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Making Electric Machinery Labs Easier to Grade

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Abstract

The best way to teach electric machinery is with hands-on labs. At the beginning of the Fall 2020 semester, due to COVID-19 concerns, it was unclear whether in-person laboratories were going to be allowed. As the semester drew closer, it was determined that we could have in-person labs, but we could only have one person per lab bench. Due to high voltages and rotating machinery on the benches, this would be a safety hazard. A compromise was reached and we were allowed to have two students per bench, but the students were required to wear face shields in addition to the required face mask and gloves. When running the lab in the past, all lab data, calculations, and discussions about the lab assignment were written on engineering data sheets (similar to industry). With the possibility of touch transmission of COVID-19, we switched to electronic forms. To do this we added input boxes into the existing lab handouts using Adobe Acrobat. The students then submitted their assignments via our Moodle-based learning management system (LMS). With forms created with Adobe Acrobat each of the input blocks can be assigned field names. You can then transfer the form data into an Excel spreadsheet. Once in spreadsheet form, you can create equations in Excel to quickly check the accuracy and appropriateness of the students' data. Color coding was used to indicate when values were off by more than 0.5% to 5% of the expected value. The instructor could then determine if points should be deducted. If the error was small, it was simply noted with a comment on the student's submittal. For larger errors, points were deducted using a rubric in the LMS created for each lab assignment. For the discussions, the text was also imported into the spreadsheet and the rubric was used to assign a grade. Both the lab handouts and the Excel spreadsheets have been used in subsequent semesters. This paper looks at the process to create forms from the lab handouts, creating the Excel spreadsheet to check the students' data, the responses of the students to this type of lab assignment, and problems encounter with the implementation.

Keywords: Learning Management System (LMS), Lab Forms, Automated Grading, Transformer and Electric Machine Lab Assignments

Introduction

Automated grading and assessment is not a new concept. Automatic grading of programming assignments has been around since at least the 1960s [1]. This work continues with the advent of E-Learning systems [2]. There are numerous platforms for grading and student assessment list in [3]. This paper uses these concepts in grading of lab assignments for electric machinery.

Literature Search

A search of the ASEE PEER Document Repository system for "Automated Grading Motor Labs" yielded 434 results. None of these appeared to directly relate to electric machinery laboratory assignments. For example in [4], the author discusses grading an embedded systems and microcontrollers lab, but not electromechanical devices; whereas in the authors' focus in [5] is on flipped classrooms.

