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Work in Progress: Assessment of Google Docs and Drive for Enhanced Communication and Data Dissemination in a Unit Operations Laboratory

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Work-in-Progress: Assessment of Google Docs and Drive for Enhanced Communication and Data Dissemination in a Unit Operations Laboratory

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Abstract

Unit Operations (UO) Laboratories serve as a valuable hands-on setting for the application of the theory learned in multiple lecture-based chemical engineering courses. These labs build practical knowledge of equipment and design, encourage good engineering practices such as traceability and reproducibility of data, and help develop skills such as interpersonal and technical communication skills.

Our senior UO laboratory is comprised of interconnected experiments in a "pilot-plant" scale as well as interconnected rotational objectives for the experiments. As a result, dissemination of information amongst current project group members, amongst group members of the next rotation, and amongst lab personnel is extremely important. In previous years, students have been asked to use pen-and-paper lab notebooks and/or binders to record their data. This author has seen a decline in the use of traditional laboratory notebooks from students over the past couple years in both our junior and senior UO laboratories. It is unknown to this author if the students are just not using the pen-and-paper lab notebook or if they are using some alternate not given by the laboratory.

To teach the importance of data record keeping for the UO labs, especially as industry shifts towards electronic record keeping, we have implemented electronic laboratory notebooks using Google Drive and Google Docs in Fall 2017. This Cloud-based storage not only allows easy sharing and tracking of changes by group members but also sharing of analytical results and tracking of progress by lab personnel. This talk will discuss the implementation of the electronic lab notebooks as well as benefits and difficulties in the use of cloud-based programs within the UO Laboratories. Student usage of the electronic laboratory notebooks will be assessed by observational data and student satisfaction will be assessed by a survey. Due to changes in lecturer leadership every semester, a correlation of electronic lab notebook implementation to grade improvements is not possible.

Introduction

The purpose of academia is to train students, within the best of our abilities, in preparation of their professional lives outside of the proverbial collegiate walls. For chemical engineering as well as many other engineering disciplines, many of these students will continue into industry, and with the increase of quality assurance and regulations set forth by government agencies, recording of data and results will be an important skill for those students to have. For instance, electronic notebooks can comply with CFR Title 21 Part 11: Electronic Records and Electronic Signatures of the United States Food and Drug Administration.

With increase of personal technology and implementation of "cloud" storage, many companies are implementing some form of electronic laboratory notebooks.

- In 1997, Collaborative Electronic Notebook Systems Association (CENSA) was formed through the support of eleven major pharmaceutical and chemical companies. [1]
- In 2014, Takeda Pharmaceutical published an article regarding their E-Notebook Project Report in the Fujitsu Scientific & Technical Journal. [2]
- In 2017, AIT Bioscience presented their usage of electronic notebooks at the 11th Annual Workshop on Recent Issues in Bioanalysis in Los Angeles, CA. [3]

Recent pushes for electronic notebooks stem from more rigorous regulations and the importance for industries to patent technology and processes. Even though the Leahy-Smith America Invents Act shifted the U.S. patent system from "first to invent" to "first inventor to file" system in 2011, meticulous record keeping is still beneficial to industries as it helps patent attorneys in preparation of documentation.

While industry has been interested in electronic or cloud-based laboratory notebooks for a while, academia and research has been slow to implement this technology. The core sciences (biology and chemistry, specifically) seem to be implementing electronic notebooks in both research and academic laboratories already. One of the more recent publications shows the Chemistry department at Fairfield University successfully implementing a cloud-based and smartphone-based digital electronic notebook using Evernote software [4]. However, very few articles have been found implementing an electronic lab notebook in an engineering undergraduate course. Harvey Mudd College compared paper and electronic notebook usage in their undergraduate experimental engineering course, which covers multiple engineering disciplines [5]. Their results did not show any marked improvements using electronic over paper notebooks. This result could be due to types of experiments and equipment used with the laboratory. With the style of our senior unit operations laboratory, it was felt that the electronic laboratory notebook might be a beneficial addition.

