Evaluation of a New Interactive First-Year Undergraduate Symmetry Coursework Activity

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1. Introduction

The knowledge of symmetry operations and point groups in first-year undergraduate chemistry is crucial for the understanding of more advanced topics in later years (Rosen, 1973), such as spectroscopy, group theory and crystallography. However, symmetry is a topic with which many first-years struggle (Carlisle *et al.*, 2015). In particular, the visualisation of molecules in 3D and applying symmetry operations presents a key challenge for many students. Strategies to overcome these challenges have been proposed, such as guided activities (Carlisle *et al.*, 2015; Luxford *et al.* 2012), 3D models (Flint, 2011) and even a periodic table of point groups derived from everyday objects (Fuchigami, *et al.*, 2016). With our activity, we combined the strategies of familiarity with everyday objects (Fig. 1), peer dialogue and guided activities to aid students' understanding of symmetry operations and point groups. Pre- and post-coursework quizzes and questionnaires were used to determine the activity's effectiveness at improving understanding and engagement.

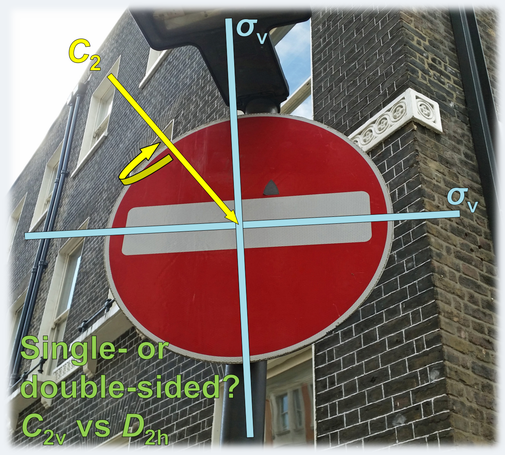

Figure 1: Symmetry of a road sign?

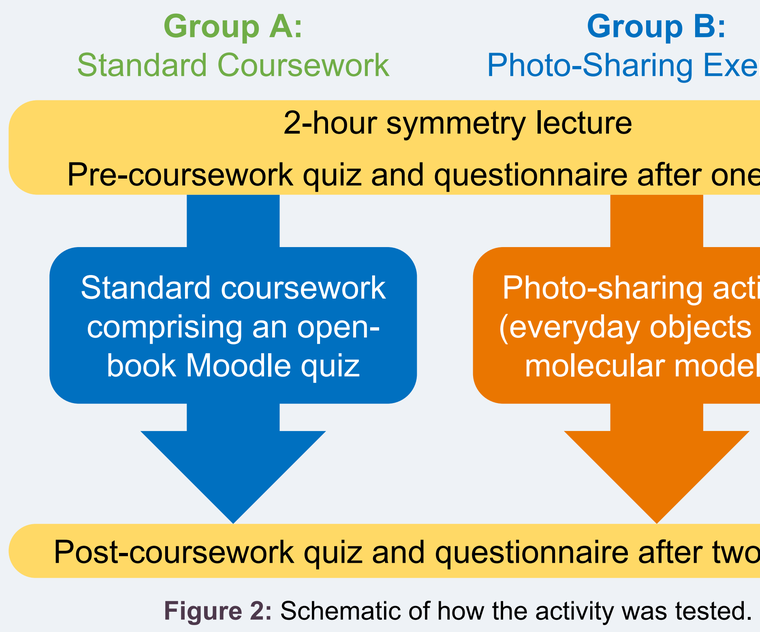

Figure 2: Schematic of how the activity was tested.

2. The Activity & Method

Group discussion and peer dialogue is known to foster deeper learning (Boyle and Nicol, 2003), so these methods were employed during this activity (outlined in Fig. 2).

1. Students uploaded photos to Moodle (UCL's virtual learning environment) of interesting everyday objects they found and models of assigned molecules.
2. Within groups, they discussed online the symmetry elements within them (Fig. 3).
3. The group came to a consensus on the point group of the object/molecule.

With most everyday objects (*e.g.*, Fig. 1), there was room for debate. For example, when considering the symmetry of a street sign, should the whole sign be included or just the face? Should the door to a building be counted or ignored? Would the symmetry be reduced or increased?