Creating the Forms in Adobe Acrobat

In Adobe Acrobat Pro there is a feature that allows you to create forms. To access this feature, open up a PDF document and click Prepare Form as shown in Figure 1. All of the labs for the course were already in PDF format and available in the LMS.
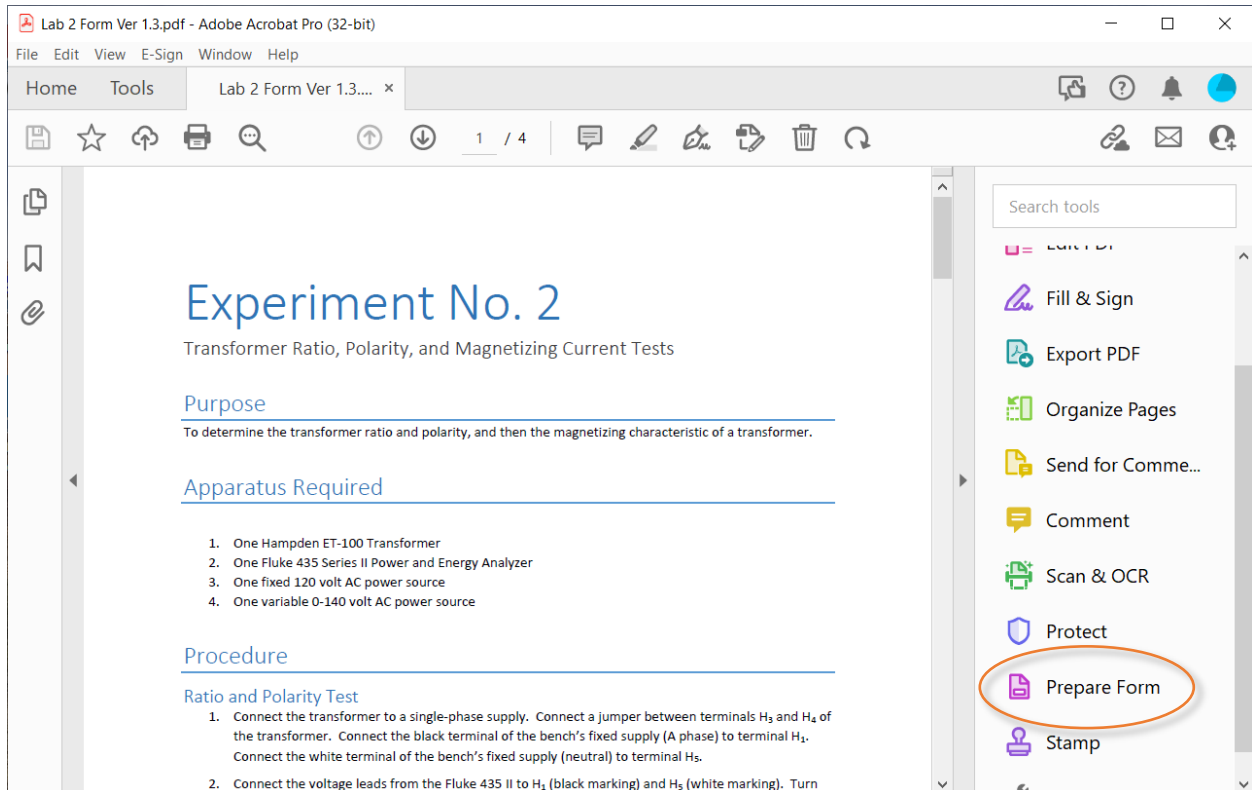

Figure 1. Form Creation in Adobe Acrobat

The program will automatically create fields based on the formatting features of the document. Adobe Acrobat gives cells in tables or underlined blocks a unique field name. The program also creates fields for other items, such as parts of the headers and footers. These fields and several others are not needed, so they were deleted. In Figure 2, the field for the measured voltage at V_1 has been selected. Clicking on that field brings up the dialog box shown in Figure 3. The name that Adobe automatically assigns to the field is usually not descriptive enough, but it can be changed. In this case the field name is "Measured V1" and a tooltip (seen when the student's mouse hovers over the field) has been defined as "Measured Voltage from H1 to H5" for this cell.

