Bringing Chemical Biology to First-Year Organic Chemistry: Adapting Workshops to Remote and Online Contexts

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Introduction

Many students elect to specialise in STEM fields because of their interest in and enthusiasm for the fundamental questions these fields attempt to answer and the global challenges they can help to address. Introductory courses, in contrast, tend to focus on fundamental concepts and methods of problem solving, building the foundation for further study and deeper understanding. While the link between core concepts and big-picture research questions might be clear to instructors, they can feel disconnected to students which can be frustrating and demotivating as students begin study in higher education. In our particular context, we are providing a First-Year course in Organic Chemistry to Biochemistry students, so conveying its relevance to students takes on a further dimension.

To address this challenge, we designed active learning-based workshops with the following key features:

- Student collaboration
- Research-centred questions
- Student-led discussion (the instructor facilitates)

Based on these principles, we initially designed two workshops to be incorporated as consolidation activities at the end of each half of the course.

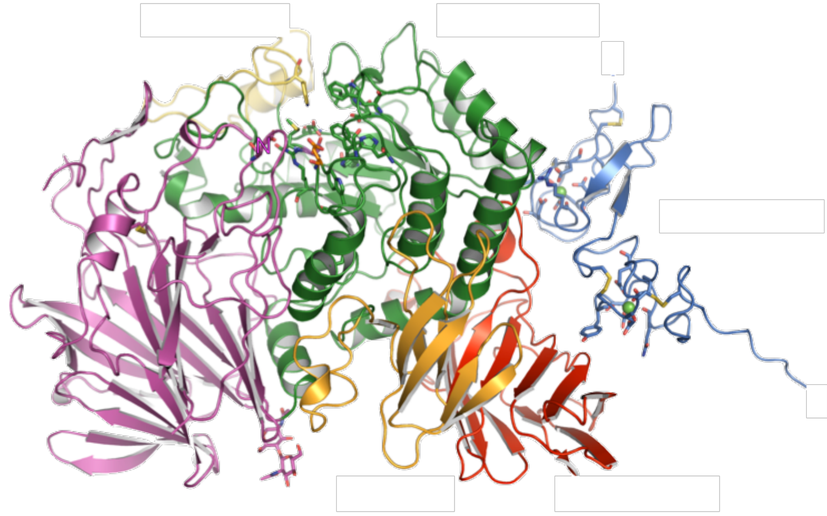

Figure 1: Endoplasmic Reticulum α-Glucosidase II Structure.[1] Each workshop is centred on a piece of recent biochemical research that can be interpreted with the concepts and approaches introduced in the First-Year course. One workshop allows students to use crystallographic data including the structure seen here to propose and understand the enzymatic mechanism.

Here, the content is described to provide an examples of the types of questions presented to students in both onsite and online formats. The successes and challenges of adapting the workshop to online format are discussed as the teaching environment may be employed across diverse disciplines.

DNA Alkylation: Epigenetics and Chemotherapy

This workshop takes place at the start of second term, as a way to reinforce and refresh the ideas discussed during first term including resonance, nucleophilicity and electrophilicity. Students apply these to predict the reactivity of DNA itself and consider the ways that both biological processes and medicine make use of these tendencies.