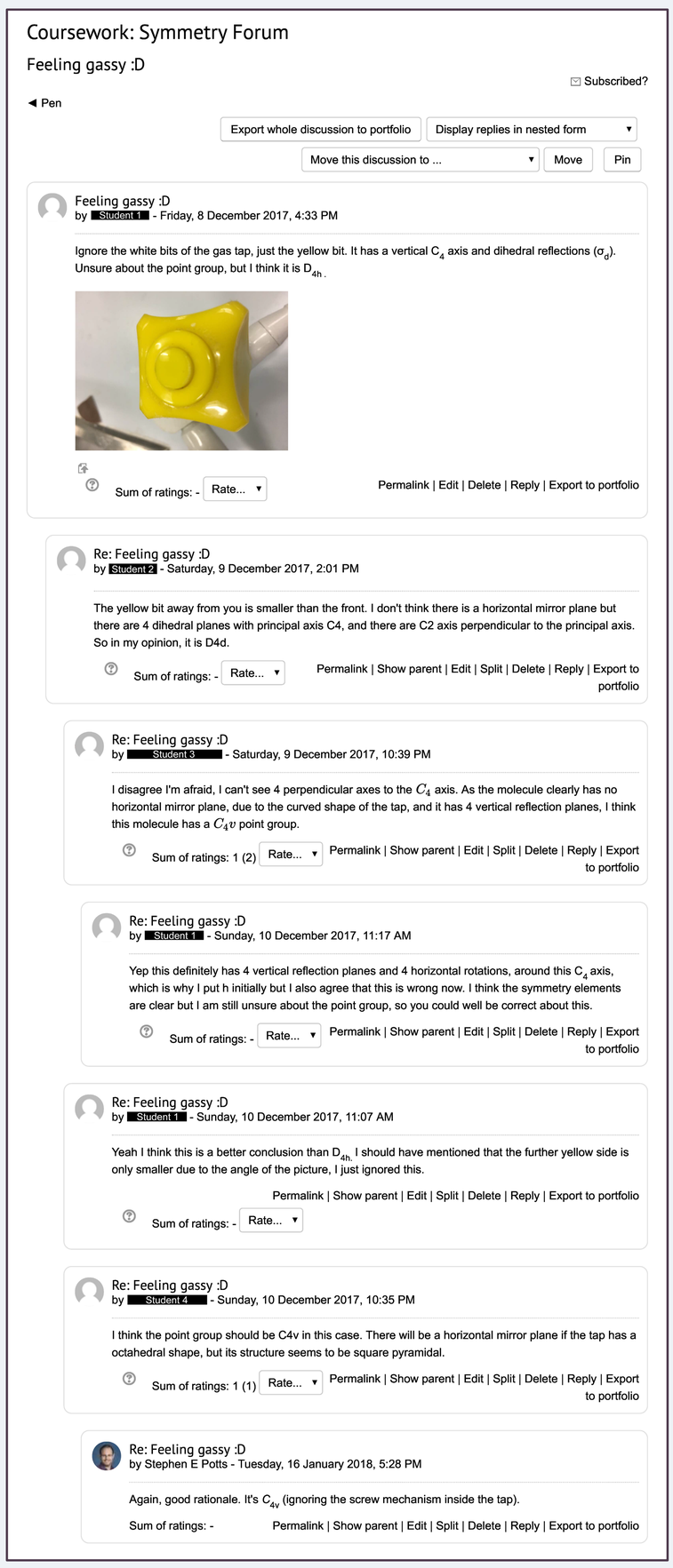

Figure 3: A screenshot of one student group's forum.

3. Results

Table 1: Summary of the pre- and post-coursework quiz marks. T-tests were used to determine whether there were statistically significant differences between the two groups' marks.