The dialog box tab for formatting the cell has been selected in Figure 4. For numerical answers, usually two decimal places are sufficient. One problem that was encountered was the students adding units to their values even though the units were given in the table. In later forms a drop down box was added that contained several choices for units.
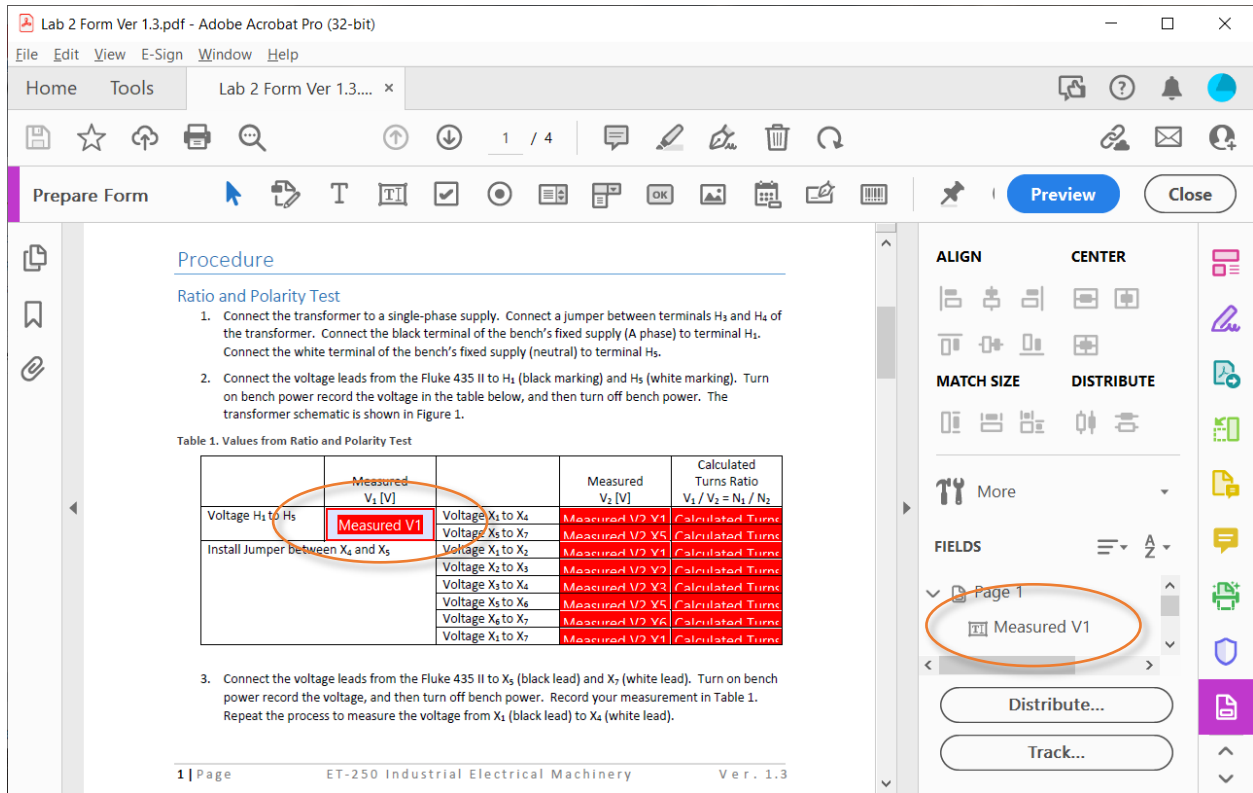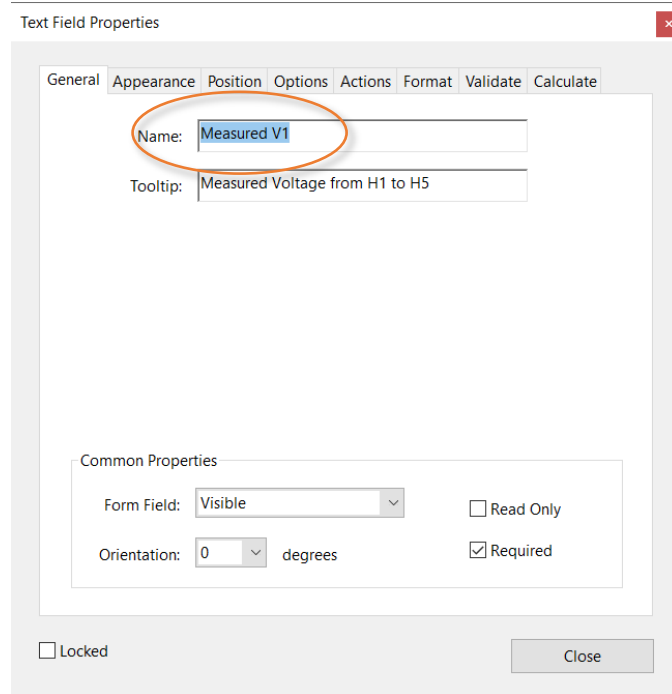
Figure 2. Define the Fields