Background of laboratory scheme

The unit operations within our senior UO laboratory comprise different stages in a "pilot-plant" biodiesel production and purification. This process starts with production of algal oils and continues through production of biodiesel from those oils, separation of impurities, and recycling of excess reactants. Because of this scheme, a major focus of the course is the cause and effect between different stages within a plant.

Over the course of the semester, each student experiences three different unit operations (called rotations) working with three different groups. Rotational objectives for the experiments are also interconnected. In general, the first rotation focuses on exploring the operational space of the equipment while the second rotation builds upon the first rotation's work in an attempt to optimize the particular unit operation. This optimization may focus on a specific purity or yield or achieving an industrial standard needed for selling biodiesel. Because of the complexity of the systems involved, much of the analysis is completed using analytical equipment such as gas chromatography (GC) or high-pressure liquid chromatography (HPLC). Prior to the implementation of electronic project folders, students would have to come into the laboratory to

retrieve hard copies of their results. In the case of our lab, each sample result was printed on a separate page, which resulted in paper waste and chances that the students will lose pages of their results. With the implementation of the cloud-based electronic project folders and results saved as PDFs, GC and HPLC results are shared with students for easy and expedient access. For the third rotation, students compile results from previous rotations and, while working with other unit operations, perform a scale-up and economic assessment for the biodiesel production plant as a whole.

Implementation of electronic laboratory project folders

Over my tenure within the unit operations laboratory, I have observed declining student usage of the traditional pen-and-paper laboratory notebooks. This reduced usage is especially prevalent if the laboratory notebooks are not checked and/or graded. Although the root cause of this reduced usage is unknown to this author, it is assumed that the increase in portable electronics (laptops and cellphones) capable of recording data is at least a part of the cause. As a result, it was decided to attempt to implement electronic lab notebooks and project folders for students to use within the senior unit operations laboratory.

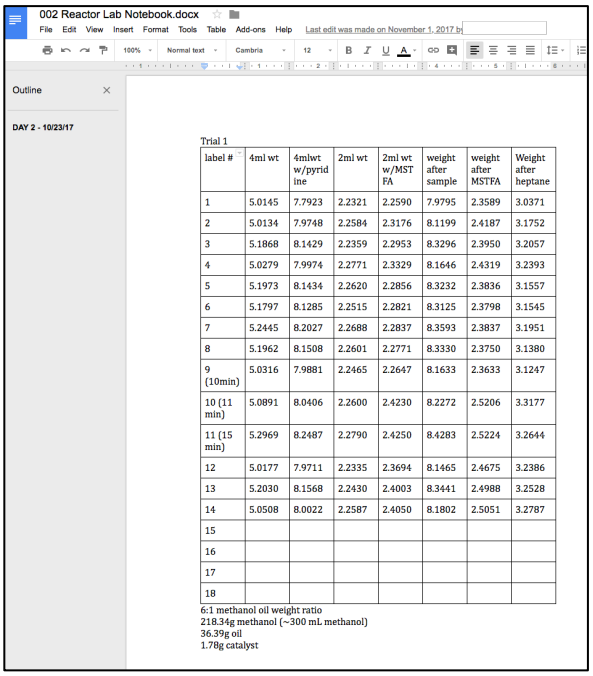
While there are many software packages focusing on electronic laboratory notebooks, such as sciNote and LabArchives, many of these cost monies and/or take time for students and faculty to learn how to use. Since many universities are using companies such as Microsoft and Google to host email and provide cloud storage, it seemed natural to utilize the existing technology that students have experience using for group collaboration in other courses. As our university uses Google, the newly-implemented project folders and electronic lab notebooks were set up using Google Drive and Google Docs.

