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Bringing technology to the First Year Design Experience through the use of Electronic Design Notebooks

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In 2011, I joined the Biomedical Engineering (BME) Department as a Lecturer and Outreach Coordinator. As part of the BME design faculty, I work on curriculum development, as well as innovative approaches for teaching design. I coordinate BME outreach, advising BME seniors as they develop interactive hands-on activities for K-12 students that teach biomedical engineering concepts. Additionally, in 2012, I began teaching an introductory engineering course (Introduction to Engineering Design) to incoming freshmen in the College of Engineering. In 2014, I became a coordinator for the Introduction to Engineering Design course, which has become a popular course with over 900 students enrolled per year, and an expected enrollment of 1000 students this coming academic year.

John Murphy, University of Wisconsin, Madison

John Murphy received a Bachelors of Science degree in Mathematics in 1983 and a Masters of Science degree in Mechanical Engineering in 1985, both from the University of Wisconsin-Madison. He then was employed for four years as an Aerospace Engineer with Rockwell International in Los Angeles. His work effort was concentrated in Space Shuttle Main Engine (SSME) rocket performance and Strategic Defense Initiative (SDI) kinetic kill experiment verification. He performed various analytical and design functions on both programs. He then moved to Milwaukee where he worked as an energy consultant for Wisconsin Electric Company, concentrating his efforts in their demand side management energy conservation program. In 1990, he returned to the University of Wisconsin-Madison where he completed a Masters of Science in Nuclear Engineering in 1992. He has continued his employment with the Engineering Physics Department since then. He completed a Masters of Business Administration degree from Arizona State University in December of 2006. Mr. Murphy is a licensed Professional Engineer and currently works in mechanical and nuclear engineering at the University of Wisconsin-Madison in the Department of Engineering Physics. His duties involve coordinating and teaching the freshman design course and the freshman introduction to nuclear engineering. He teaches and coordinates the senior design function for nuclear engineering students. He also teaches Advanced Nuclear Reactor Systems and Power Plant Technology courses. He is the outreach coordinator for the Department of Engineering Physics. In addition he was a licensed senior reactor operator at the University's nuclear reactor lab for twenty years. His research interests involve nuclear reactor safety and operations.

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Introduction

Including a coordinated curriculum that provides an atmosphere of collaboration and support from peers with first-year engineering students has been shown to increase graduation rates and the overall positive experience for students.[1,2] Our freshman *Introduction to Engineering* design course strives to accomplish this in part by providing a collaborative real-world engineering design experience that pushes students to work well together to accomplish a design goal. Many of these first year engineering students take the same general math and science courses as part of the engineering requirements, thus working in teams forces collaboration and often friendships that carry over into other engineering courses. In addition to providing a collaborative engineering design environment, we strive to introduce our first year engineering students in our *Introduction to Engineering* design course to cutting-edge resources and technology to prepare them for a successful engineering career.

Introduction to Engineering Design Course

Our *Introduction to Engineering Design* course offers first year engineering students from all engineering disciplines a chance to work together on design projects, and participate in lectures covering design topics that span multiple disciplines of engineering. This introductory freshman engineering course has been offered since 1994, and is highly valued by faculty and students.[2] In the laboratory section, they work in teams of 8-12 with a $200 budget (funded by our College of Engineering) to solve a real-world, client-based engineering design problem proposed mostly by individuals in the local community. Our regular clients often encourage others in the community to apply to our program. To further recruit clients and projects, mass emails are sent out in the fall, spring, and summer to past clients, University researchers, and to local non-profit organizations. For example, one of our clients is the United Cerebral Palsy (UCP) of our county. What started as one lone project in 2012 to build a stair railing for a woman with cerebral palsy, has now turned into several projects every semester due to the overwhelming success with our students. UCP is now in constant contact, continually supplying new projects, and even additional funding in some cases, to help those with motor disabilities in our community. We have also partnered with children's museums, the Department of Natural Resources, local farmers, and many other individuals and communities in need with similar success stories.

