Transforming the Chemistry Lab Notebook with Elements™

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ELN Background

As scientists, we all value the skill of maintaining a complete and functional laboratory notebook. This has been discussed extensively in the literature.[2] They have great value as a record of work done in research situations and as a tool to teach students how to prepare to be a professional scientist. More recently, transitioning to electronic laboratory notebooks (ELN) in teaching situations has been discussed.[3] The communication and organization value of these ELNs has been highlighted. This work sets out to identify how one example of an ELN can work within a typical teaching workflow.

Why Elements?

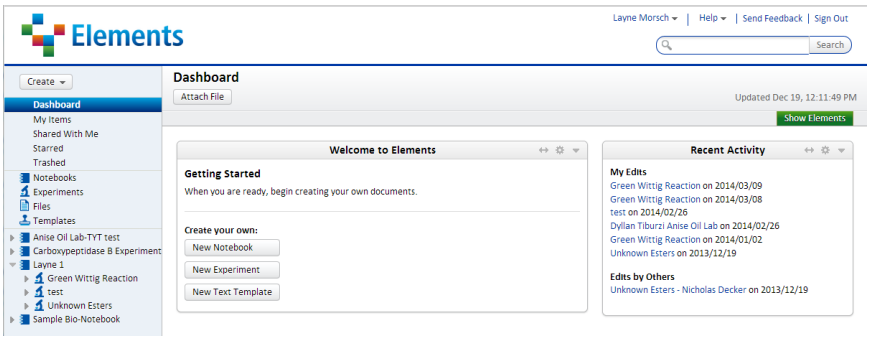
During the summer of 2013 I began to incorporate technology into my lecture courses using the newly released ChemDraw for iPad app. During winter semester 2014 we began to pilot test PerkinElmer's new "cloud collaboration platform" Elements in place of traditional paper laboratory notebooks. I was excited for the workflow of this type of product as my past experience with electronic laboratory notebooks (ELN) showed them to be much more focused on data organization and control of data than on collaboration[1]. This interaction between student and instructor, lab researcher and mentor has the potential to increase communication between scientists as not just a replacement for a paper lab notebook, but an improvement on these traditional methods of documenting science.

Since working with an electronic format significantly alters the typical instructor and student workflows, I felt it would be beneficial to show examples of these workflows.

Workflow for Instructors

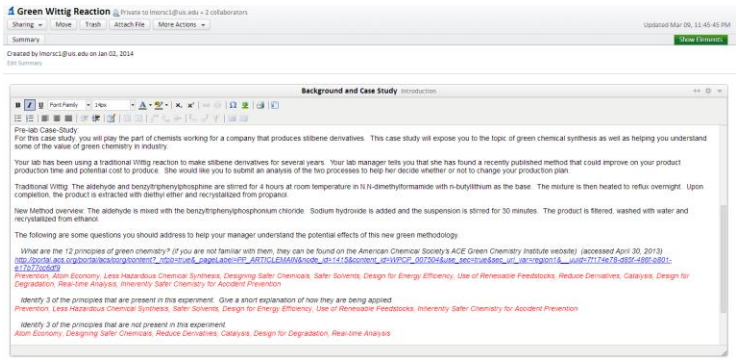
Create a new experiment

When creating a new experiment, a template may be used or the experiment can be created from a blank document.



Add in all the elements you wish to deliver to the students

Elements can be used to deliver the laboratory materials that might otherwise be delivered through a campus copy center, bookstore or LMS (ex. Blackboard or Moodle). These can be placed in the template as pdf files or as editable document files that allow the students to type on them. In addition to instruction delivery, blank sections or sections with small prompts can be placed to help the students learn how to organize laboratory information. For example, on a typical experiment, the following sections may be included: instructions, prelab questions, images of apparatus to be assembled, experimental procedure, data tables, postlab questions, spectral analysis, discussion and a grading rubric.