Observation of student usage

Since laboratory notebook usage within the chemical engineering undergraduate laboratories is not graded, there is not a good metric with which to compare student usage of the paper and electronic lab notebooks. Student usage tends to vary depending on their previous lab experiences, undergraduate research opportunities, internship experiences, and personal organization skills. Regardless, since the basis of implementation of the electronic notebooks was due to observed reduction in usage, this author felt it was important to discuss observed successes and failures of usage.

Upon exploration of the electronic lab notebooks, student usage varied as with traditional notebooks and depended on the experiment that was being completed. For instance, a reactor experiment tended to have more data recorded due to sample preparation for gas chromatography (Figure 1). In comparison, a distillation experiment was less data heavy due to no sample preparation and quick analysis by refractive index and a quick gas chromatography measurement. Overall, this author feels that the students who did use the laboratory notebooks had a more organized and more legible set of data. There is still room for improvement within the lab notebook usage as students tended to include the trial conditions, recorded data, and sample preparation but did not include results and/or connections to PDF or excel files within their project folder (Figure 2). Another shortcoming is that, in general, students did not consider

writing "journal entries" or summaries of what was accomplished during the day or what went wrong. Only in one case, an experiment in which students are required to cooperate with multiple laboratory days to collect data from a biological system, did students use their lab notebooks to record what work was completed on their given day, what issues had arisen, and what additional work, if any, was requested of the next day's group.



002 Reactor Lab Notebook.docx

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Outline

DAY 2 - 10/23/17

Trial 1

label #	4ml wt	4mlwt w/pyridine	2ml wt	2ml wt w/MSTFA	weight after sample	weight after MSTFA	Weight after heptane
1	5.0145	7.7923	2.2321	2.2590	7.9795	2.3589	3.0371
2	5.0134	7.9748	2.2584	2.3176	8.1199	2.4187	3.1752
3	5.1868	8.1429	2.2359	2.2953	8.3296	2.3950	3.2057
4	5.0279	7.9974	2.2771	2.3329	8.1646	2.4319	3.2393
5	5.1973	8.1434	2.2620	2.2856	8.3232	2.3836	3.1557
6	5.1797	8.1285	2.2515	2.2821	8.3125	2.3798	3.1545
7	5.2445	8.2027	2.2688	2.2837	8.3593	2.3837	3.1951
8	5.1962	8.1508	2.2601	2.2771	8.3330	2.3750	3.1380
9 (10min)	5.0316	7.9881	2.2465	2.2647	8.1633	2.3633	3.1247
10 (11 min)	5.0891	8.0406	2.2600	2.4230	8.2272	2.5206	3.3177
11 (15 min)	5.2969	8.2487	2.2790	2.4250	8.4283	2.5224	3.2644
12	5.0177	7.9711	2.2335	2.3694	8.1465	2.4675	3.2386
13	5.2030	8.1568	2.2430	2.4003	8.3441	2.4988	3.2528
14	5.0508	8.0022	2.2587	2.4050	8.1802	2.5051	3.2787
15							
16							
17							
18							

6:1 methanol oil weight ratio
218.34g methanol (~300 mL methanol)
36.39g oil
1.78g catalyst

Figure 1: An example of student usage of a Google Doc lab notebook. Lab notebooks were not used to full potential, mainly being used to record experimental conditions or sample preparation weights.