The students learn how to interact with a real client, work as a team, as well as communicate using respectful people-first language. The students learn the design process first-hand, from brainstorming, design specifications, literature research, and design evaluation to design implementation. Students are required to record this entire process in a design notebook, present their prototype to their classmates and client, and write a report at the end of the semester. The design notebook also serves as documentation of each individual student's contribution to the project. Through this process the students understand the value of team-work and maintaining a design notebook.

Over the last five years, the number of students taking our course has nearly doubled to now nearly 1000 students per year. Currently, there are 13 instructors to instruct the laboratory

sections of this course. These instructors are tenure-track faculty, teaching staff, and individuals from industry. To assist the instructors, each lab section has two student assistants who have previously taken the course or have an engineering background. Maintaining consistency between labs and evaluating the course work for the increasing number of students has become arduous.

Especially daunting is assessing their design notebooks, which on average are 33 per laboratory section. Design notebooks are a critical piece that highlight an individual's contribution to the team and protect their intellectual property. Additionally, even as freshmen, the students utilize a variety of technology in their designs, much of which is difficult to print or include in a bound paper notebook. To combat these issues, as well as offer new technology to first-year engineering students, we implemented LabArchives electronic laboratory notebooks (ELN) as a replacement for the previously used paper notebooks. First, ELNs were introduced as a pilot in three lab sections in Spring 2014. Due to the success of this pilot, as well as success in other courses, ELNs were then offered to all sections this past Fall 2014 semester. Here we assess the implementation strategies and use of the ELN (LabArchives Classroom Edition) in the freshman *Introduction to Engineering* course, including the facilitation of instruction, enhanced student design notebook performance, and the added benefit of peer-to-peer collaboration and learning through notebook sharing. Evaluation was performed through student and instructor surveys at the end of the Fall 2014 semester.

Electronic Laboratory Notebooks

Electronic laboratory notebooks (ELNs) give students an opportunity to utilize advanced technology to record and store data online that has traditionally been hand-written in paper notebooks. In general, ELNs have numerous advantages over paper notebooks including: sharing with teammates; accessing remotely; cannot be lost; easily graded anytime; can easily upload videos and computer generated images; organized system; and saves resources such as paper. ELNs have also shown direct benefits to our students in our Biomedical Engineering (BME) upper classmen design classes. The benefits include neatness, organization, quality and quantity of entries, and availability of the content to instructors, clients, and teammates.[2]

LabArchives ELN was chosen due to the very successful implementation of the classroom version in the Department of Biomedical Engineering (BME) Design Courses, and the fact that our university began a campus-wide contract with LabArchives to provide this technology to research labs and other courses. LabArchives was well-studied and compared with numerous other ELNs and deemed the best option currently available that provided both a research and classroom edition.

Electronic Laboratory Notebook Format

Due to considerable reluctance by many instructors teaching the freshman course, implementation of the ELN as a replacement for the paper design notebook was strongly encouraged, but optional. During the Fall 2014 semester, 7 (of 13) instructors elected to use the ELN in their classrooms. A master notebook was created with folders representing the general stages of the design process including: brainstorming, background research, design sketches, design evaluation, fabrication, and prototype testing and analysis. Other folders within this

master notebook, such as the contact information table and entry format, were modeled after the BME design notebook.

Survey Results

At the end of the Fall 2014 semester, all students, student assistants and instructors (regardless of whether they used paper notebooks or the ELN) were asked to complete a survey on the use of laboratory design notebooks in our course that semester. Although nearly 50% of students did not use the ELN, response to the notebook survey was very good, with a 76% response rate. Of our lab instructors, 6 used the ELN, 1 used both ELN and paper, and 6 used paper only. Instructors that used paper only did not respond to the survey. Overall, the percentage of students who would choose to use the LabArchives ELN in the future was low at just 40 %. Here, we report some preliminary data related to time spent learning LabArchives (Figure 1), resources used to learn LabArchives (Table 1), and multivariate plots of ELNs vs. paper notebooks performance in logistical categories (Figure 2). Figure 3 shows a multivariate plot of ELNs vs. paper notebooks performance in instructional logistical categories.

