Supporting Lab Report Writing in an Introductory Materials Engineering Lab

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Abstract

This paper will describe the development and implementation of a web-based support site for helping students write and reflect on lab reports in an undergraduate Materials Science lab. This project, part of a larger NSF project to support undergraduate lab report writing, details the specific challenges of implementing lab report writing support materials for engineering labs. The lab report writing project, LabWrite, is focused on helping students better understand the process of writing lab reports. This includes help with organization of information prior to coming to lab, how to organize data collection in the lab and finally, writing, graphing, and interpretation of the results.

One of the biggest challenges was the creation of support materials that would be relevant not only to basic science courses, but also to engineering courses. This paper will focus on how lab report writing in materials engineering differs from report writing in traditional science courses, such as chemistry and biology. Also discussed is a more general implementation issue of providing on-line support for writing, graphing, and interpretation of data. Lessons learned include the importance of taking a holistic approach to the infusion of these support materials into lab-based courses by involving faculty, lab instructors, lab support personnel, and students in the development and implementation of the material.

I. Introduction

Communication skills of engineering students have long been a concern of engineering educators [1-3]. Indeed, poor communication skills are often cited by engineering professionals as one of the primary inadequacies of entry-level engineers [4,5]. The ability to communicate effectively as engineers now has a place among the eleven curricular standards of ABET EC2000 Criterion 3. Certainly, many engineering educators would like to place the entire responsibility--and blame--for their students' writing and speaking on teachers in freshman composition and technical writing. But the problem lies much deeper than that. The difficulty engineering students have with

communication is not so much with grammar, spelling, and sentence structure as it is with learning what it means to think like engineers in their writing and speaking.

It is necessary, therefore, that those who are most able to help their students learn to think like engineers should also play an important role in helping them learn to write and speak like engineers. This places the responsibility back on engineering professors. Of course, the challenge has always been about finding time in engineering courses for teaching communication skills. One response to that challenge is to take advantage of the opportunities for teaching communication skills that already exist in the curriculum. While Wheeler [6] lists a number of possible venues for writing in the engineering curriculum, the most ubiquitous and yet the most overlooked is the lab report.

Practically all engineering students take laboratory courses and do lab reports. These reports offer an excellent opportunity for engineering educators to shape their students' thinking, helping them to think like engineers. Lab reports offer students the chance to reflect on what they have done in the lab and to frame their lab experience in the logical form defined by the engineering lab report. The problem, though, is how teachers of lab courses can find the time to run their labs and also provide sufficient instruction on the lab report.

Our solution to that problem is LabWrite, an instructional website designed to help engineering students learn how to think and communicate as engineers (see Figure 1). Part of a larger NSF-funded project to support undergraduate lab report writing, LabWrite was developed originally for science labs. But to make the website applicable to engineering labs, the LabWrite developers worked with teachers of an introductory materials science course (MAT 200) to customize the site for students of that course. This paper will detail the specific challenges of implementing these support materials for the materials science lab, specifically the shift in genres from the science lab report to the engineering lab, the results of from the evaluation of the project, and implications for using the LabWrite site in other engineering labs.

II. Developing the Site for the MAT 200 course

Materials Science and Engineering faculty and the LabWrite developers teamed together over the summer of 2000, motivated by a common interest in improving the quality of lab reports and the learning experience of students enrolled in the introductory materials science course for non-majors, MAT 200. This course had recently been expanded to be a required course for all engineering majors. In reviewing the existing LabWrite web site designed for basic science courses, the Materials Science faculty concluded that the lab experience and required lab reports differed enough to warrant significant changes to portions of the LabWrite site in order for it to be useful to the MAT students.

Changes needed to be made in the LabWrite site for Materials Science arise from the fact that there are different types, or genres, of lab reports. The 'classic' science lab report is based on the empirical scientific journal article. With this type of lab report, students form an a priori hypothesis that they then test through either qualitative or quantitative data collected during the

lab. These labs follow essentially a deductive process, with the important exception that in most cases, students are not generating new scientific knowledge during their investigations.