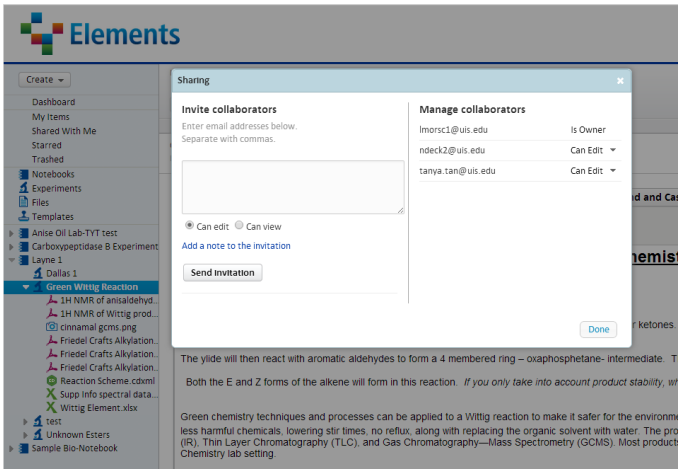
Save this experiment as a template

By saving as a template, this allows initiation of new experiments using this set of materials exactly as they have been prepared.

Share the template with students

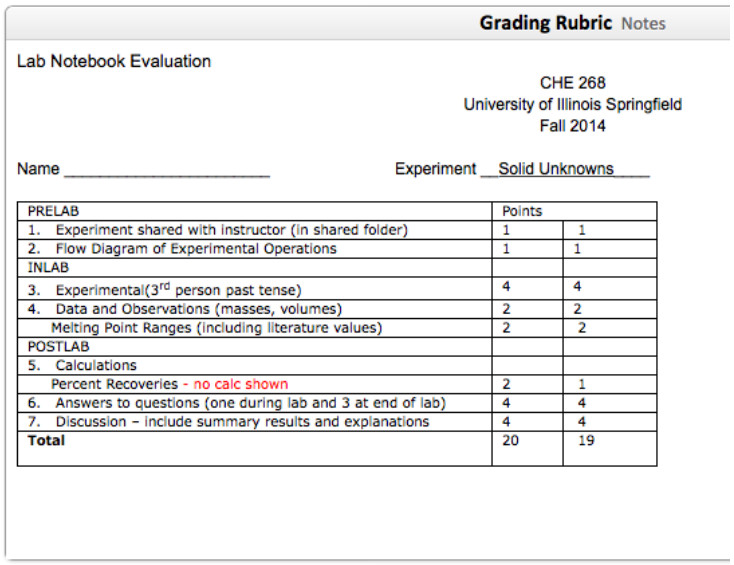
By copying and pasting email addresses, collaborators can be invited to share your materials. Options exist to allow others to edit the materials, which would be very useful for research collaborations and is also the way students must share their notebooks with the instructor. However, when sharing a template, students must be invited to share with the "can view" option enabled. Otherwise any edits they make will change the template for all other students that use it. It is important to share templates when you have many students working in the lab. If an experiment was shared instead, all edits would happen on

a single document and it would be very difficult to determine what each student contributed. This would have great usefulness in combined research projects where students are working together as a team. That way as each student worked on the project, all others collaborators would be aware of the work of the remainder of the team.



After the experiment is complete, feedback and grades can be given directly to students

A scoring sheet or rubric can be created and added to the template of each experiment with the points available for each required section. These have been shown to be effective at enhancing reliability of scoring performance as well as promoting learning.[4,5]



Grading Rubric Notes

Lab Notebook Evaluation

CHE 268
University of Illinois Springfield
Fall 2014

Name _____ Experiment __Solid Unknowns____

PRELAB	Points	
1. Experiment shared with instructor (in shared folder)	1	1
2. Flow Diagram of Experimental Operations	1	1
INLAB		
3. Experimental(3rd person past tense)	4	4
4. Data and Observations (masses, volumes)	2	2
Melting Point Ranges (including literature values)	2	2
POSTLAB		
5. Calculations		
Percent Recoveries - no calc shown	2	1
6. Answers to questions (one during lab and 3 at end of lab)	4	4
7. Discussion – include summary results and explanations	4	4
Total	20	19

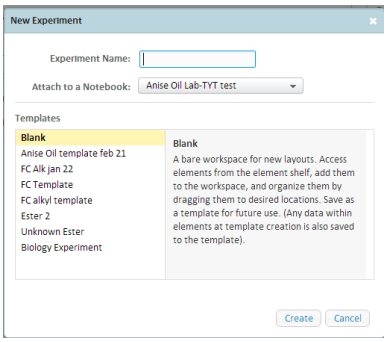
Workflow for Students

Students create a notebook and share with the instructor.

It is important that the student give the instructor "can edit" permission, otherwise it will be impossible for the instructor to give feedback on the student's work. Each experiment the student creates throughout the term is kept within this notebook and since the notebook has been shared, the instructor can see and interact with all of the student work for the course. If Elements is being used for multiple classes, this allows the students to easily keep each class work separate and shared with the appropriate instructor.

