Opportunity assessment for the introduction of the integrated learning unit in chemistry education

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Abstract

This study is a structural analysis of chemistry teaching efficiency, in order to streamline the students’ learning process. After introducing the integrated learning unit concept, which includes laboratory experiments as well as other learning methods, our paper presents a comparative analysis of how students achieve their educational goals through classical laboratory experiments vs. the integrated learning unit. To investigate the efficiency of the integrated learning unit compared with other forms of teaching we have evaluated the performance of three groups of students. After statistical analysis, we concluded that the introduction and use of integrated learning units increases the students’ learning efficiency.

Keywords: Cross-curricular skills, Integrated curriculum, Integrated learning unit, Key competencies, Laboratory experiments, Problem-based learning, Project-based learning, Student teaching/learning methods.

1. Introduction

Integrated curriculum and integrated learning unit (ILU) are two concepts with a long tradition. Both concepts are also very important because of their contribution to learner-centred education. Most class time is traditionally spent with teachers directing the learning process and students assuming a receptive role by watching and listening, with a small provision for formative feedback.

The ILU approach allows students to learn in a way that is more natural to them. The benefits include more adequate planning and implementation of the curriculum, addressing students’ needs and interests, creating an incentive learning environment, improving teaching management and allowing flexible schedule (Krogh, 1990).

There is a wide range of ILU practices along a continuum from more theoretical to very practical and creative forms of learning. Two of them are further discussed in this paper, namely problem-based learning and project-based learning.

Laboratory experiments have their importance in effective learning chemistry. However, the role of experiments is enhanced if they are integrated into the ILU.

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2. Integrated Learning Unit

Traditional curriculum is divided into distinct disciplines with their own learning objectives and methodology of teaching. In contrast, the integrated curriculum links multiple curricular areas and encourages the inter-disciplinary and trans-disciplinary approach. In its simple conception the integrated curriculum is about making connections, be they knowledge-based and/or skill-based connections (Drake and Burns, 2004, p.13).

The subject of curriculum integration has been under discussion for more than fifty years. The more and more diverse knowledge, skills and transversal competencies that students need to achieve, the lack of connections and relationships among disciplines and the concern about curriculum relevancy are, but some, of the reasons for a move towards an integrated curriculum (Jacobs, 1989).

In this context one interesting example is the EU Reference Framework that sets out eight competencies for lifelong learning and implies an integrated approach for a number of themes: problem-solving, critical thinking, creativity, initiative, integrated assessment, decision-taking and others. One competence closely related with our chemistry education topic of this paper is “the mathematical competence and basic competencies in science and technology” that is defined as “the ability and willingness to use the body of knowledge and methodology employed to explain the natural world, in order to identify questions and to draw evidence-based conclusions” (European Reference Framework, 2006, p.10-18). In other words, to achieve this key competence all education actors – curriculum developers, teachers, students and other stakeholders – are encouraged to ensure both an integrated learning approach within mathematics and science and a better connection of both with the natural world.

Following the idea of integrated curriculum, we have implemented for many years the integrated learning unit (ILU) in chemistry curriculum for high school and undergraduate students in our country. In the classical curriculum a teaching/learning unit usually contains a number of inter-related topics, their specific objectives and/or learning outcomes, teacher and students’ activities, suggestions for assessment and required resources. The unit is taught in the classroom through different teaching/learning methods that sometimes include activities in the laboratory and/or ICT facilities (i.e. tutorials, simulations).

The ILU uses diverse forms of learning: connecting skills and knowledge from multiple sources and experiences, applying skills and practices in various educational contexts, implementing active learning and utilizing diverse learning resources (Norbert et al., 2008).

Particularly, in chemistry education the ILU integrates:
- knowledge from other disciplines (i.e. physics: gas laws, enthalpy; mathematics: equations, derivation);
- cross-curricular skills (i.e. collecting, interpreting and reporting data; identifying and controlling variables; formulating hypotheses and experimenting);
- student-centred learning methods (i.e. active and cooperative learning, problem-based learning, project-based learning, discovery-learning and others);
- classroom and laboratory learning resources and equipment.

In the paragraphs below we give a short description of classical laboratory experiments vs. two student-centred learning methods that we frequently use in our chemistry ILU strategy.