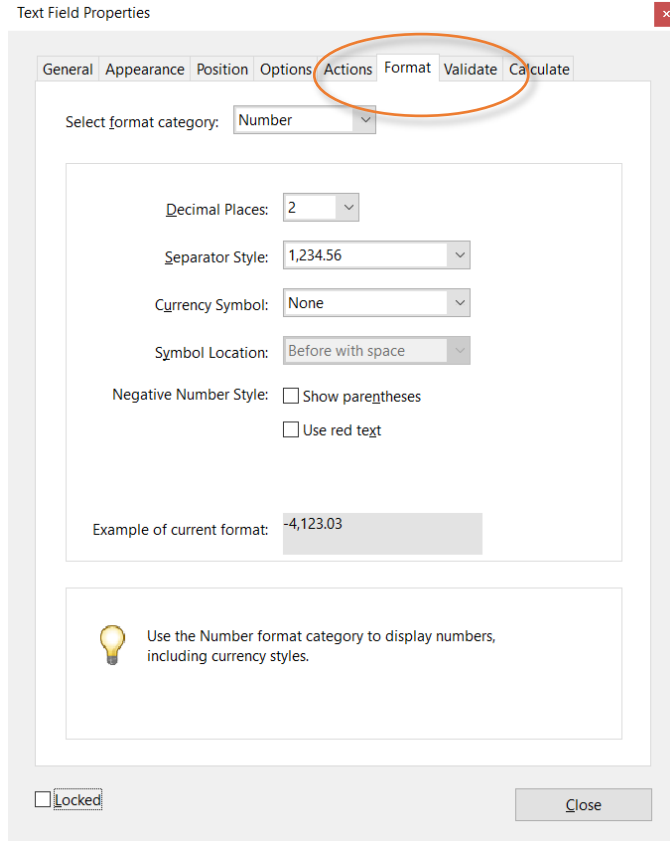Figure 3. General Information about the Measured V1 Field

Figure 4. Formatting the Cell

Exporting the Form Data to Excel

To export the data from the student submitted forms into Excel, open up one of the forms, click Prepare Form, and then click More as shown in Figure 5. A menu appears as shown in Figure 6, and the Merge Data Files into Spreadsheet… item is selected. The dialog box shown in Figure 7 opens and all the student forms for the lab assignment are entered. Clicking the Export button creates a comma separated variable (.csv) file that can be opened in Excel. A row of student data is selected and pasted into the second row of the grading spreadsheet. The spreadsheet has formulas to calculate the required values and determine the error. Three examples are given in Table 1.

Table 1. Sample Calculations in Grading Spreadsheet

Grading the Lab Assignment

The lab assignment is opened in the LMS and a grading rubric is used along with the grading spreadsheet to quickly grade the assignment. The grading spreadsheet is converted to PDF and included with the student's grade in the LMS. This means the student has the correct answers to compare to their values and the reasons why points were lost, if their answers were incorrect.
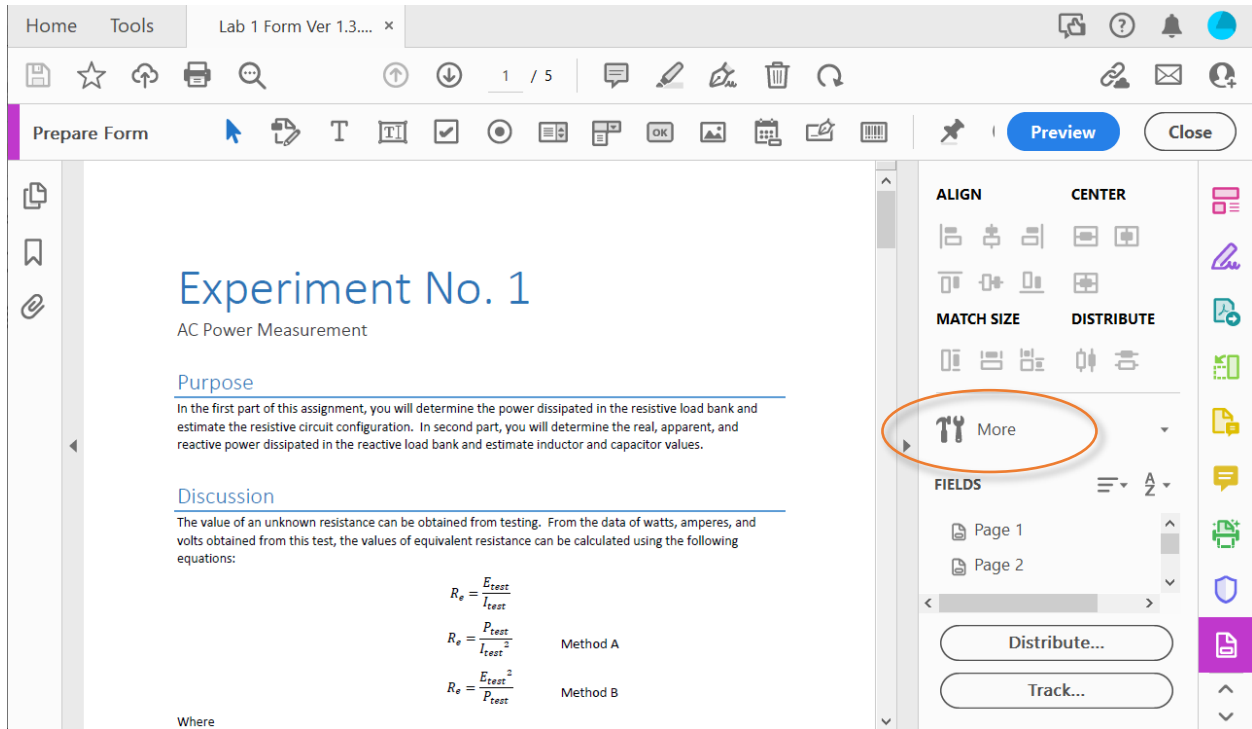