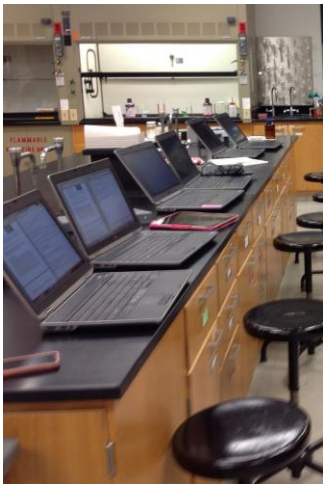
Students create an experiment

Each experiment can be created from a template within the shared folder. This means the student only needs to remember to share their work one time at the beginning of the semester. The instructor will only have to share once for each template they have students use.



Students can edit their experiment during lab

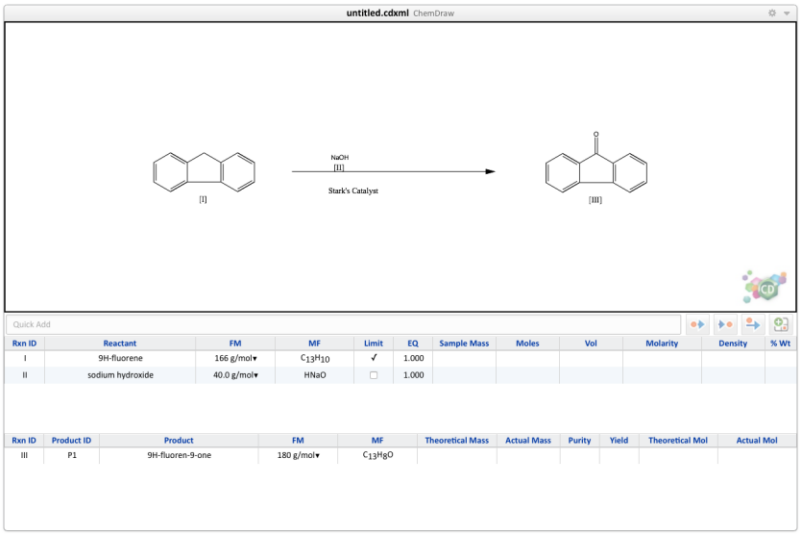
There are many ways that students are able to edit the experiment to make sure that it contains a complete record of all the work they performed before, during and after lab. Working with computers, tablets and smart phones during lab requires a "safe" location for students to keep their electronics in lab. In our lab, the fume hoods were utilized for all chemical operations while the benchtops were saved for computing devices.



Add new elements

The template can be set up with several blank elements for students to use, but they can add their own elements as desired. For example, if the students take 3 pictures of TLC plates, they could add all three pictures to the experiment by using the attach file button, then they could be viewed by adding an image element.

The ChemDraw element includes a stoichiometry table that helps calculate amounts of reagents as well as yields of products. It automatically determines reactants and products based on the placement of chemicals relative to the reaction arrow in the reaction drawing.