A variation of the 'classic' science lab report is the observational lab report. With this type of lab, a hypothesis is not formulated and tested. Instead, an inductive process is used whereby students use the observations they record in lab to formulate generalizations about the scientific or technical concept being explored in the lab.
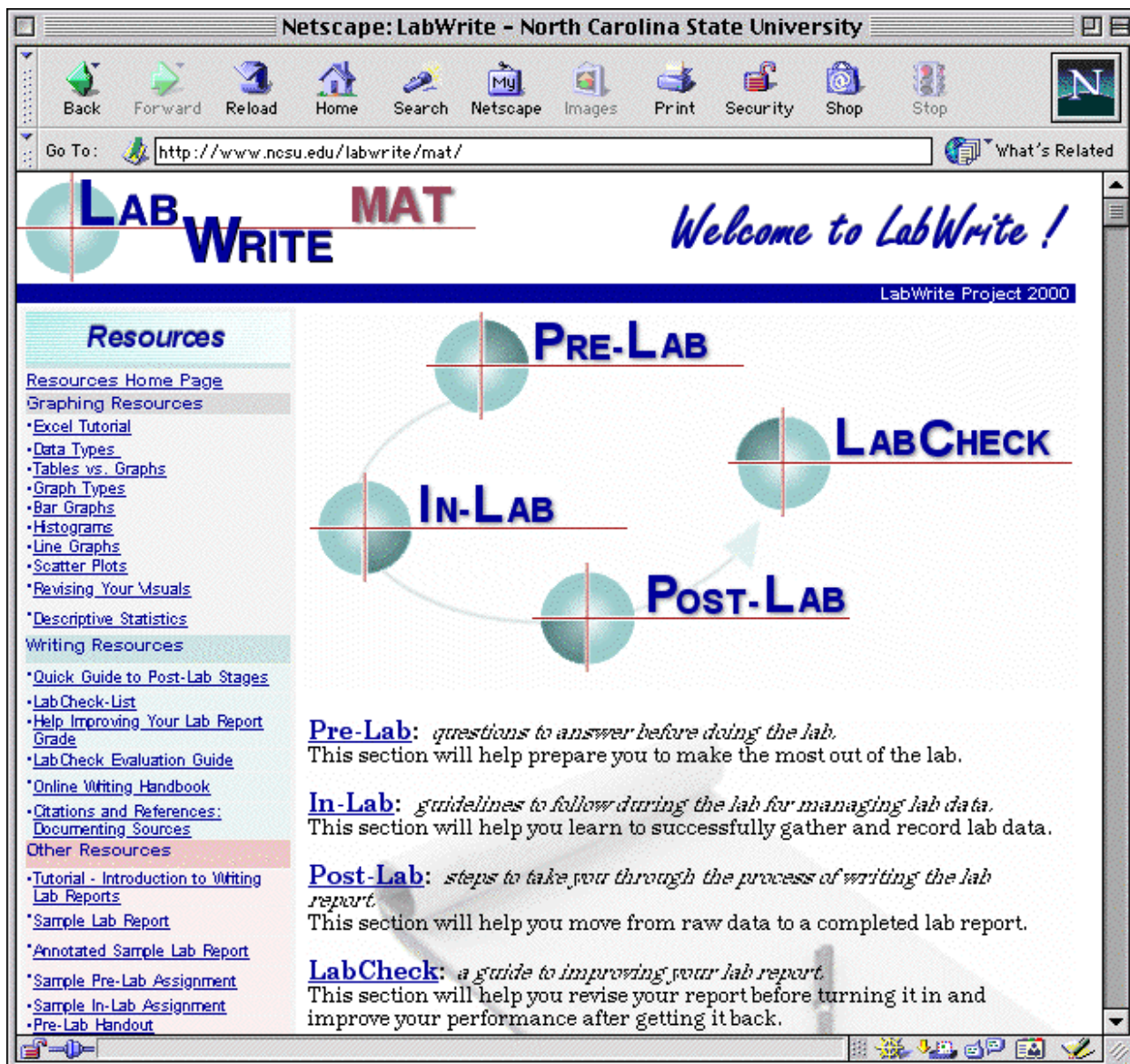

Figure 1. Main page for the LabWrite-MAT site.

