article:1131

Critical Thinking in the Chemistry Classroom and Beyond

Critical thinking is often associated with subjects such as philosophy and social sciences. In contrast, chemistry – and chemistry education – hardly consider explicit concepts of disciplines like logic, epistemology or ethics. This leads to the curious situation that chemists make ample use of logical reasoning (e.g. during the interpretation and discussion of experimental results), yet learn little about the foundations of such thinking. The study at the School of Chemistry at Exeter was therefore driven by the following question: Can learning of simple concepts of critical thinking, which are embedded within the chemistry curriculum, improve students' performance in chemistry?

In this study, I familiarised 2^{nd} and 3^{rd} year undergraduate chemistry students with basic concepts of classical logic, such as Modus Ponens, Modus Tollens and a couple of common logical fallacies. These concepts were presented within the context of chemistry, *i.e.* by employing examples of chemical relevance. For example, the silver nitrate reaction with halides was used to explain how an observed event ('precipitation') can be used to deduce the presence (or absence) of a particular halide anion. Similarly, different colours in solution can be used to deduce the presence of particular metal ions. On the other hand, the rather familiar 'negative controls' - as employed in biochemistry - were used to explain the Disjunctive Syllogism. The latter allows us to deduce the presence of one particular entity by ruling out the presence of all others. This exercise took no more than 90 minutes in total, and was great fun for all involved.

After these exercises were completed, I was able to analyse the learning outcome by assessing two different student cohorts, *i.e.* one with and one without the 90 minutes of prior exposure to logical concepts. The cohort of students with prior exposure included 18 students and was assessed after the 90 min learning event, the one without prior exposure included 38 students and was assessed before the 90 min event. Importantly, the assessments were carried out in two different academic years (2002 and 2001, respectively) to avoid cross-influencing of the two groups. Yet students in the two cohorts were at exactly the same undergraduate level, and the cohorts did not differ significantly in achievement levels, gender, race or prior exposure to math courses (although a statistical analysis for similarity factors was not carried out). Since none of the students was part of both cohorts, or assessed twice, possible systematic disturbances of the assessment were unlikely.

This assessment was done by using a questionnaire containing logical reasoning which was packed within a chemistry context. Students were asked to assess and analyse a number of simple statements, such as "Electrolysis of aqueous sodium chloride solutions leads to the generation of hydrogen at the cathode and chlorine at the anode. During power failure, electrolysis does not occur and therefore it is expected that chlorine is not observed at the anode." Most students without prior exposure judged the validity of such deductions by using their experience or ‘gut feeling’, and often made mistakes by not realising that such deductions ‘sounded right’, yet were not strictly valid deductions and could easily be rejected by simple counter examples. In stark contrast, students who had learned to dissect such passages and determine the underlying logical structure easily spotted fallacies, unearthed implicit assumptions and ultimately provided the correct answers.

Overall, student performance increased from an average of around 55% correct answers in the cohort without exposure to logical concepts to around 80% correct answers in the cohort which had attended the 90 min introduction. In addition, the latter cohort was also able to employ a basic logical formalism to ‘translate’ passages into their logical format. This greatly helped them to decide if a conclusion drawn was certain, possible or impossible. Although I did not perform a full statistical analysis of these percentages at that early stage of the research, the overall trend was clear: Learning basic logic helped chemistry students to deal with correct - and wrong - conclusions.

At the end of the course, students were asked to fill out an evaluation questionnaire where they could provide their rating of the critical thinking module. Not surprisingly, the module received high marks (around 7/10 in most categories) and was seen as a valuable addition to the conventional chemistry curriculum at the University.

Naturally, this study had weaknesses that need to be addressed in the future. One major weakness is the limited number of students and instruments available at the time to monitor the learning process, which made a full statistical analysis of the results difficult.

Author 1: Claus Jacob email: c.jacob@ex.ac.uk

: Back to Fall 2005 Issue Vol. 1, No. 2

: Back to List of Issues

: Back to Table of Contents