TECHNOLOGY IN THE CLASSROOM:
Transitioning Lab and Design To an All-Digital Workflow

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Although students may not appreciate it during the course of their undergraduate program, they will spend a large portion of their professional lives engaged in technical writing almost every day.[1] To prepare students for this reality, many chemical engineering curriculums use either their laboratory courses or their design courses to also teach technical writing.[2-4] At many universities, including the University of Connecticut, these courses are also used to at least partially fulfill the university's writing requirement. In such classes, guidelines as to number of pages, revisions, and assignments are often influenced by a higher authority in the university. The draft-revision-final report structure (sometimes with multiple drafts) can result in instructors dealing with numerous versions of the same work, multiplied by the number of students taking the class. Managing the sheer amount of paper can become a burden on instructors and students alike. While there have been numerous studies of the advantages and pitfalls of incorporating new technologies (*i.e.*, laptops, iPods, iPads, tablet computing, cloud computing) into the classroom on the student side of the equation,[5] there has been less work done on the impact that some of these newer technologies have on the faculty/instructor side. In the world of iPads, PDFs, and online collaboration tools, we wondered whether the technology had advanced sufficiently to allow us to do away entirely with the paper copies of lab reports and design reports. Murphy describes multiple

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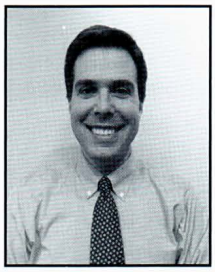

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typologies for iPad/tablet use in the college environment, focusing on the technology's ability to grant "ubiquitous" access to course materials and foster peer-to-peer as well as peer-to-instructor collaboration, as well as the productivity enhancement generated by the use of these devices, not only for the students, but for faculty as well.[6] Variations on these advantages are also noted by Park, Melhuish, and Falloon, and Economides and Nikolaou.[7-9]

Prensky notes that students are ever more becoming "digital natives," having grown up using computers and, increasingly, the Internet and portable computing devices.[10] Many faculty, on the other hand, pre-date the technological explosion and must often play catch-up with the latest abilities and tools that their students take for granted. While many faculty are often slow to adopt new technologies, due to time constraints, lack of interest, and aversion to change, among other reasons,[11] those that do typically do so because they believe it will improve student learning, as well as bring about efficiencies in their workflow, allowing them to rededicate that "found time" to improve their teaching in other ways.[12,13]

For our application of technology to the writing course, we sought the flexibility of easier reading, mark-up, and correction that these types of assignments generally require, while simultaneously reducing the copious amount of paper that the students were using (and we, the instructors, were hauling around). One thing that we didn't want to do was to have students clogging our e-mail with reports and attachments, nor did we want to be tethered to a computer to read lab reports. We also wanted to avoid making corrections with a feature such as Microsoft Word's "Track Changes," which we felt would enable students to edit their reports by simply selecting "Accept Changes" without reading any critique—defeating the iterative process of editing and revising between student and instructor. Given these caveats, we hypothesized we could develop a workflow that would:

- *Allow students to submit reports electronically, but not via e-mail, and keep a record of all of the transactions between student and instructor.*
- *Allow course instructors to easily read, comment on, and correct reports without being tethered to a computer or making the revision process too trivial for the students.*

In order to accomplish these goals, we needed to establish the following: a file format, a computing platform, and a collaboration platform.

FILE FORMAT

Perhaps the easiest of the three choices to make, we wanted a format that was near-universally recognized, generally platform-agnostic, and not able to be trivially edited once comments have been made. The PDF format easily met all of these requirements. PDF files are common in both the PC and Macintosh environments, and both platforms have either the built-in ability or free software to output to the PDF format. In our implementation, students can use any platform that they want (PC/Mac/mobile) for document creation, as long as the final format for submission is a PDF—students weren't required to purchase anything (hardware or software) in transitioning to online submission. Additionally, once created, the PDF is generally not editable in the same way as a traditional word-processing file. This difference ensures that any corrections or suggestions that we, the instructors, made on the document would have to be incorporated through manual student revision of the original document, not by quickly re-editing the electronic copy we returned. We wanted the students to have to read and reflect on our comments and suggestions in the same way they would have to if they had received a series of comments written in red ink on a printed page. This process was also facilitated by the PDF format, since, while the original content is typically locked once the document has been produced, there are numerous pieces of software that can be used to "mark-up" or annotate a PDF, adding content on top of the existing document.