2.1. Classical Laboratory Experiments

The main role of the traditional experiments is to expose the students to basic laboratory and core chemical principles. These are mainly done under standardized instructions under the direct supervision of the teacher. However, since chemistry is not only a collection of facts but also a learning process about the real world, the students, depending on their age, should be encouraged towards competencies such as: make observations, design experiments, use laboratory instruments and draw conclusions. Also, safety and waste management information should be included (Kent et al., 2000, p. 36-39).

Example: Ask your students to bring to the laboratory different samples of water, such as pool water, tap water, bottled water, rain water etc. The students in small groups, using a pH tester kit, should test the pH of the collected samples and record the findings.
2.2. Problem-Based Learning (PBL)

In PBL students work in small groups to define, carry out and reflect mainly on a ‘real-life’ problem (Breslow et al., 2005). Through PBL students are encouraged to develop their problem solving skills, critical thinking, creativity as well as initiative and responsibility for their own learning (self-directed learning). Also, PBL helps the development of collaboration skills and intrinsic motivation (Hmelo-Silver, 2004, p. 241-245).

Example: Students are asked to make a laboratory investigation to determine the concentration of Vitamin C in a solution by redox titration with iodine. As resources they can use Vitamin C tablets, fruits, vegetables and juices. At the end of the investigation they should record the results and present them to the other groups.

2.3. Project-Based Learning (PjBL)

Project-based Learning combines PBL and learning from experience. This brings together investigations, real-world problems and student engagement in relevant practical work (Barron et al., 1998). Planning and preparation are amongst the most important factors for successful work on a project.

Example: Students are asked to research the “Presence of Insecticides and Pesticides in Vegetables”. To carry out this project students need to plan carefully: the hypothesis, the research procedure, the materials required, the observations recorded, the conclusion and the method of reporting.

3. Experimental Design

The authors were interested in whether the different teaching methods have significant influence on students’ performance. The sample was composed by ninety 11th high school students who were randomly assigned into three groups. In order to teach the chemistry unit named “Additive Reaction” we used three teaching/learning methods, namely: (i) laboratory experiments method (experimental group 1); (ii) integrated learning method (experimental group 2); and (iii) classical learning method (control group). The latter represents the method through which the students are not taught the chemistry experiments in the laboratory but in the classrooms using different teaching aids (charts, simulation software etc.)

At the end of the teaching period all groups had a two-hour test. The test consisted of two parts. The first part had 50 multiple choice items, scoring 1 point each and the second part contained 5 short practical tasks, scoring 10 points each which also allowed for partial scoring.

After collecting the data we looked at the average test scores for students exposed to one of the three different learning methods (three levels of a single independent variable). We than asked ourselves if we could come to the conclusion that the average of the dependent variable (score) is different for all groups. The null hypothesis of the experiment assumed that the independent variable (learning method) had no effect on the dependent variable (score), i.e. there are no differences between means, while the alternative hypothesis assumed that the learning method has an effect on student’s scores, i.e. the means are different.

Null hypothesis  \( H_0: \mu_1 = \mu_2 = \mu_3 \) all means are equal, against
Alternative hypothesis  \( H_1: \mu_1 \neq \mu_2 \neq \mu_3 \) at least one of the means is different from the others

A one-way ANOVA (Howitt and Cramer, 2005, p.155-162) was performed to test the effects of teaching method on students’ performance, followed by a t-test.

4. Results

Table 1 displays the descriptive statistics of our experiment. The number of subjects (N=30) is equal for each group and the group means are 52.17, 58.43 and 69.23, respectively.

In order to check the homogeneity of the variance of the three distributions a Lavene’s HSD test was performed. As shown in table 2 the significance value exceeds 0.05, proving that the variances for the three distributions are equal, therefore the assumption is justified.
Table 1. Descriptive Statistics