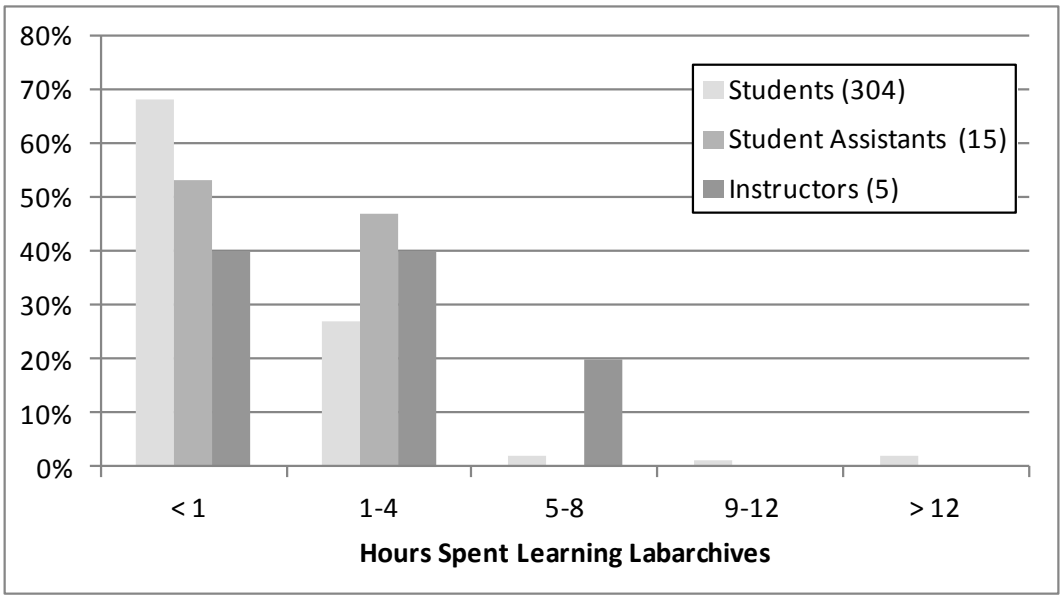


Figure 1. Time spent learning LabArchives by those using ELN or ELN and paper. Within each time categrory, the first bar (light gray) is students, the second bar is student assistants (medium gray), and the third bar (dark gray) is instructors. Survey results of 304 students, 15 student assistants, and 5 instructors. Students and student assistants generally spent 0-4 hours, and instructors spent 0-8 hours learning LabArchives.

In general, the trends show that students and student assistants spent a similar amount of time (0-4 hours) and instructors spent more time (0-8 hours) learning LabArchives (Figure 1). Students, student assistants, and instructors were then asked to rate the usefulness of resources available to learn LabArchives (Table 1). Although numerous resources were available to assist with learning LabArchives, students, student assistants, and instructors rarely utilized them. Especially interesting is the lack of using the Quick start guide, and the webinars since these were specifically discussed at meetings and via email to all students and instructors (Table 1).

Students	Did not use	Very Helpful	Somewhat Helpful	Neutral	Somewhat Not Helpful	Not Helpful
Webinar / Web training	241	4	23	26	7	1
Quick Start Guide PDF (emailed to students)	212	11	33	28	13	2
YouTube videos on LabArchives	262	0	10	20	3	4
Hands-on Tutorial Notebook	233	8	26	22	3	5
Instructor and/or SA	69	83	100	35	11	3
Explored and figured it out myself	20	181	75	19	4	2
LabArchives Tech Support	259	2	10	21	4	3
Another team member	120	72	81	23	3	1