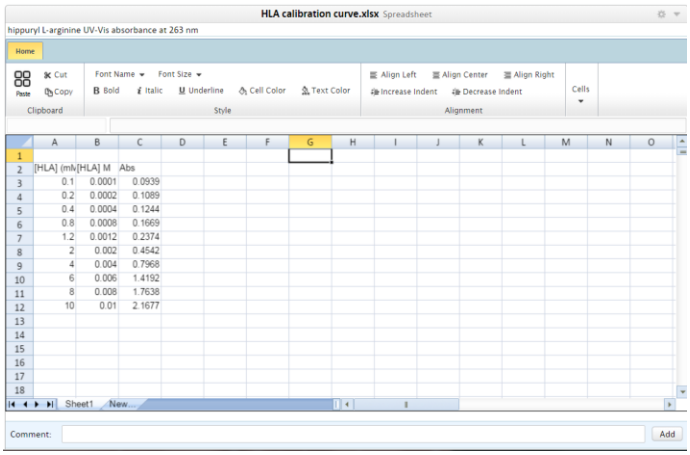


Edit the elements –

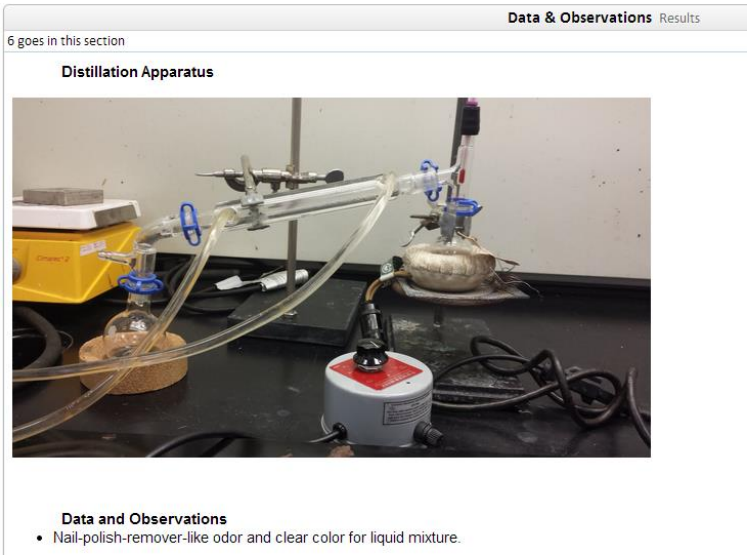
The students can write in the elements already provided to answer questions or to add their experimental protocol as the work is conducted during lab.

Organize data into spreadsheets

There is a spreadsheet element that allows students to organize their data within the experiment.



Add media they create during lab



Students don't need to "turn in" the experiment, once the folder is shared, the instructor can always see the student work
Students get immediate feedback and don't have to wait for instructor to "return" graded lab report

Educational advantages

Using an electronic lab notebook has improved communication between students and lab instructors. The potential for students to forget to bring materials that need to be turned in is eliminated. It is also impossible for students to lose materials they work on as they are all stored on a server. The cycle of getting feedback to the students is faster as well. Typically students would turn in lab notebooks or reports the week following completion of an

experiment. Then they would have to wait until lab the week after this to receive their graded reports back. Using Elements has allowed this process to be much faster as the students can view their graded reports immediately without waiting until the next class period.

Incorporation of grading rubrics into the templates helps students as they are working on their lab have clear guidelines for what they need to include in their lab reports.

Prepare for future careers

Most of our students are either interested in industrial employment upon graduation or careers in the health sciences. These positions are incorporating electronic lab notebooks at much higher levels than has been seen in academia to this point. If we want to prepare our students for these jobs, we need to help them become more used to archiving and communicating their work electronically.

Expanding what a lab notebook can be – media

We began to get used to the capabilities of using a digital lab notebook to replace what we used to do within our paper lab notebooks. We also began to explore new ways to incorporate media that would have been difficult or impossible under the old paradigm. One example is inclusion of thin layer chromatography (TLC) information in the notebook. In earlier times, we would attach our TLC plates to our lab notebooks. This has mostly been discontinued since it poses safety risks carrying around chemicals in students' bags. This technique was replaced by drawing a picture of TLC plates into the lab notebooks. This could be done quickly to give a rough estimate of what was seen, or much more slowly with careful measurements that would allow for calculation of Rf from the drawn plates. Several methods have been used to denote differences in appearance of the plate under UV light and/or after being prepared with a stain such as I_2 or phosphomolybdic acid. However, with Elements and the availability of cameras on iPads and phones, all our students are able to take pictures of their TLC plates and incorporate those pictures directly into their lab reports.