PLATFORM

As mentioned above, the experience of reading, commenting on, and grading physical lab reports is very different than that same action performed sitting in front of a computer. For many faculty, reading and interacting with a document via computer screen, mouse, and keyboard is an awkward and unpleasant experience. We decided that we wanted to mimic the traditional grading experience as much as possible, so we decided to use tablet computing as a platform. Tablets are generally much smaller than laptops, and, like e-book readers, are more akin to a traditional reading experience than reading a document on a laptop or desktop machine. While there are many tablet platforms available, we chose to use the Apple iPad due to the large existing market and the numerous tools for interacting with documents on the device, although similar arguments can be made for the Android mobile platform. There are a number of applications on the Apple App Store, some of which are free, that allow users to view and annotate PDF documents on the device. As the iPad and many other tablets have an interactive touch screen, it is possible to use one's finger or a capacitive stylus to interact with the screen, providing a natural analog to correcting a physical document with a pen or marker. There is also the added benefit of being able to have all report documents with you at all times, avoiding the need to carry around a stack of papers, while facilitating grading or reviewing when you have a few minutes of time.

SOFTWARE

A simple search of Apple's App Store will turn up dozens of applications that have the ability to interact with PDFs. We examined a number of these for cost, usability, and overall feel.

Of particular use are programs that can integrate and interact with one of the numerous cloud storage options available, which facilitates easy collaboration and avoids collection of student documents through e-mail. Most of the applications on the App Store for PDF annotation are relatively inexpensive, especially when compared to the cost of the tablet itself. We found a number of options, ranging between free and about $10. One of the simplest is neu.Annotate PDF (<http://www.neupen.com/>), which is free to download. This application is fairly bare-bones, but it does allow the user to import PDFs, mark them up with a finger or stylus, then save the marked-up document to a variety of online storage solutions or send it via e-mail. For a free application, it is fairly robust, but not as full-featured as some of the other options. It is, however, a great application for quickly signing documents and has been useful at the University of Connecticut for electronically signing forms or letters.

The solution we settled upon for our use was iAnnotate PDF by Aji LLC ($9.99 on the App Store, <http://www.branchfire.com/iannotate/> for more info). iAnnotate has a host of mark-up tools that are useful during the grading process, including easily accessible tools for underlining, striking through, and highlighting text in addition to allowing the insertion of handwritten notes and text boxes, all in a variety of sizes and colors. It also has integration with numerous cloud-based storage solutions for easy moving of annotated files. iAnnotate is also specifically mentioned in several studies on tablet technology, with one specifically stating that the "majority of students perceived electronic course materials on an iPad in iAnnotate to be as good as or better than printed course materials."[6,14] iAnnotate is currently only available on the iPad, although a version for Android-based tablets is in production at this writing, according to the software's publisher. Figure 1 (next page) shows a typical document with annotations created in iAnnotate.

The last piece of the workflow is the collaboration software. We wanted to avoid the inconvenience of students e-mailing us their documents, which would only serve to fill inboxes and make keeping track of submissions needlessly time-consuming. We decided to use the freely available Dropbox (<www.dropbox.com>) to create an online space where all of the student submissions would live. The benefits of this system are numerous:

- *Free 2GB storage space (more than adequate for our purposes)*
- *Centralized storage and organization of all student work*
- *Available across multiple platforms (PC, Mac, web interface, and mobile)*
- *Ability to keep a time-stamped record of all submissions/deletions from the Dropbox*
- *Ability to natively link with many PDF annotation tools, including iAnnotate*

We wanted the students to have to read and reflect on our comments and suggestions in the same way they would have to if they had received a series of comments written in red ink on a printed page.