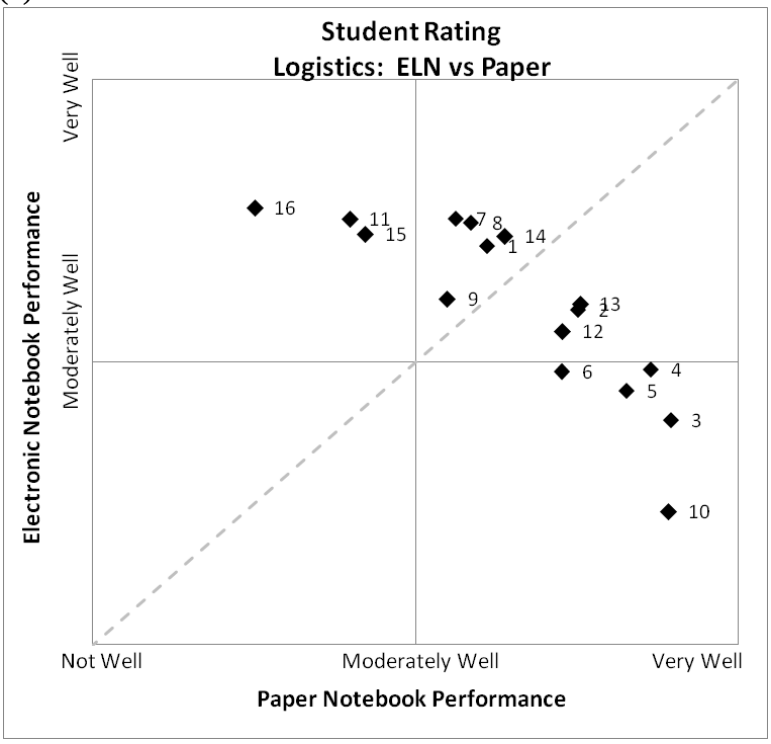
Student Assistants	Did not use	Very Helpful	Somewhat Helpful	Neutral	Somewhat Not Helpful	Not Helpful
Webinar / Web training	11	0	2	1	1	0
Quick Start Guide PDF (emailed to you)	9	0	2	4	0	0
YouTube videos on LabArchives	13	0	0	2	0	0
Hands-on Tutorial Notebook	12	0	1	2	0	0
Instructor and/or SA	5	3	4	3	0	0
Explored and figured it out myself	0	7	6	2	0	0
LabArchives Tech Support	10	0	2	2	1	0
Another team member	9	0	4	2	0	0

Instructors	Did not use	Very Helpful	Somewhat Helpful	Neutral	Somewhat Not Helpful	Not Helpful
Webinar / Web training	4	0	0	1	0	0
Quick Start Guide PDF (emailed to you)	2	1	2	0	0	0
YouTube videos on LabArchives	5	0	0	0	0	0
Hands-on Tutorial Notebook	2	0	2	0	0	0
Instructor and/or SA	3	2	0	0	0	0
Explored and figured it out myself	0	3	1	0	1	0
LabArchives Tech Support	2	2	0	1	0	0
Another team member	2	1	0	2	0	0

Table 1. Resources used to learn LabArchives by those using ELN or ELN and paper. Survey results of Students (n=302) Student Assistants (n=15) Instructors (n=5). In general, the majority of students, student assistants, and instructors did not use many resources available and instead figured it out on their own. The highest scores are highlighted in blue.

The multivariate plots of the ELN vs paper notebooks performance in logistical categories (such as formatting, neatness, sharing content, etc--see Figure 2 a-c), showed that student assistants rated ELN performance lower than students and instructors in most categories with the exception of neatness, sharing content, and linking to other media. In contrast, the instructors rated the ELN performance higher than paper notebooks in most categories with the exception of taking meeting and research notes, keeping the notebook up-to-date, and being accountable to keep the notebook up-to-date. Data points above the dotted line indicate better ELN performance, and data points below the dotted line indicate better paper notebook performance. Each number corresponds to a category listed in the key, with those highlighted in gray indicating ELNs performed better than paper notebooks.

