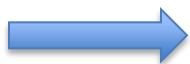


What Have We Learned?

Typically, organic chemistry laboratories teach two basic skill sets – one is kinesthetic and the other is argumentation. For the most part, the kinesthetic skills, e.g. running a column, setting up a distillation apparatus, acquiring spectra, and reaction work-ups take priority due to the amount of time they require in the lab. With the COVID-19 pandemic, the ability for students to learn these kinesthetic laboratory skills is thwarted.

After reviewing out data from Spring 2020 when the course was taught remotely, we learned that students became significantly more proficient in their argumentation abilities using the **Thinking Through the Laboratory Workbook** framework. They were much better at writing a claim, selecting supporting, relevant evidence, and creating an argument that was supported by evidence. We coded and analyzed over 300 “Post Lab Round Up” pages from the Substitution lab and the Elimination lab, both done remotely, and compared them with previous semesters done live. What we found is that the **Thinking Through the Laboratory Workbook** format promoted a better understanding of how to select data that would support a claim. We also noted students increased their capacity for a good argument. We are in the process of submitting this data for presentation.



How Can You Use Thinking Through the Laboratory Remotely?

I suggest the following format based on our data collection:

1. Each student has a paper version of the Workbook. (We can offer an e-Book if this is your personal preference)
 - a. We have found this creates cohesion between students in the course. They can work on their Workbook pages as a team (or partners) through Zoom (or FaceTime or even by a simple phone call) without having to toggle back and forth between screens.
 - b. The students read the assigned pages from the workbook before attending the Zoom version of lab.

2. Students ‘attend’ lab during their schedule time via Zoom. We have 2 hours and 50 minutes for lab. Students are required to have their **Thinking Through the Laboratory Workbook** with them during the Zoom meeting.
- The students take a real-time quiz given by the instructor. There is a page in **Thinking Through the Laboratory** where they can write their answers to quiz questions (handwritten!). Students take a photo and electronically submit their handwritten answers. This allows each instructor to create a unique quiz. The handwriting also allows for mechanisms and other types of questions.
 - We have created videos of each lab that shows the experiment step-by-step. There is a voice over on the video.
 - Students watch the video together. They can follow along with the workbook for each step as well.
 - The instructor stops the video and asks students to respond to the relevant **Some Assembly Required** questions in the workbook. This can be handwritten work or graded as a discussion. This is a unique opportunity for students to think, predict, and reflect while the video is ‘doing’ the lab. We can take advantage of this time to create better scientists who understand the experiment.
 - The instructor then provides data from the experiment.
 - He/She can provide this on a white board during the Zoom meeting or electronically provide students with data sets.
 - An instructor can choose his/her data.
 - We provide relevant and irrelevant data.
 - The students analyze the data (e.g. analyze and annotate an NMR spectrum) and write their Post Lab Round Up (claims, evidence, rationale, and argument) as the instructor facilitates discussion.
 - Students take photos of the workbook pages and submit them electronically.

The workbook allows each student to literally be on the same page during a synchronous, remote laboratory. In addition, since each student is creating a handwritten submission in real-time, it is easier to maintain academic integrity. Students must submit all graded work during the Zoom lab meeting.

We have found that the biggest benefit of the workbook is that students can use any device they want for communication and use the workbook for information. The workbook provides students with everything they need during a Zoom session to complete the lab.