An additional advantage of Dropbox is that copies of all files are kept on the user's local machine, and are only synchronized when an Internet connection is available. As such, a persistent connection isn't required, and in the case of a large-scale failure of the service, students could resort to e-mail or a hard copy. It should be noted that Dropbox is one of several online cloud-storage collaborative tools, and that others (Microsoft SkyDrive, Google Drive, etc.) may also be used. Indeed, if the university computing technical services supports it, it may be possible to deploy a shared-folder approach using entirely internal resources, which may allay worries about dependency on an free, external service.

For our laboratory course, we created an individual folder for each student in the class and invited the student to be a shared user on that folder. In this way, any time the student completed a draft or a finished report, they would place it in their personal Dropbox folder on their computer. That file would instantly appear in that student's folder on the instructor's computer, tablet, or other linked mobile device. In this way, we were able to see submission times to guarantee on-time work while organizing all of a student's work in one place. We also adopted a naming convention to keep the files organized and to differentiate between different versions of student work. For example "LastName_ExperimentName_Version.pdf," where the "Version" indicated the current iteration of the work, *e.g.*, "Draft," "Draft_Reviewed," "Final," and "Final_Graded." In this way, all versions of the student's work could live together in the same folder, and we as instructors could easily differentiate and compare versions.

Once the student submitted work for review (in PDF format), the instructors would use the iAnnotate software to read, review, and comment on the work, and then return it to the student's folder alongside the original work. At the end of the semester, the student's folder was essentially a portfolio of work for the semester, containing all of their drafts, final reports, and other graded material. Having all of this data for all students, easily accessible in a single place, makes it incredibly easy to collect examples of student work and the revision process for evaluations like internal reviews or ABET accreditation visits. Garmon indicates that this cloud-based approach facilitates the instruction of writing as a process, rather than a one-shot effort, as students and instructors can