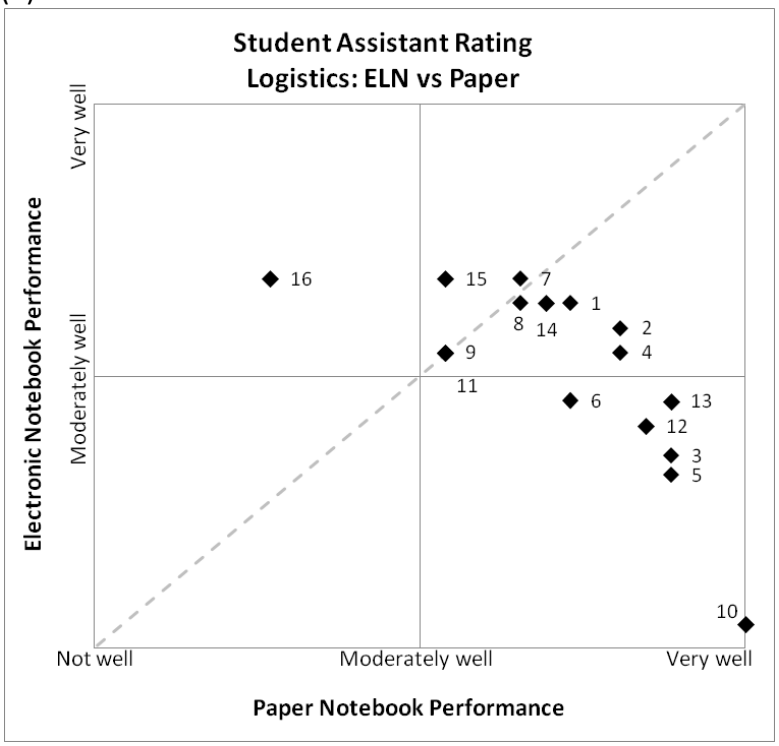
(a)



KEY

1 Maintain contact information
2 Format notebook entries
3 Take meeting notes
4 Take research notes
5 Keep the notebook up-to-date
6 Be accountable to it keep up-to-date
7 Maintain neatness
8 Maintain organization
9 Manage draft revisions
10 Make design sketches
11 Insert images
12 Annotate content
13 Review the notebook
14 Ability to find information from previous entries
15 Share content
16 Link to materials outside notebook (citations, data, webpages, etc.)

(b)



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(c)

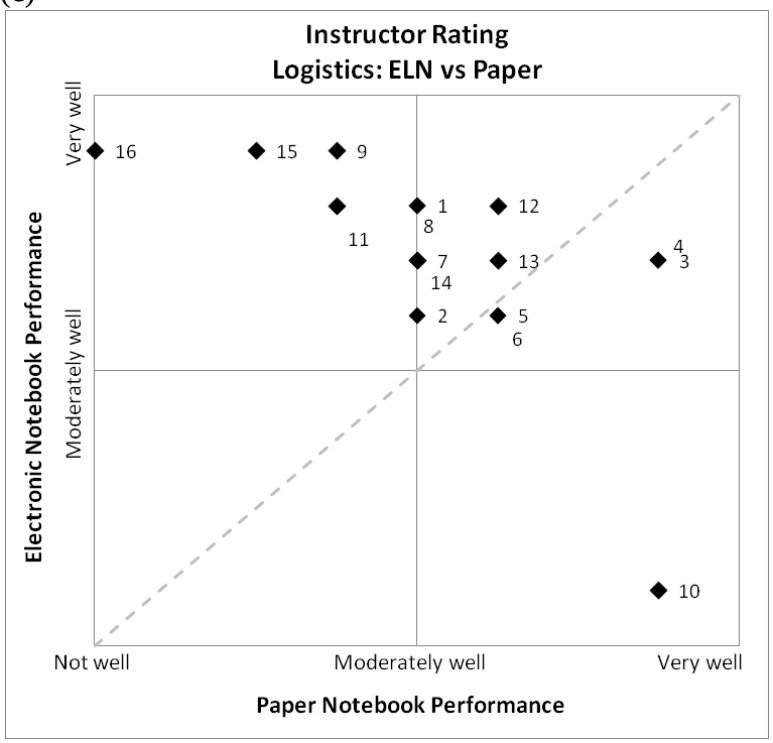

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Figure 2 a-c. Multivariate plots of ELNs vs. paper notebooks performance in logistical categories, with each category rated not well, moderately well, or very well. (a) Students, (b) Student Assistants, (c) Instructors. Each number corresponds to a category listed in the key, with those highlighted in gray indicating ELNs performed better than paper notebooks.

Instructional logistics were surveyed for student assistants and instructors only. Student assistants and instructors were asked to rate the ease of completing various tasks in the ELN vs. paper notebooks, such as notebook viewing, performing notebook checks, and finding information. A multivariate plot of the ELN vs. paper notebooks performance for instructional logistical categories with combined results of student assistants and instructors is shown in Figure 3. Again, student assistants rated the ELN lower than instructors in most categories. Instructors rated ELNs highest for viewing students' notebook and performing notebook checks.