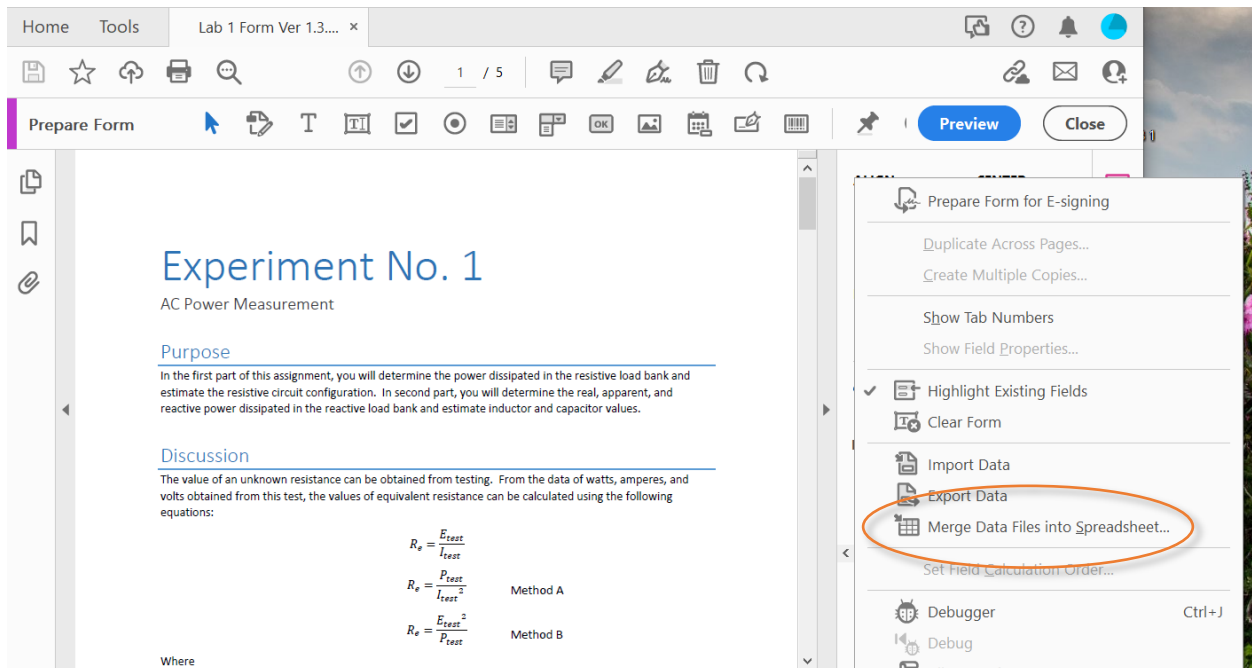*Figure 5. Using the More Menu Item*

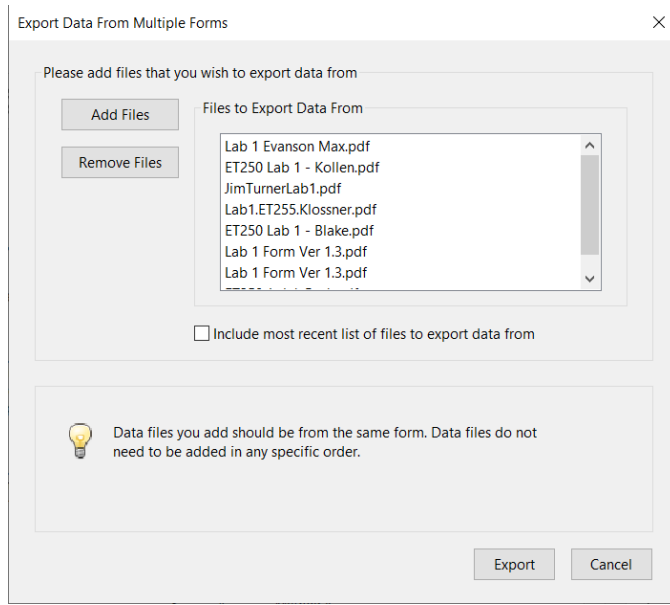*Figure 6. Merge Data Files into Spreadsheet… Menu Item*

Figure 7. Exporting Data from Multiple Forms to Excel

Figure 8. Excel CSV File with Student Data

Figure 9. Student Data Inserted into Grading Spreadsheet

The correct values are calculated from the student's measured values. These calculations usually require complex numbers and several intermediate calculations. For example, the transformer voltage regulation calculation requires:

a) Calculation of R_e and X_e from the student's measured values of I_{sc}, E_{sc}, and P_{sc}

$$R_e = \frac{P_{sc}}{I_{sc}^2}$$

$$Z_e = \frac{E_{sc}}{I_{sc}}$$

$$X_e = \sqrt{Z_e^2 - R_e^2}$$

b) Then the no-load voltage is calculated from:

$$\vec{E}_s = \vec{V}_s + \vec{I}_s \times \vec{Z}_e$$

Where:

V_s = the rated secondary voltage (the full-load voltage, V_{FL})
E_s = the voltage required to provide rated secondary voltage (no-load voltage, V_{NL})
I_s = the rated secondary current at the requested phase angle (obtained from the power factor)
Z_e = the equivalent impedance on the secondary (the series combination of the equivalent resistance and reactance)

c) Then, the voltage regulation (VR) can be calculated from:

$$VR = \frac{|V_{NL}| - V_{FL}}{V_{FL}}$$

	Record the voltage, current, and real power with switch one on, then switch one and two on, and so on until you have completed all the tests.	Missing 0 point s ×	Errors 0.5 point s ×	Done 1 point s ×	+
	Use the measured voltage and current to calculate the real power for each test. Does the calculated value agree with the measured real power? What test had the largest percent error?	Missing 0 point s ×	Errors 1 point s ×	Done 2 point s ×	+