<table>
<thead>
<tr>
<th>Groups</th>
<th>N</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Std. Error</th>
<th>Lower Bound</th>
<th>Upper Bound</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control Group</td>
<td>30</td>
<td>52.17</td>
<td>15.953</td>
<td>2.913</td>
<td>46.21</td>
<td>58.12</td>
<td>25</td>
<td>84</td>
</tr>
<tr>
<td>Experimental Group 1</td>
<td>30</td>
<td>58.43</td>
<td>18.152</td>
<td>3.314</td>
<td>51.66</td>
<td>65.21</td>
<td>28</td>
<td>90</td>
</tr>
<tr>
<td>Experimental Group 2</td>
<td>30</td>
<td>69.23</td>
<td>14.564</td>
<td>2.659</td>
<td>63.79</td>
<td>74.67</td>
<td>37</td>
<td>91</td>
</tr>
<tr>
<td>Total</td>
<td>90</td>
<td>59.94</td>
<td>17.597</td>
<td>1.855</td>
<td>56.26</td>
<td>63.63</td>
<td>25</td>
<td>91</td>
</tr>
</tbody>
</table>

Table 2. Test of Homogeneity of Variances

<table>
<thead>
<tr>
<th>Lavene Statistics</th>
<th>Df1</th>
<th>Df2</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>793</td>
<td>2</td>
<td>87</td>
<td>.456</td>
</tr>
</tbody>
</table>

The findings of ANOVA are displayed in table 3.

Table 3. ANOVA

<table>
<thead>
<tr>
<th>Sum of Squares</th>
<th>Df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>4471.822</td>
<td>2</td>
<td>2235.911</td>
<td>8.426</td>
</tr>
<tr>
<td>Within Groups</td>
<td>23086.900</td>
<td>87</td>
<td>265.367</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>27558.722</td>
<td>89</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

We found that the F-ratio has a p-value of 0.00045. As we have set the alpha level at 0.05 this result is significant. However, this only supports the alternative hypothesis that the learning method has an effect on the students’ score. For meaningful findings, we must see if the experimental treatments were significantly different to each other. To do this, comparisons had to be made between the experimental conditions. That is why, after the ANOVA analysis, we ran a t-test for each pair of means for the three groups. The results of Tukey’s HSD test are shown in table 4.

Table 4. Multiple Comparisons

<table>
<thead>
<tr>
<th>(I) Group</th>
<th>(J) Group</th>
<th>Mean Diff. (I-J)</th>
<th>Std. Error</th>
<th>Sig.</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control Group</td>
<td>Experimental Group 1</td>
<td>-6.267</td>
<td>4.206</td>
<td>.301</td>
<td>-16.30</td>
</tr>
<tr>
<td></td>
<td>Experimental Group 2</td>
<td>-17.067*</td>
<td>4.206</td>
<td>.000</td>
<td>-27.10</td>
</tr>
<tr>
<td>Experimental Group 1</td>
<td>Control Group</td>
<td>6.267</td>
<td>4.206</td>
<td>.301</td>
<td>-3.76</td>
</tr>
<tr>
<td></td>
<td>Experimental Group 2</td>
<td>-10.800*</td>
<td>4.206</td>
<td>.032</td>
<td>-20.83</td>
</tr>
<tr>
<td>Experimental Group 2</td>
<td>Control Group</td>
<td>17.067*</td>
<td>4.206</td>
<td>.000</td>
<td>7.04</td>
</tr>
<tr>
<td></td>
<td>Experimental Group 1</td>
<td>10.800*</td>
<td>4.206</td>
<td>.032</td>
<td>7.77</td>
</tr>
</tbody>
</table>

*The mean difference is significant at the 0.05 level

We can see that significant differences were found between the experimental group 2 and the control group, on the one hand and between the experimental groups 2 and 1, on the other hand. There was no significant difference between the experimental group 1 and the control group.

5. Conclusion

The results suggest that the integrated learning unit method has an important influence on students’ performance in comparison with the other methods used. This proves that the integrated learning unit is an alternative form of learning which has value in a certain set of circumstances as outlined in the first part of this paper. To determine the magnitude of its influence in the long term, we started to use integrated learning in other teaching units and grades and convince our colleagues to also try it. However, there are some difficulties in the daily implementation of this method which concern the availability of resources and school schedules.

Alternatively and somehow surprisingly is the fact that learning only through experiments in laboratories does not help students to effectively learn chemistry to any great extent. One of the reasons that we have noticed is that students do not have enough autonomy in doing the experiments and quite often prefer to follow the teacher’s instructions. However, this finding should be further investigated.
References