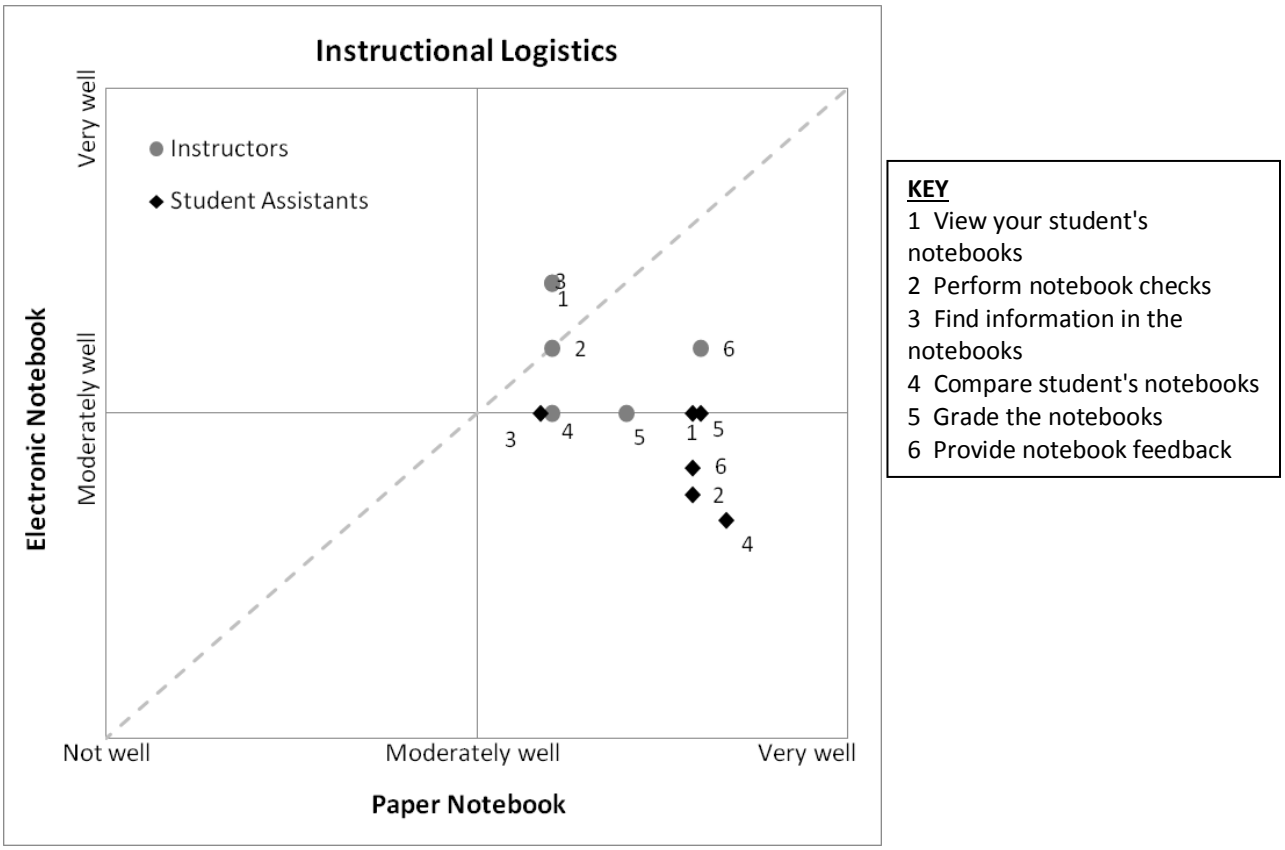

Figure 3. Multivariate plot of ELNs vs. paper notebooks of instructional logistics. Instructor responses indicated by gray circles, student assistant responses indicated by black diamonds. Within the upper right quadrant, data points above the dotted line indicate better ELN performance. Data points below the dotted line indicate better paper notebook performance. Each number corresponds to a category listed in the key. In general, student assistants rated ELNs lower than instructors.