	Use the measured voltage and current to calculate the total equivalent resistance for each test. For one test, i.e., switches 1, 2, & 3 on, calculate the resistance using the two equations that include power in the discussion section.	Missing 0 point s ×	Errors 1 point s ×	Done 2 point s ×	+
	Measure the voltage, current, power factor, and real, apparent, and reactive power for five dial positions	Missing 0 point s ×	Errors 0.5 point s ×	Done 1 point s ×	+
	In the first part of the lab we used V times I to calculate real power. Was that formula correct for the second part of the lab? Why or why not?	Missing 0 point s ×	Errors 0.5 point s ×	Done 1 point s ×	+

Figure 10. Rubric for Grading the Lab Assignment

Our Moodle-based LMS cannot handle complex numbers and hand-grading each of these calculations for three different power factors for each student is tedious and time-consuming.

Once the correct value based on the student's measured values is calculated in the spreadsheet, it is compared to the student's answer. A percent error calculation is made and the cell is color-coded green for within tolerance (usually within ±5%), yellow (usually within ±10%), or red (for errors greater than ±10%). An example of this color-coding is shown in Table 1 for Measured Power Error.

Student Safety

One of the important aspects of the student experience is safety. To protect themselves during the pandemic, the students needed to use the proper personal protective equipment (PPE) and follow the Centers for Disease Control and Prevention (CDC) guidelines.