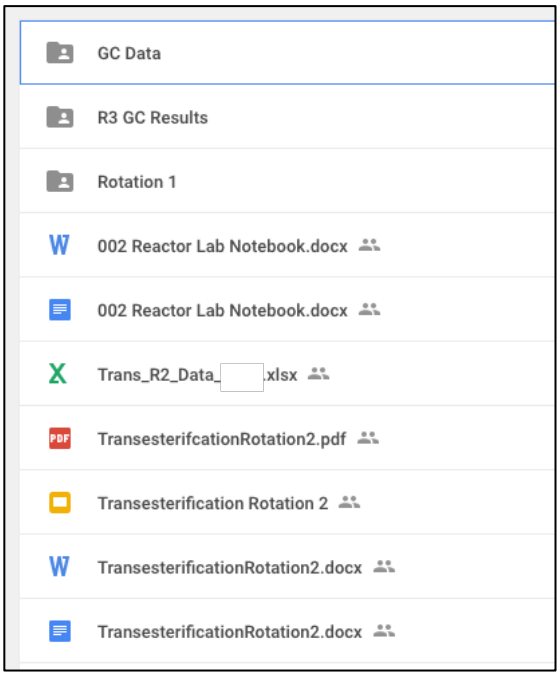

Figure 2: An example of student usage of a Google Drive project folder. It was used for data recording/dissemination, calculations, and even presentation/report collaboration.

Preliminary student feedback

In order to determine how students viewed using Google Drive/Docs versus a traditional pen-and-paper lab notebook, a survey was sent to the students via Google Forms. This survey was sent after final grades were submitted for the course so students were not afraid of repercussions. All students have taken the junior laboratory where pen-and-paper laboratory notebooks were given for usage. Also, for the senior unit operations laboratory during Fall 2017, students were given the option to use either electronic or traditional notebooks. Out of 72 students in the course 26 students completed the survey. Of those 26 students, all but one student used the provided electronic lab notebook in Google Drive. The other student used another electronic format but not Google Drive. This is an interesting result since I was not requiring students to use the Google Drive/Doc as electronic lab notebooks in the Fall semester. As for the dissemination of GC and HPLC results via the cloud-based project folders versus printed results, 25 out of 26 of the responding students felt that using Google Drive was effective.

One major piece of feedback that I feel needs to be addressed is that some of the students do not understand the importance of using a laboratory notebook. Two comments stated:

> "As long as they get their work done and use a system that works for them, I don't see how lab notebook usage matters. It's nice for it to be there but students should absolutely not be forced to use them in my opinion."

While there are some students who don't understand the advantages of learning to properly to use a lab notebook for organization and data reporting, some students have a positive attitude towards organization of data.

> "A way to increase lab notebook usage is to explain the benefits of keeping one. For example, a student can use an observation written in their lab notebook in order to disqualify a data point. If the lab notebooks are online, they are faster to type in (than writing), and the student doesn't need to remember to take a picture, they always have the page to reference from their computer."

> "Inform them about the benefits of using lab notebooks to remember things in the future. Then, when you're looking at the data again, you'll easily remember if some error during the experimentation affected the results because the group would have taken note of it during real time."

Ultimately, it seems that while students are asked to use laboratory notebooks in multiple classes, it is never covered what should be included in them and, most importantly, WHY it is important to use laboratory notebooks. When asked if they should have a document or lecture over lab notebook usage, 17 of the 26 students thought it would be beneficial. However, it was split as to whether the students would prefer it in a text document or as a lecture and, if a lecture, which of our two lab courses they would like it to be covered in. Additional surveys will be given at the end of the Winter 2018 semester to collect additional data from another sub-set of students.

Future work

Currently, our unit operations laboratory disseminates necessary information to the students through four main avenues: an online course site, Google Drive, email, and in-person. In order to more efficiently disseminate information, combining some of these may help eliminate confusion within the laboratory and improve student experiences. Future exploration will focus on integrating assignment memos and manuals within the electronic project folders.

In addition to the physical implementation of the electronic lab notebook, I think more exploration needs to be focused on teaching ABOUT the importance of laboratory notebooks. It is relatively easy for students to understand why it is important if they are going into graduate school or research and development. More difficult is connecting notebook to general organization needed if they are project or design engineers.

It is this author's opinion that if we are requiring students to use laboratory notebooks, whether traditional pen-and-paper or electronic, there needs to be some skill being taught through this usage. As such, there needs to be some system of grading or checking the notebook. This goes against student feedback, which overwhelmingly did not want laboratory notebooks graded. It is uncertain at this time the best method for this grading/checking.