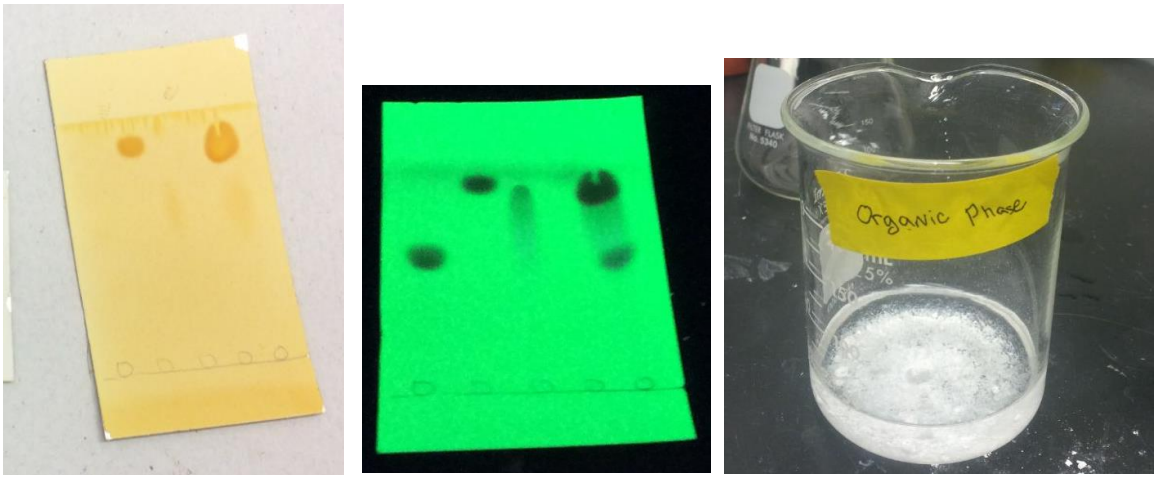


Figure 1. Images taken by students during lab Fall 2014. Images included in student Elements reports. (Left to right) TLC plate stained with iodine, TLC plate being visualized under UV light and the organic phase of a separation during the process of a reaction.

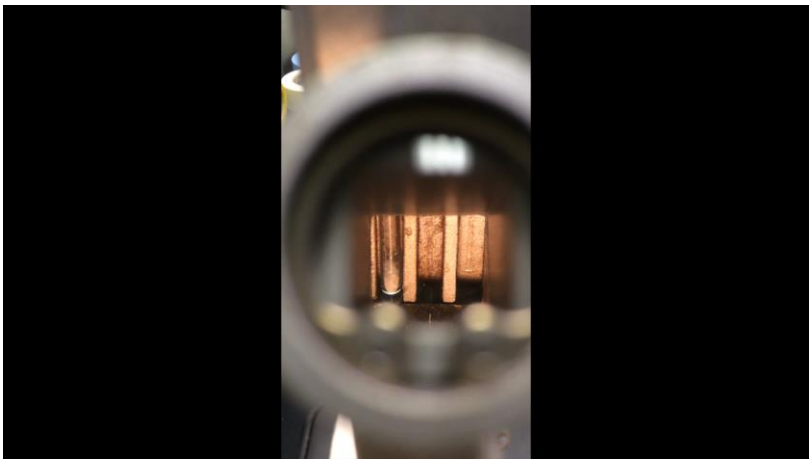


Figure 2.
Video of a melting point taken with iPhone and uploaded into Elements.

Grading and feedback

Grading is now done within the lab notebook environment. A rubric is included with each experiment that gives students clear expectations for what needs to be included in their experimental write-up. These rubrics are designed with spaces to input student scores on each component of the lab. In addition to filling in these rubrics, it is also easy to add comments on each "Element". This is typically accomplished by adding the comments in a color that is different from any that the student has used.

Student evaluation

PerkinElmer sent a user interface and usability expert, Jennifer McCormick from User Experience, to run a focus group with the students using Elements in class. Her top findings through surveys and interviews of the students included:
The sharing and collaboration function of Elements is well received within both the learning and research contexts.
Users reported Elements to be generally easy to use, though they struggled to understand how to rearrange the elements within an experiment.
They requested incorporation of spreadsheets (that didn't exist at the time) and more reliable data saving.

The issue with data saving came about as in the early beta version of Elements, the login would time out without alerting the user. Students would type in a few sentences or even paragraphs before realizing that they were no longer connected and that writing was all lost. In a subsequent update, connections do not disconnect as soon and saving occurs at a much more often and so students have not continued to have this problem during the current semester.

Figure 3. Results of summer 2014 interview/survey on using Elements at the University of Illinois Springfield during organic chemistry lab (n=5)

While students felt that most activities were fairly easy to accomplish, their overall perceived usefulness was rated at 4.7 on a 7-point scale with 7 being highly useful. This was before the incorporation of spreadsheets and the stoichiometry table that now accompanies the ChemDraw window, so it will be interesting to re-assess the student attitudes at the end of the current semester to see if these improvements have any effect. It is also of interest that students in graduate research labs at two other universities rated Elements higher in every category. This is presumably due to a greater familiarity with keeping laboratory notebooks and exchange of this information within their research team.

Conclusion

Elements has successfully replaced the carbon-copy paper lab notebooks that were previously used in our labs. Use of a digital, web-based platform has enhanced the rate of communication between students and instructors. The definition of what a lab notebook is and what type of data is contained in a lab notebook is expanding to include more media. Students have responded moderately well to the incorporation of this new technology into

the curriculum. The lab instructors in our program are continuing to work on how to adapt our teaching methods to best take advantage of Elements and are encouraged that our students may be better prepared for working with technology in their careers.

Acknowledgements

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