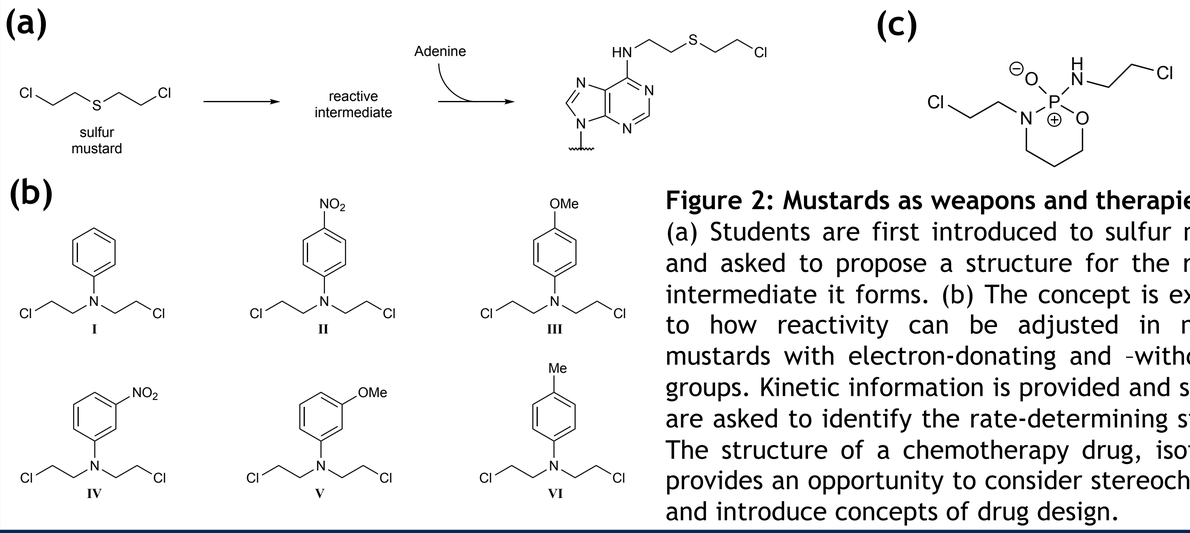

Figure 2: Mustards as weapons and therapies. (a) Students are first introduced to sulfur mustard and asked to propose a structure for the reactive intermediate it forms. (b) The concept is extended to how reactivity can be adjusted in nitrogen mustards with electron-donating and –withdrawing groups. Kinetic information is provided and students are asked to identify the rate-determining step. (c) The structure of a chemotherapy drug, isofamide, provides an opportunity to consider stereochemistry and introduce concepts of drug design.

Adapting to Online Delivery

Maintaining the content was straightforward. In terms of format, we wanted to allow students to continue to synchronously collaborate in small groups (4-6 students), and we wanted the role of the tutor to remain that of facilitator.

Breakout rooms in Zoom enabled students to work in groups effectively. However, facilitator interaction proved more challenging. While possible to "float" around the room in an onsite workshop, entering breakout rooms was often found to disrupt or even halt the flow of student discussion.

Miro whiteboards allow the facilitators to see what each group is working on at the same time, rather than entering each breakout room to see their whiteboard. Furthermore, the whiteboard remains active after the workshop as a "living" artefact for the students to continue collaborating.

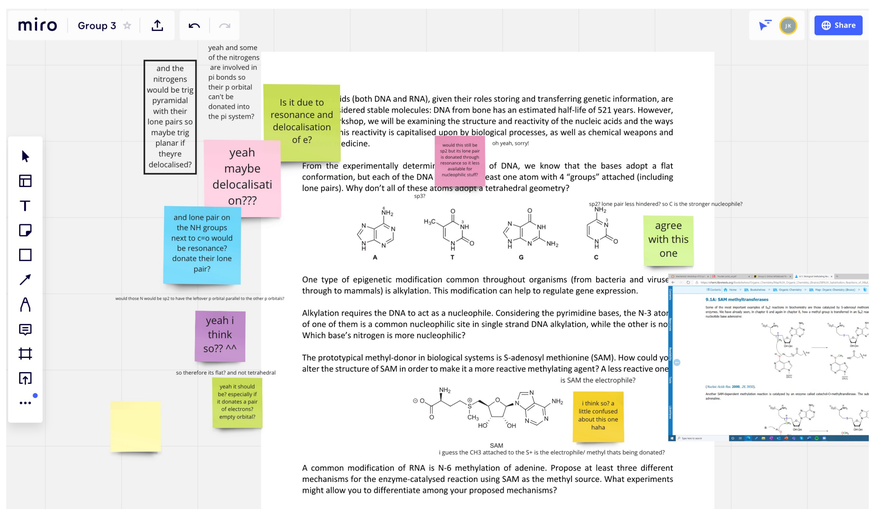

Figure 4: Student Miro Board. Students share ideas via post-it notes on the board, as well as verbal discussion in the Zoom breakout room. They also paste relevant images or screenshots to share with their teammates. It is also possible to directly write or draw on the board. Miro is available through web browsers, as well as tablet and mobile phone applications so it is readily accessible to students. Instructors can share the board via link; students do not need an account.