A completely different type of lab report is the technical lab report. The technical lab report is

modeled after industry lab reports written by consultants for industry clients or for managers within an organization. Rather than expanding the base of scientific knowledge, technical reports use existing scientific and technical knowledge to address specific, practical problems. Unlike the science journal article, the technical report has as its audience someone other than scientific peers. This difference in audience for the technical report leads to a student version, the technical lab report, which is different from science lab reports. A technical lab report has a structure that is somewhat different than a science lab report, including sections such as a letter of transmittal and executive summary.

While the original LabWrite site was based on the 'classic' science lab report, the MAT 200 course used a format that was closer to the observational lab report. MAT 200 also differs from many other engineering labs which use the technical lab report as its basis. Because of the observational nature of the MAT report, the hypothesis-generating, deductive approach to the report taken in the main LabWrite site had to be transformed to an inductive approach. In addition, the MAT lab reports used a combined results and discussion section, a common variation on the science lab report.

Rather than create extensions to the existing LabWrite site, the decision was made to create a separate, parallel site [7]. The primary reasons for doing this were twofold:

1. It provided a discrete, self-contained website for the MAT students, where there would be no confusion as to what material was relevant for their course.

2. It offered an opportunity to track the LabWrite-MAT website usage separate from the main LabWrite website using Web server log analysis tools.

A clear disadvantage to this approach was the necessity of updating and maintaining two parallel websites that contained a large percentage of common materials. Once the main LabWrite website was produced and carefully edited, a copy was made and revised to create the LabWrite-MAT site.

III. The LabWrite-MAT site

Like the main LabWrite site, the LabWrite-MAT site was designed to support the lab report writing experience as it unfolded in class and in the lab (Figures 1 and 2). The site was divided into two main components:

- The core lab report writing support materials

- Additional resources to support lab report creation

In addition, these two main areas of the website, all key terms and concepts throughout the website are linked to pop-up windows containing definitions and examples.

The core section
Within the core section there are four parts, each representing a key stage of the lab report creation process (refer to Figure 2):

- Pre-Lab: This section provides an opportunity for students to prepare for their lab by guiding them through some basic questions about the lab. Answering these questions before each lab was designed to help students reflect on the engineering and science concepts being explored in the lab prior to performing the lab. In particular, MAT students are asked to identify the materials they will be working with and the properties of those materials they will be measuring. These questions are also provided in the form of a handout that students can complete and bring into their lab with them.

- In-Lab: This section provides support for organizing and recording data and observations made during the lab. If quantitative data is being collected, students are encouraged to define the type of data (i.e., scalar, ordinal, nominal) being collected, which are the independent and dependent variables and what is the relationship between them. In addition, the issues of accuracy, precision, and sources of error are introduced.

- Post-Lab: This is the section where students are led through the process of taking the data they have collected and the background material provided with the lab and transform it into a finished lab report. A critical element of this section is to impress upon students that the most effective way of writing the lab report is to write from the middle outwards. That is, begin by transforming the data collected into visuals (e.g., charts and graphs) and tables, formalize the goals of the lab and the scientific principles being explored in an introduction, and then write a discussion of the findings of the lab. Though the exact order of lab report sections written may vary slightly, it is never from beginning (abstract) to end (discussion) as most students assume.

- LabCheck: This section provides resources for checking on the completeness of the lab report prior to submitting it to the TA, for providing an explanation as to how a grade for the lab was arrived at, and support for understanding how to improve this report or the next one to be written.

