group 1 (control)</td>
<td>41.0</td>
<td>13.7</td>
<td>38.7</td>
<td>21.0</td>
</tr>
<tr>
<td>Group 2</td>
<td>39.6</td>
<td>13.7</td>
<td>37.0</td>
<td>16.6</td>
</tr>
<tr>
<td>Group 3</td>
<td>45.3</td>
<td>14.3</td>
<td>41.6</td>
<td>21.7</td>
</tr>
</tbody>
</table>

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

- Negative change in each group, but only significant in the experimental groups (Group 2 and Group 3).
4.2. Results – experiment-designing tasks

<table>
<thead>
<tr>
<th>Group</th>
<th>Pre-test</th>
<th>Post-test</th>
<th>g-factor*</th>
<th>p (sign: p&lt;0.05)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M (%)</td>
<td>SD (%)</td>
<td>M (%)</td>
<td>SD (%)</td>
</tr>
<tr>
<td>Group 1 (control)</td>
<td>25.6</td>
<td>17.7</td>
<td>34.7</td>
<td>24.9</td>
</tr>
<tr>
<td>Group 2</td>
<td>24.6</td>
<td>17.7</td>
<td>33.0</td>
<td>20.9</td>
</tr>
<tr>
<td>Group 3</td>
<td>31.6</td>
<td>19.4</td>
<td>38.3</td>
<td>25.8</td>
</tr>
</tbody>
</table>

\[ g\text{-factor} = \left( \frac{M_{\text{post-test}} - M_{\text{pre-test}}}{100 - M_{\text{pre-test}}} \right) \]

- 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*

<table>
<thead>
<tr>
<th>Group</th>
<th>Pre-test</th>
<th>Post-test</th>
<th>Relative change/g-factor</th>
<th>p (sign: p&lt;0.05)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M (%)</td>
<td>SD (%)</td>
<td>M (%)</td>
<td>SD (%)</td>
</tr>
<tr>
<td>Group 1 – Lowest achievement</td>
<td>8.9</td>
<td>9.3</td>
<td>22.2</td>
<td>20.6</td>
</tr>
<tr>
<td>Group 1 – Medium achievement</td>
<td>22.1</td>
<td>10.1</td>
<td>35.7</td>
<td>26.5</td>
</tr>
<tr>
<td>Group 1 – Highest achievement</td>
<td>43.8</td>
<td>16.3</td>
<td>42.4</td>
<td>21.4</td>
</tr>
<tr>
<td>Group 2 – Lowest achievement</td>
<td>6.9</td>
<td>8.3</td>
<td>21.9</td>
<td>20.4</td>
</tr>
<tr>
<td>Group 2 – Medium achievement</td>
<td>21.8</td>
<td>9.9</td>
<td>34.1</td>
<td>20.2</td>
</tr>
<tr>
<td>Group 2 – Highest achievement</td>
<td>45.0</td>
<td>13.8</td>
<td>40.9</td>
<td>18.3</td>
</tr>
<tr>
<td>Group 3 – Lowest achievement</td>
<td>8.3</td>
<td>10.7</td>
<td>19.4</td>
<td>20.65</td>
</tr>
<tr>
<td>Group 3 – Medium achievement</td>
<td>25.3</td>
<td>13.5</td>
<td>35.0</td>
<td>2.3</td>
</tr>
<tr>
<td>Group 3 – Highest achievement</td>
<td>45.2</td>
<td>15.5</td>
<td>47.9</td>
<td>24.3</td>
</tr>
</tbody>
</table>

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

Significant positive change in the lowest and medium achievement sub-groups. – the effect of doing experiments?
### 4.4. Results – other tasks

<table>
<thead>
<tr>
<th>Group</th>
<th>Pre-test</th>
<th></th>
<th>Post-test</th>
<th>Relative change*</th>
<th>p (sign: p&lt;0.05)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M (%)</td>
<td>SD (%)</td>
<td>M (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group 1 (control)</td>
<td>56.6</td>
<td>16.3</td>
<td>42.7</td>
<td>-0.246</td>
<td>sign</td>
</tr>
<tr>
<td>Group 2</td>
<td>54.7</td>
<td>15.7</td>
<td>41.1</td>
<td>-0.249</td>
<td>sign</td>
</tr>
<tr>
<td>Group 3</td>
<td>59.1</td>
<td>17.8</td>
<td>44.9</td>
<td>-0.240</td>
<td>sign</td>
</tr>
</tbody>
</table>

*Relative change = (M_{post-test} - M_{pre-test}) / M_{pre-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 achievement 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?
This study was funded by the Content Pedagogy Research Program of the Hungarian Academy of Sciences. Many thanks for all the colleagues’ work.

THANK YOU FOR YOUR ATTENTION!