Glucosidase: Enzyme Mechanism and Drug Design

At the end of the course, we present a workshop centred around protein structure determination and how chemical tools can, expectedly and unexpectedly, give insight into how these enzymes work. By using research from the department,[1] students glimpse the projects they can pursue in their final year and link it to first-year ideas.

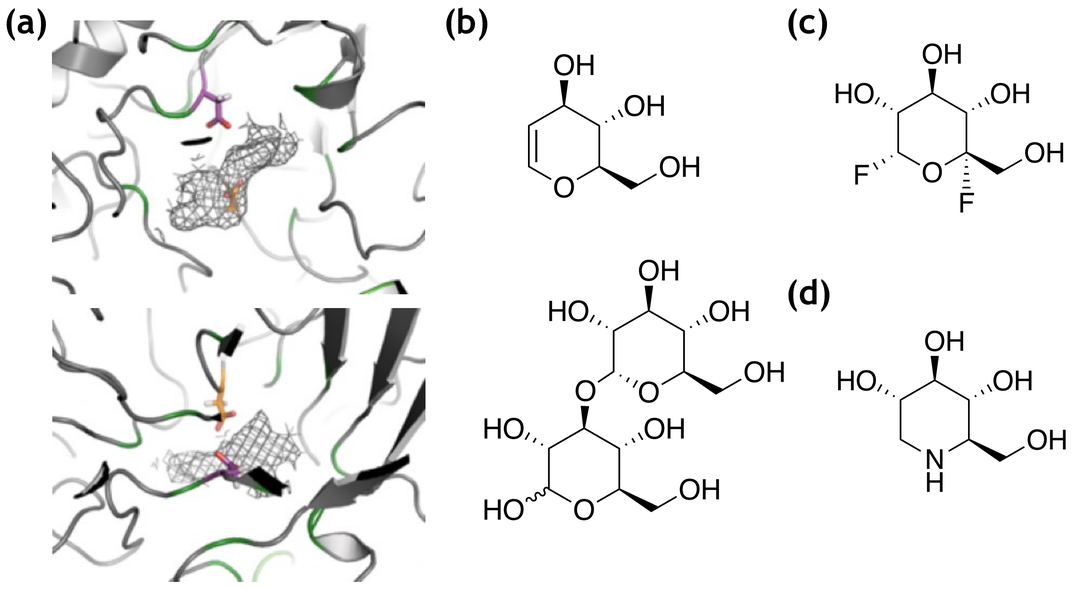

Figure 3: Sugars and Mimetics. (a) Students are presented with X-ray crystallographic data about ER a-glucosidase II, including structures with small molecules bound. (b) Students follow in the footsteps of researchers to explain why soaking the crystals with glucal (the upper molecule) results in the density in (a) of a larger shape—using chemical reasoning to propose a dimer such as the lower structure. Students then identify alternate small molecules as alternative substrates (c) or inhibitors (d).

Conclusions and future work

- Research-centred workshops provide an opportunity to apply learning to novel, modern contexts and challenges.
- Zoom breakout rooms provide a forum for student discussion in small groups.
- Miro allows facilitators to observe unobtrusively and students to collaborate both synchronously and asynchronously.
- Open-ended questions encourage discussion and peer-to-peer learning.
- Positive student feedback about the format (both onsite and online) has led us to develop further workshops, with two new ones added to the series this year.

[1] Caputo AT *et al.* Structures of mammalian ER a-glucosidase II capture the binding modes of broad-spectrum iminosugar antivirals. *Proc. Natl. Acad. Sci. U. S. A.* 2016.

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