The resource section
The resource section of the website exists both as a separate section with its own homepage, but also as relevant links interwoven throughout the core lab report writing pages. Main areas of the resource section include:

- Graphing resources. Since the creation of visuals is both a critical element in the creation of lab reports and the least well supported, extensive guides, tutorials, and examples are given for the creation of visuals such as scatter plots, line graphs, bar charts, regression lines, and error bars. Initially, students are led through a process of deciding if their data should be presented in a visual (as opposed to a table) and, if so, which type of visual would be most appropriate. Step-by-step instructions in using Microsoft Excel® software are given for the most common visuals.

- Writing resources. Here, direct links are given to brief guides to the stages of lab report writing, the checklist of required elements in a lab report, and a rubric that can be used to evaluate the lab report. In addition, links are given to outside resources on scientific and technical writing and how to properly cite references.

- Other resources. This section contains a number of additional support materials for students. Included in this section is a short tutorial for students, introducing them to the importance of lab reports and their relationship to scientific inquiry and the scientific method. Also in this section is an example lab report with extensive commentary on its key elements and a completed example pre-lab handout. Finally, a glossary of all of the defined terms contained in pop-up windows is provided.

IV. Working with the Lab TAs

The LabWrite development group understood the critical importance of working with the Teaching Assistants (TAs) who would be running the laboratory sections of the MAT course. While the lead materials science faculty might construct the labs and the LabWrite group the supporting website, it would be the TAs who play a critical role in encouraging students to make use of the website and to take an instructional approach that allows students to make maximal use of the resources on the site.
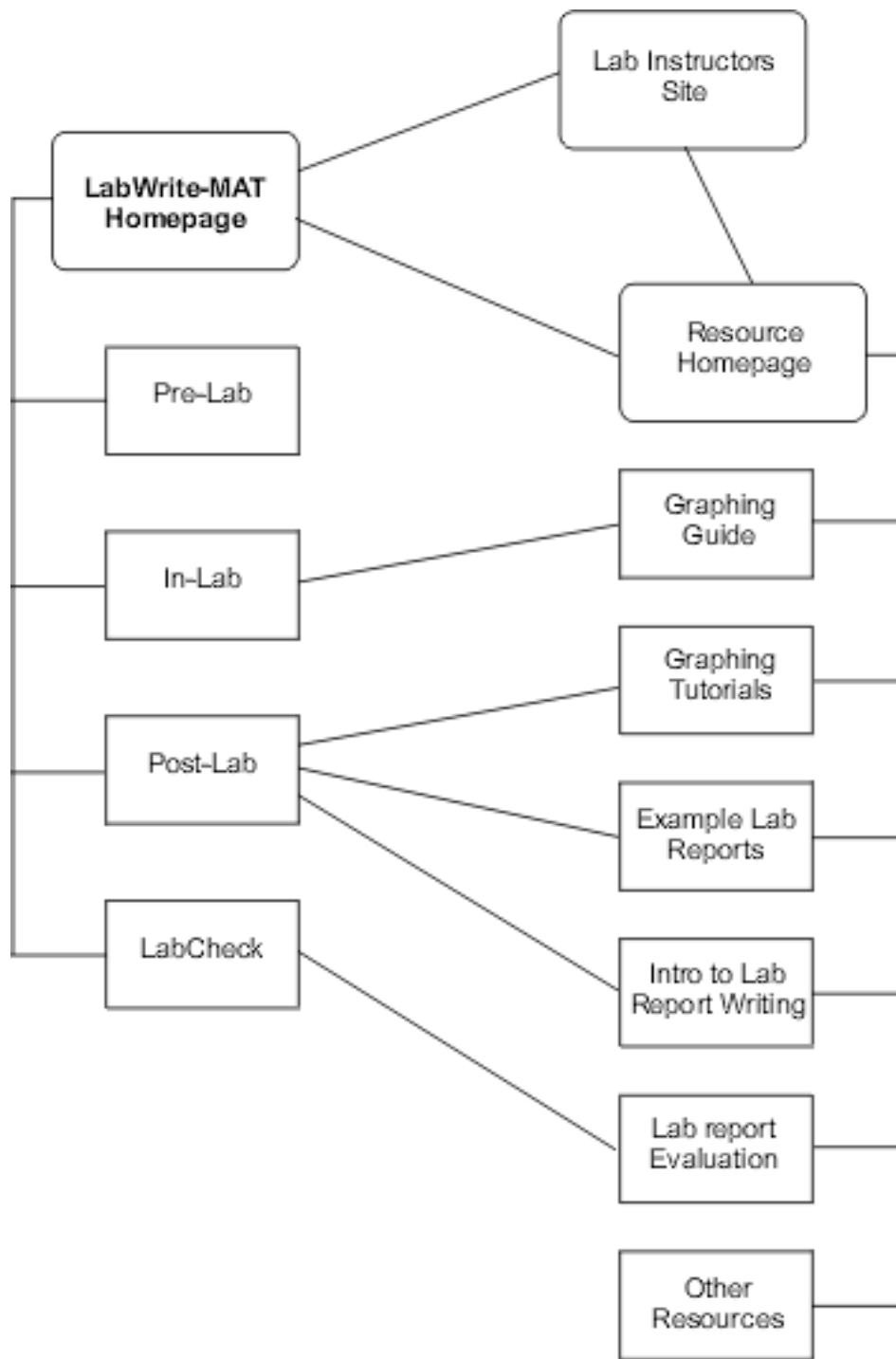
Figure 2. LabWrite-MAT site design