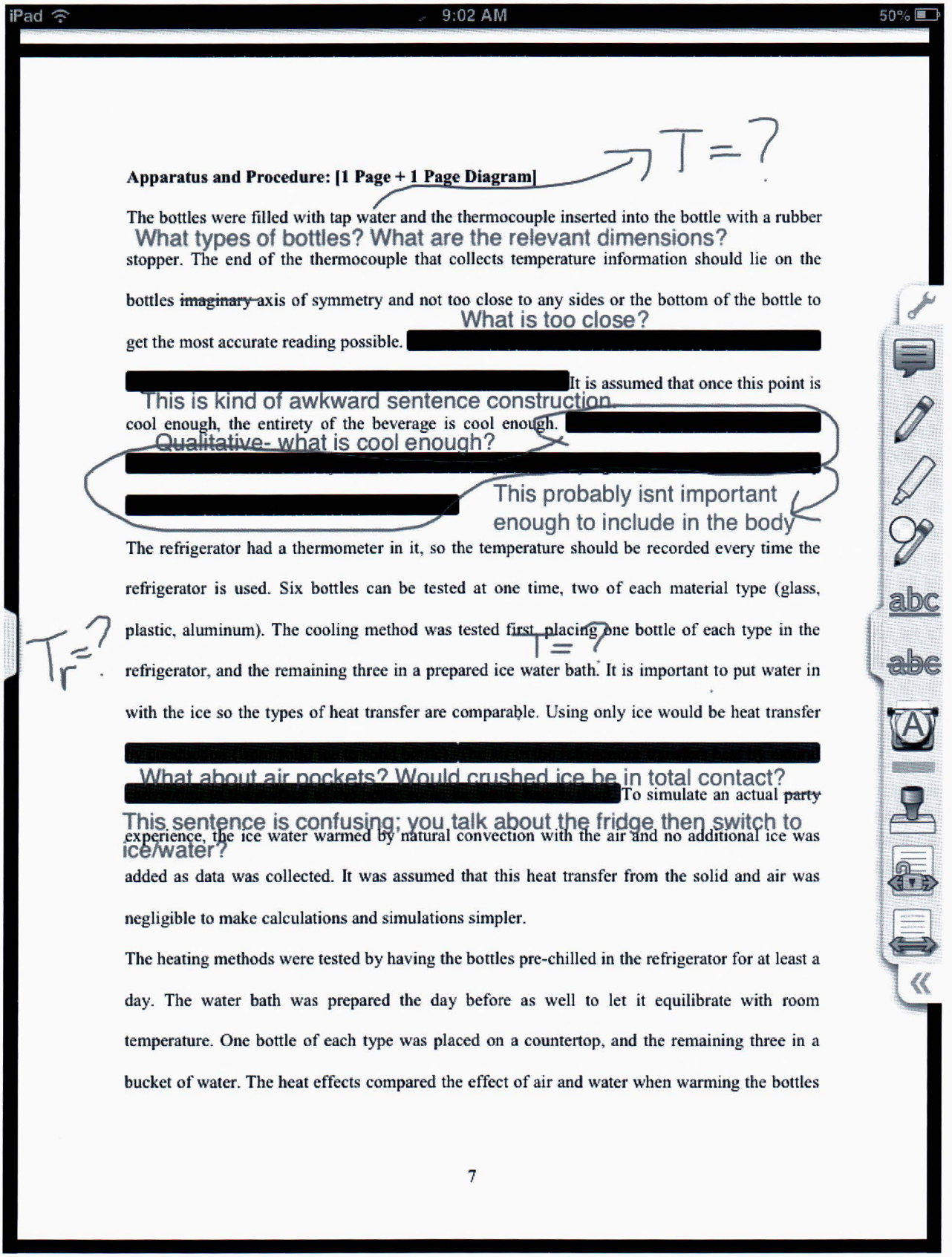

Figure 1. *An annotated student report, with different highlights, strikethroughs, comments, and other edits during the revision process.*

easily compare versions, corrections, and the like without being physically co-located.[15] We would like to point out, however, that this methodology was meant to streamline the grading and organization process for the faculty, and to create an easy system for students to submit work—not to act as a substitution for meaningful interaction with students. As instructors, we found that we spent about the same amount of time actually reading and commenting on drafts as we did with pen and paper, and still spent significant time reviewing our comments and suggestions with students in person. The comments and feedback to students will only ever be as good as the time and effort we put into it, regardless of the way we provide that feedback.

STUDENT RECEPTION

At the end of the term, after submitting and receiving their work in this format for the entire academic year, we asked the students about their experience, focusing on the effectiveness and the convenience of the workflow. Figure 2 shows a summary of their responses. The number one positive comment we received was that the electronic workflow significantly cut down on their printing budget, either personally or through the cost-per-page of using the university printing resources. This sentiment, whether driven by financial motivators or green ones, was echoed in numerous studies on the advantages of the digital workflow.[12,16] Additionally, students appeared to enjoy the features of Dropbox, independently creating new folders in order to share information between group members for their lab reports and design projects.

SUMMARY AND CONCLUSION

We set out to create a paperless, online workflow for our senior laboratory class, which has succeeded beyond our expectations. Students liked the flexibility of submitting everything electronically as it saved them time (and printing costs!), and the course instructors liked the convenience of a lightweight, mobile platform for receiving, organizing, grading, and returning student work. We've implemented a workflow that is reasonably close to the experience one would get grading paper materials by hand, but adds the conveniences described above without trivializing the editing process students must go through. We tried to keep costs manageable for this project. The iPads (for faculty) were by far the most expensive part ($499 for the least expensive model), but this