- **Face shield**: Used to block large droplets from coming into contact with the wearer's mouth or nose
- **Mask**: The university supplied cloth masks to all students, faculty, and staff
- **Gloves**: Most of the students choose not to wear them
- **Distance**: Six foot spacing whenever possible

During the pandemic, only two students were allowed to work together at each lab bench. The benches were disinfected after each lab session. Students working at the lab benches prior to COVID-19 are seen in Figure 11, while students observing the protocols are seen in Figure 12.

Student Feedback

Feedback on the student evaluations have generally been positive for the laboratory portion of the course using the forms. The students are very appreciative of getting their labs back in a reasonable time with a clear indication of where points were lost.
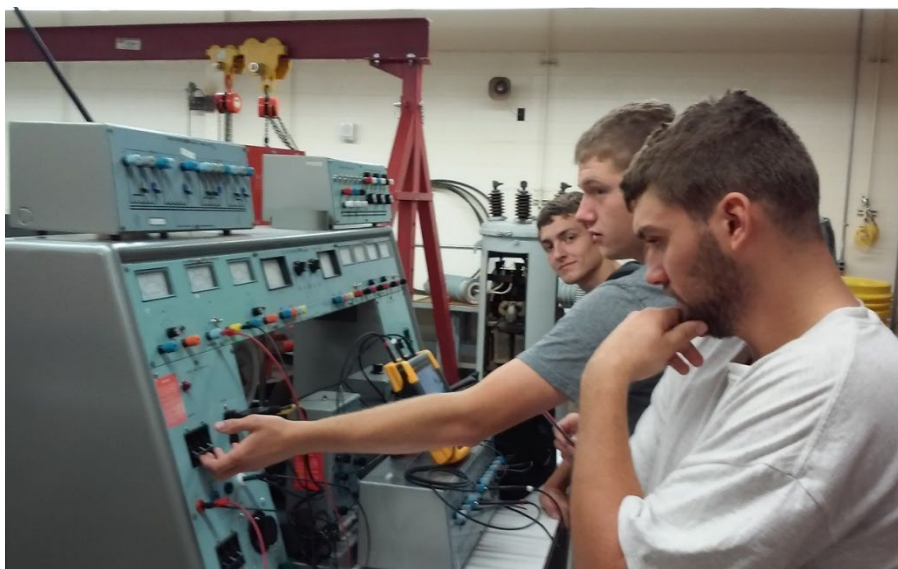
Figure 11. Students in the Laboratory Prior to COVID-19 Protocols

Figure 12. Students Observing the COVID-19 Protocols

Assessment of Student Learning

The learning objectives for the course ET 250 are that upon successful completion of the course, the student should be able to:

1. Compute reluctance, magnetic flux, and magnetic flux density in a magnetic circuit

2. Determine the operating characteristics and proper application of single-phase transformers and three-phase transformer banks

3. Understand the application and be able to compute the operating characteristics of three-phase AC induction motors

4. Understand the operation of three-phase AC synchronous machines

5. Contrast the different types of DC machines and determine the operating characteristics and application of each type

The results for each student on each objective for Fall Semester 2022 is given in the table below. This course is also used as a part of our program's ABET assessment. Portions of Objectives 1 and 3 are also part of our ABET outcomes. It is a requirement at Northern Michigan University (NMU) that we evaluate each course in the program for continuous improvement.

Table 2. Assessment Results for Each Student and Learning Objective

	Objective #1	Objective #2	Objective #3	Objective #4	Objective #5
Student #1	1	1	1	1	1
Student #2	0	0	1	0	1
Student #3	1	0	1	1	1
Student #4	1	1	1	0	1
Student #5	1	1	1	1	1
Student #6	1	1	1	1	1
Student #7	1	1	1	0	1
Student #8	1	1	1	1	1
Number successful	7	6	8	5	8
Number of students	8	8	8	8	8
Success rate	87.5%	75%	100%	62.5%	100%

The fourth course objective involves synchronous machines. It is assessed via exam questions, a test report, and observations in the lab. In the table, a 1 is given when the student score is above the target of 75%. As shown in the table, the students did very poorly of on Objective #4, and were marginal on Objective #2. For Objective #4, the students did not have a lab assignment on synchronous machines and not enough time was spent on the subject. Therefore, next year I will spend more time on synchronous machines. The drop in the scores for Objective #2 is puzzling, since nothing was changed in the coverage of this material. Both of these scores have been much better in the past.