For this reason, a special website was set up for lab instructors [8] and a special introduction to the LabWrite site was conducted for the TAs. The introductory session provided a brief overview of the principles that guided the development of the website and the main features of the site. The Instructors' website contained more detailed information concerning the philosophy and goals of the LabWrite site along with handouts and notes the TAs could incorporate into their own instruction on lab report writing.

The goal of the Instructor's site and special introductory session was to try to help the TAs see the value of the website to their teaching. Besides appealing to the more altruistic goals of better science and engineering writing and understanding, the LabWrite team also tried to convince the TAs that the website would result in grading lab reports easier and more consistent. In addition, the website should relieve the TAs of routine questions concerning the content of the lab report and use of Excel to create charts and graphs.

V. Results and Lessons Learned

Approximately 150 students were enrolled in 13 MAT 200 lab sections in the Fall 2000 semester. Web server log data was acquired and processed revealing a total of 1211 unique sessions on the LabWrite-MAT site between September 4 and November 30, 2000. Though it cannot be guaranteed that individuals or instructors in MAT 200 initiated all of these sessions, sessions not initiated from a web browser (i.e., spiders, bots) and those initiated by search engine queries were filtered out. The sessions per day means were 11.7, 22.8, and 12.5 for September, October, and November, respectively with a high of 71 sessions recorded on October 2nd and a low of 1 session recorded on a number of days. When compared to the number of students in the class, this would translate roughly to 8 visits to the site per student. In all likelihood, there would have been a number of students who did not visit the site and all, leaving a higher residual average for those students who did use the site.

The mean number of unique web pages visited per session was 3.8, 2.9, and 2.0 for September, October, and November, respectively. A review of entry and exit pages for the sessions revealed that, besides the main LabWrite-MAT homepage, the pre-lab and post-lab homepages were particularly popular destinations, as was the pre-lab handout page.

A visit was made to two lab sections in early October. Discussion with the students revealed that five of ten students in one section and five of twelve students in the other section had made use of the LabWrite-MAT site. When asked why they did not make use of the site (more or at all), students indicated either that they had forgotten about the site or that the course lab manual provided all of the information they needed for completing the labs. Further discussion with the site users revealed a couple of common threads. One thread was the usefulness of the Excel tutorial material posted on the site since some students indicated that they were not familiar with some of the software techniques required of them in their labs. Second, the site helped inform the students about how a lab report is organized, that is, what order the sections of the lab report are written and what content goes into each section. Related to this, students made use of the site to

confirm that they had the necessary content.