Unpaired T-Tests	Control Mean % Mark (S.D.)	New Mean % Mark (S.D.)	*p*
n	68	67	—
Pre-Quiz	63.15 (19.40)	58.07 (18.61)	0.124
Post-Quiz	69.19 (19.54)	70.09 (19.09)	0.787
Mean of Difference % Post – % Pre	6.04 (16.95)	12.01 (18.49)	0.053

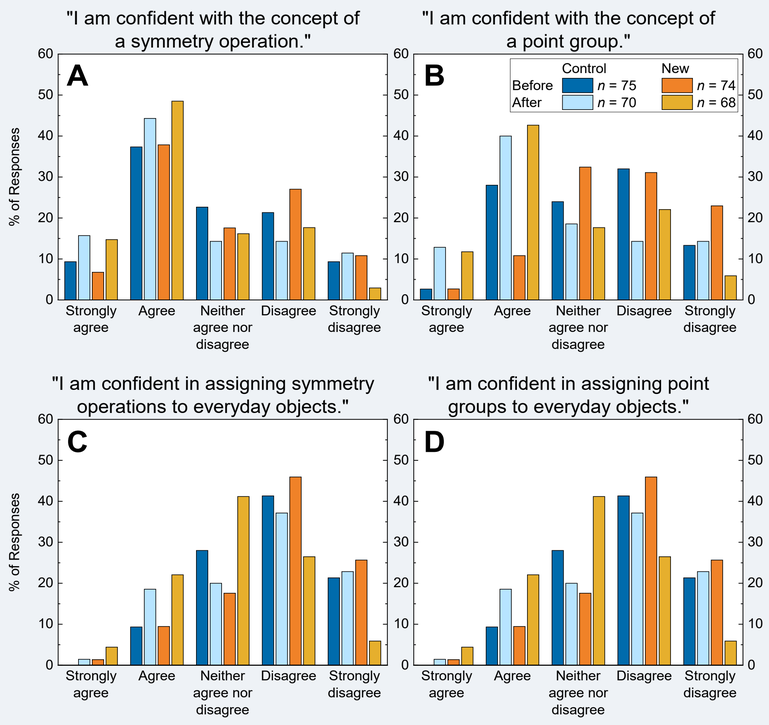

Figure 5: Students' confidence in symmetry operations (A, C, E) and point groups (B, D, F). Plots A and B refer to general confidence, C and D to everyday objects and E and F to molecules.

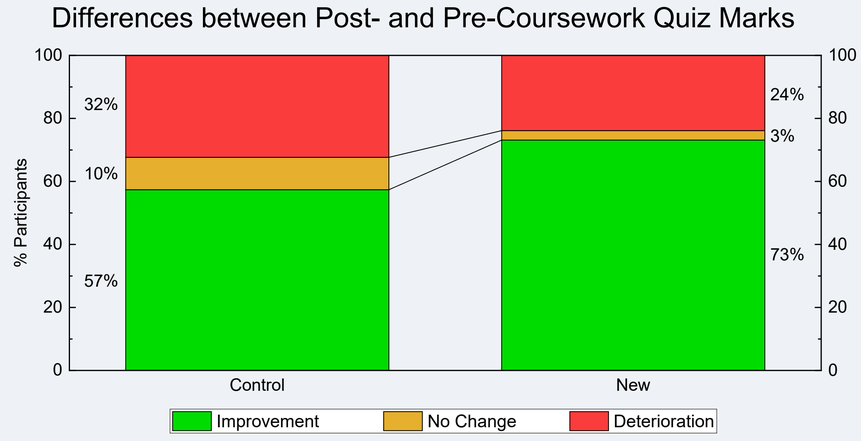

Figure 4: Summary of diagnostic quiz marks showing the proportions of each group who improved on or deteriorated from their initial result.

4. Conclusions

Do students show an increase in attainment? How do the groups compare?

- Both groups showed an improvement (Table 1). More students in the new group improved compared with those in the control group (Fig. 4).
- The new group showed an average improvement of 12% compared with the control group's average improvement of 6% (p = 0.053).
- The mean mark of the control group pre-quiz was already ~5% higher, which is likely a reason for the perceived bigger improvement.

Do students show an increase in confidence?

- After the coursework, both groups felt more confident in the topic than they did initially (Fig. 5).
- Students taking the new coursework felt more confident with symmetry afterwards than the control group, but some students taking the new coursework did not see the relevance of the approach.
- Interestingly, the control group felt more confident assigning symmetry operations to molecules.

5. Outlook

- Next year, the coursework will be redesigned to encourage more offline dialogue and include a peer-marking element.

References

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