Future Suggestions for Improvement

Rather than saving forms in individual student folders, require the students to use a standard naming format for their files, for example, Lab 01 Joe Student, and then store all of the lab forms in one folder. This will make exporting the forms into Excel quicker because all of the files can be selected at one time.

As a general issue, the majority of our students are white and male. About 30% of the students in the Engineering Technology (ET) Department at NMU are nontraditional (older) students – including military veterans and displaced workers. The ET Department is looking at ways to increase female and minority representation. We are looking at the success of NMU's Construction Management Program's online program (https://online.nmu.edu/women-in-construction-management/) and their female youth outreach program (https://nmu.edu/tos/clone-women-construction-day-marquette).

It would be nice to use another package to create the labs. Google Forms was investigated but was found to be limited. A sample form is shown in Figure 13. The software does not allow text formatting, such as subscripts, and would require the lab handout to be completely written with Google Forms. Using a different LMS might be possible.
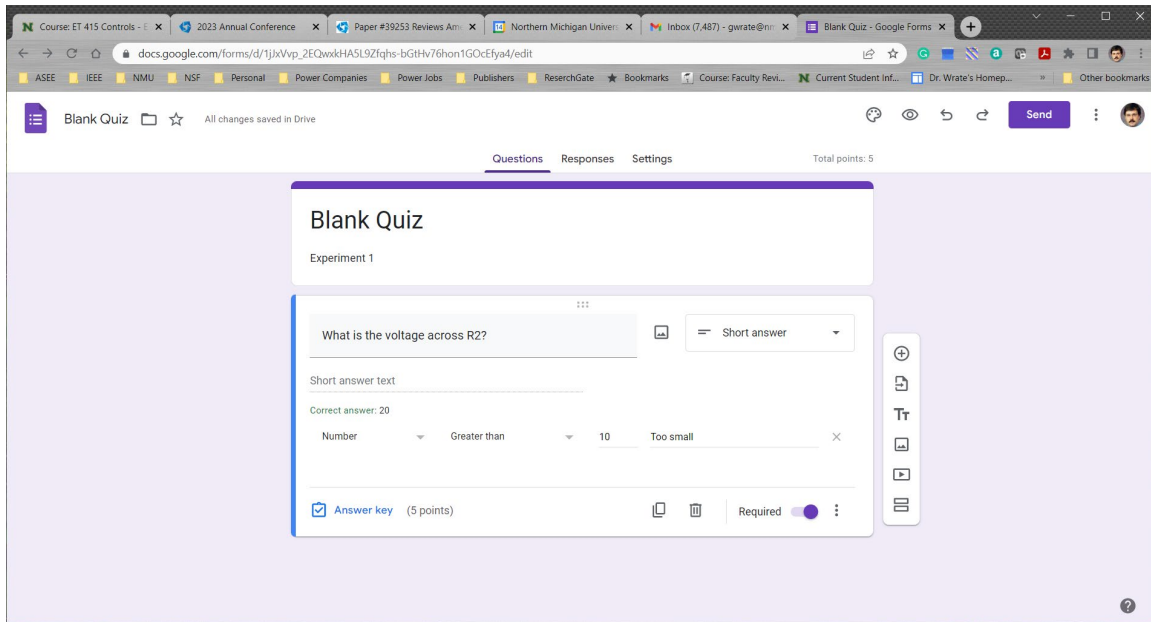
Figure 13. Attempt to Use Google Forms

Conclusions

Student feedback on the automated lab report grading has been positive. Automated grading allows the students to get their graded labs back much sooner. This is an important activity that should be done as quickly as possible to determine if review is necessary and to assist in the students understanding. It is hoped that this paper will assist others in creating lab experiments in electric machinery and provide a basis for further discussions. With a little modification, this same technique could be used for other engineering labs that are calculation intensive.

Bibliography

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