In late November, a more in-depth interview was conducted with two other students who had made extensive use of the LabWrite-MAT site to gather more specific information concerning the content and design of the site. The students stated that their TAs made an announcement about the website the first day of lab, but not again. Both students indicated that it took a fair amount of time to completely go through the site. In particular, the post-lab section contained a lot of useful information on writing lab reports, but that it was somewhat difficult to get through and assimilate all of the material in this section of the site. The students also noted that while the site contained detailed information pertaining to the writing of lab reports, it contained none of the specific information for any of the labs performed. One student noted that he felt that the first lab report he wrote (after spending a considerable time at the website) was the best report he had ever written in school, but that it was marked down because he had left out specific information requested in the lab manual. Both students indicated that they were initially motivated to use the site to try and understand what the content and 'look' of the lab report was supposed to be. Their use of the site tapered off as the semester progressed, referring to the site only when needing a specific piece of information. The students did not realize that there was an electronic copy of the report grading sheet on the site with links back to specific information on parts of the lab report. Finally, neither student made much use of the Excel tutorial material because they felt they were already competent with the software.

A discussion with five of the TAs in early December revealed that many of them were not familiar with many of the specific elements of the LabWrite-MAT site. Of particular concern to the TAs was the student's ability to do some of the more difficult techniques in Excel. For example, they indicated that students had difficulty creating histograms for the last lab. Students also had difficulty extracting a sub-sample of a stress-strain curve and performing a linear regression on the remaining data points. When asked about what they would like to see in the way of improvements on the site, they listed items that were already available. Two other changes suggested for the next semester were including hot links to the website within the MAT 200 lab manual CD and to create a sample lab directly relevant to MAT 200.

The experiences piloting the LabWrite-MAT website the Fall 2000 semester have led to a number of possible changes in site content and implementation for the Spring 2001 semester. First, the post-lab section is being reorganized to provide a more salient overview of the process when the students first enter the post-lab section. For many students, the lab report is the first time that they have constructed a written work in a non-linear fashion. That is, they have not (or should have not) begun the lab report by writing the abstract and then proceed on through to the discussion. Yet the way the post-lab section of the website was organized, it was not easy for students to see the 'big picture' of what the lab report writing process was. Furthermore, the content has been organized so information is stratified in different levels of detail. While all of the content is still easily accessible, students do not have to scroll through all of it every time they visit the section. Second, efforts to make students aware of the LabWrite-MAT site need improvement. Clearly, many students did not make effective use of the site. This will be done through a two-fold effort.

Links to specific, relevant areas of the website will be hotlinked on the homepage of each lab on the MAT 200 lab manual CD. This will provide a reminder to the students of the additional resources available as well as bind lab manual content to the LabWrite-MAT website content. Additionally, more time will be spent educating TAs about the resources available at the website. TAs clearly see that many students need some level of help with using Excel for completion of the lab reports but are not aware of what is available or how to use the materials on the website to help their students.

Long term, one of the biggest efforts will be the continued exploration of tension between having a generic website supporting the writing of lab reports that can be used by a multitude of courses while also providing the specific support for the completion of lab reports in a given class. The engineering lab report is a prime example of 'situated writing' [9] and it comes as no surprise that faculty, TAs, and student alike all come to the website looking for information to address the immediate needs of writing a lab report for a specific lab. There needs to be a balance struck between providing general education in the genre-specific writing of lab reports and providing more specific support for a given lab. Feedback from all of the different courses using LabWrite has clearly indicated that students are not well versed in the art of writing the lab report. Still, if TAs do not perceive the site as providing support for their lab section, they will not encourage their students to use it. If students do not perceive value in the site for supporting their lab work, they will not use it. An initial compromise was struck by developing parallel sites to support both the 'classic' science lab report and observational science lab report sub-genres. While the development team is heartened by the site's success in the initial pilot, additional work is necessary if the websites are to reach their full potential.

Acknowledgements

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