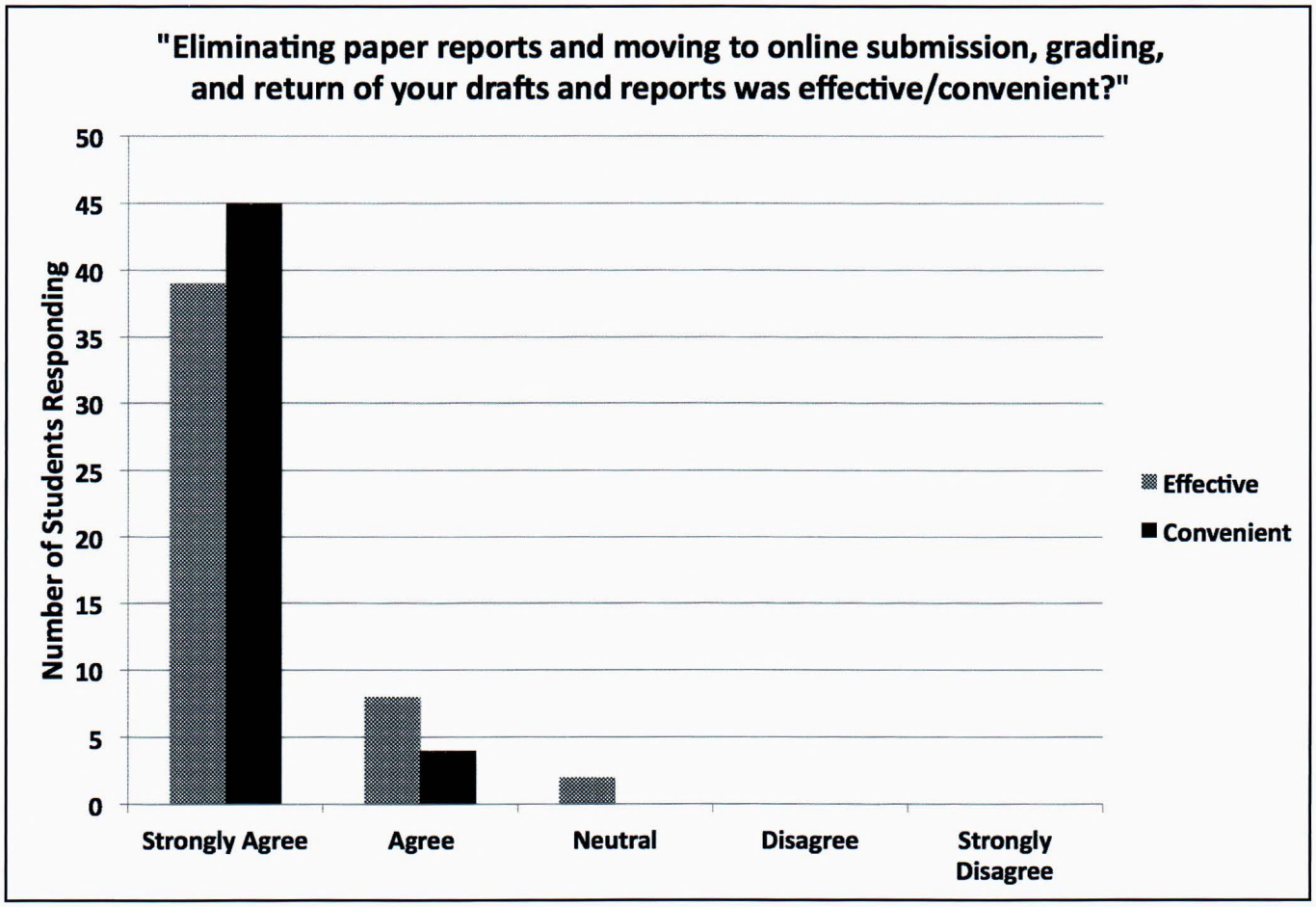

Figure 2. *Student responses on the effectiveness and convenience of moving to an all-electronic workflow for the submission, grading, and return of their lab work. The responses were uniformly positive.*

cost can be amortized over several years, and the devices are useful to the instructors as computing platforms outside the class. Software costs are either minimal, in the case of iAnnotate, or free, in the case of Dropbox. For anyone looking to streamline their workflow for courses in which there is a lot of student writing and revision, we recommend giving this approach a try.

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