Conclusion

It is possible that the lack of formal training for instructors and student assistants led to the unexpected negative outcome for a large percentage of students and student assistants. Due to this result in particular, a new strategy for implementation was deemed necessary for the Spring 2015 semester. In an effort to have a smoother transition from paper notebooks to the ELN, all labs were required to use LabArchives ELN for all laboratory design notes during the Spring 2015 semester. LabArchives ELN was briefly introduced to the lectures during the first week, (approximately 235 students each lecture) in order to avoid confusion early on and to insure that all students were aware of this requirement.

Instructors and students had differing opinions on the ease of using LabArchives for all notes, including lecture notes. One instructor using both paper and the ELN for lab design stated, "I instructed the students to use both because it was easier to jot down notes and create sketches in a paper notebook, and then transfer the content to the LabArchives later." However, numerous complaints by students and student assistants included language suggesting that scanning and uploading notes was the reason they did not like using an ELN. Due to this, during the current spring semester we are no longer requiring students to upload hand-written notes from lecture.

These preliminary results seem to indicate that student assistants felt that the ELN did not facilitate grading (as indicated in the multivariate analysis of instructional logistics in Figure 4), and was more difficult to use compared to paper notebooks (See Figure 3b). Other institutions evaluating ELNs vs. paper notebooks have also reported mixed results.[4] It would seem a worthwhile endeavor to investigate methods of introducing ELNs to make the transition from paper notebooks to electronic notebooks have a more positive outcome.

In the Fall 2014 semester, only instructors and students were emailed the Quick start guide for LabArchives and only instructors were given information regarding how to sign up for webinars. Student assistants were not directly trained to use LabArchives or involved in any discussion. It was assumed that each instructor would provide the necessary information to their student assistants to aid in the instruction of LabArchives within each individual lab.

Student assistants are undergraduate students, and as such are essentially peers of the students taking the course. Students may be more influenced by their student assistants than their instructors. Thus, in an effort to determine if the student assistant's poor ratings of the ELN were due to lack of information and training, all student assistants assigned to labs for the Spring 2015 semester were required to attend an hour long seminar on LabArchives given by a course coordinator, as well as a thirty minute webinar given by LabArchives staff. These sessions were given one week prior to the start of classes and were geared toward putting the student assistants in control of the ELN implementation and grading in the labs. Student assistants readily embraced the new technology and the opportunity to lead the implementation. This also eased the burden of learning and teaching new technology for the instructors. Instructors that previously declined using the LabArchives ELN during the Fall 2014 semester, are now required to use the ELN for the current Spring 2015 semester. The student assistants have been given the opportunity to lead the student training in each individual lab, and will serve as a liason between instructor and student. This model more closely aligns with previous successful ELN implementation in other courses in engineering[3], thus these changes are expected to have a significant positive impact this semester in our *Introduction to Engineering Design* course.

Currently, based on observation and meetings with student assistants and instructors, it appears that the additional training and eliminating the lecture notes requirement are already having a positive impact on LabArchives implementation. We are also already receiving positive feedback from students and student assistants on the ease of use, sharing, and organization capabilities of LabArchives. At instructor meetings this semester, it is clear that grading is significantly easier in LabArchives than the previously used paper notebooks. The ELN is organized into folders that follow each step of the design process, allowing instructors to quickly determine if students

have created and/or uploaded appropriate entries. The ELN is also available for viewing at any time without hindering student progress, in contrast to the previously used paper notebooks which could only be viewed when students turned them over to instructors. Implementing ELNs has already been shown to significantly improve ease of grading and student performance in many areas such as quality and quantity of entries, neatness, and organization, thus we feel compelled to determine the best mode for successful implementation of ELNs in our freshmen course.[3]

During the next few months, the Fall 2014 survey results will be further analyzed, including word analysis of student comments related to their paper and/or ELN experience. This will allow a more in-depth understanding of paper vs. ELN student notebook performance. The hope is that the data gleaned from the Fall 2014 semester will lead to a better electronic notebook experience for our *Introduction to Engineering Design* students in the future.

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