A Tool to Simplify Course, Program, and ABET Assessment Activities

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Abstract: Assessing how well a class has done in meeting course and program outcomes can be very time-consuming. If all of the data collection and processing is done manually, this protracted task can become onerous. A tool to automate part of this procedure can be very useful for course instructors.

This article presents a tool that automates part of this process using a Microsoft Excel spreadsheet. It allows the professor to assign an outcome number to each question on each exam, then get summary results of students' performance: by individual question, by course outcome for each exam, and by course outcome for all of the exams combined. It also tracks lab and quiz/homework grading, and ties everything together to summarize student grades and overall class performance. This facilitates assessment and evaluation, not only of individual course outcomes, but also program outcomes for ABET accreditation purposes.

The paper begins by describing the genesis of the tool, how it was modified to become what it is today, and then provides a detailed description of its construction and how to use it. A generic version of the spreadsheet is posted on the Purdue web site, available for download by anyone interested in using it or adapting it for their application.

I. Introduction

Assessment is an important activity because, if done well, it provides a quantitative indicator of how well students have met the goals of individual courses and the overall program. There are four specific terms used by ABET (Accreditation Board for Engineering and Technology), and one used by our program at Purdue, that need to be defined at the outset. First, the following ABET definitions come from [1]:

> **Program Educational Objectives** – Program educational objectives are broad statements that describe the career and professional accomplishments that the program is preparing graduates to achieve.
>
> **Program Outcomes** – Program outcomes are narrower statements that describe what students are expected to know and be able to do by the time of graduation. These relate

to the skills, knowledge, and behaviors that students acquire in their matriculation through the program.

Assessment – Assessment is one or more processes that identify, collect, and prepare data to evaluate the achievement of program outcomes and program educational objectives.

Evaluation – Evaluation is one or more processes for interpreting the data and evidence accumulated through assessment practices. Evaluation determines the extent to which program outcomes or program educational objectives are being achieved, and results in decisions and actions to improve the program.

In our program at Purdue, we use an additional term [2]:

Learning Outcome Objectives – Learning outcome objectives (LOOs) describe the expected outcomes of individual learning objectives for each course in the department. The LOOs are assessed and evaluated to ensure the quality of each course.

Although the term LOO is a familiar one within our department, it can be a bit confusing because it includes the word "objective," used by ABET as a broadly descriptive term, and the word "outcome," used by ABET for more specific descriptions. Therefore, the term **course outcome(s)** will be used instead for the remainder of the paper because the concern is specific topics within each course.

The focus of this paper is a tool intended to ease the assessment and evaluation processes. It facilitates collection, preparation, and interpretation of data concerning program outcomes and course outcomes. We track both sets of outcomes, which means one report per course for its course outcomes (LOOs) [2], and normally one or more reports for each course to monitor its contribution to the program outcomes for ABET purposes [2].

Setting up a rigorous system to evaluate course and program outcomes can be very tedious. Depending on the specific outcome, it may not be sufficient to use an overall exam or lab grade to evaluate it. This means the instructor must identify specific exam or quiz questions, homework problems, or perhaps explicit portions of one or more labs to measure competence in a particular area. For instance, one of our program outcomes is effective "visual and graphical" communication. Simply performing a lab and/or writing a lab report does not necessarily indicate proficiency in those areas. The grading rubric must specifically assign points to grade "visual and graphical" efficacy, and those points must be evaluated separately to rate the outcome. It can become very time-consuming and burdensome to keep track of all of the different questions—and their various point values—assigned to each outcome, then get a separate average for each outcome. A tool to relieve some of this burden can be very helpful.

This paper presents one such tool, a spreadsheet, which the author uses to track both course and program outcomes. It automatically performs the tedious calculations required to tally class results. There are separate worksheets to handle 1) details of evaluating the course exams, 2) details of the lab grading, and 3) course summary information. The remainder of the paper

provides a brief narrative of the tool's origin and evolution, followed by a detailed description of the each worksheet's construction, how it works, and the formulas used for its cells.

II. Origin and Evolution of the Tool

The assessment tool got its start as a fairly mundane spreadsheet used by one of my colleagues (before I started teaching) to track class grades. Our resident ABET expert pointed out the fact that an overall exam does not provide the needed granularity to properly assess the course outcomes, so he modified his spreadsheet to track each question on each of his exams. By crafting his exams to have a relatively small number of questions targeted specifically at the course outcomes, he was able to get a good picture of how students were doing on each course outcome on each exam. He then manually performed an average for them to get the average for the overall course. The biggest downside was that he had to manually enter the result for every test question. The upside was the insight it provided into exam results, quantifying exactly where the results were good and where they were not (as a class). This was the version of the spreadsheet that I first received.

The initial version used one column for each question from each exam, with the corresponding course outcome at the top of each column. There was, however, no mechanism for combining results from multiple exam questions that covered the same course outcome; this had to be done manually. This shortcoming was easy to remedy using MS Excel's conditional summing (SUMIF) and counting (COUNT) commands, providing an automatic breakdown of course outcome results by individual exam and for the course overall. I also added a worksheet for the lab grading, some of which provides data for evaluating specific course and program outcomes, and use them with a summary worksheet to tie everything together.

III. Exam Stats Worksheet

This section describes the worksheet used to track grading and statistical information about the course exams. It begins by describing the worksheet's general purpose, then its layout at a high level, followed by a detailed functional description, and finally an explanation of each formula used to do the calculations.

The Exam Stats worksheet accomplishes several ends. First, it allows me to track four separate performance measures for each class:

- average grade for each *question of each exam*;
- average grade by *course outcome for each exam*, including the final exam;
- average grade by *course outcome for the mid-course exams in aggregate*;
- average grade by *course outcome for the overall course*.

In addition to the performance tracking functions, it also helps me ensure all of the course outcomes are covered and provides a double-check to my scoring for each exam as I grade it.

The Exam Stats spreadsheet is depicted in Figure 1. It contains a section for each exam. The mid-course exam sections are highlighted in light brown, while the final exam section is

highlighted in light blue. Each exam section contains one column for each question on the exam. At the lower left corner of the figure is a section to summarize performance by course outcome for each exam. The first three columns, in this case, report on the three mid-course exams individually, and the fourth column does so in aggregate. The fifth column covers the final exam, and the sixth column accounts for all of the exams together. A more detailed explanation by row and column is next.

As shown in Figure 1, the rows are labeled from 1-28 down the left side and the columns are labeled from A-AS along the top. A breakdown of the exam tally section (rows 1-15) follows:

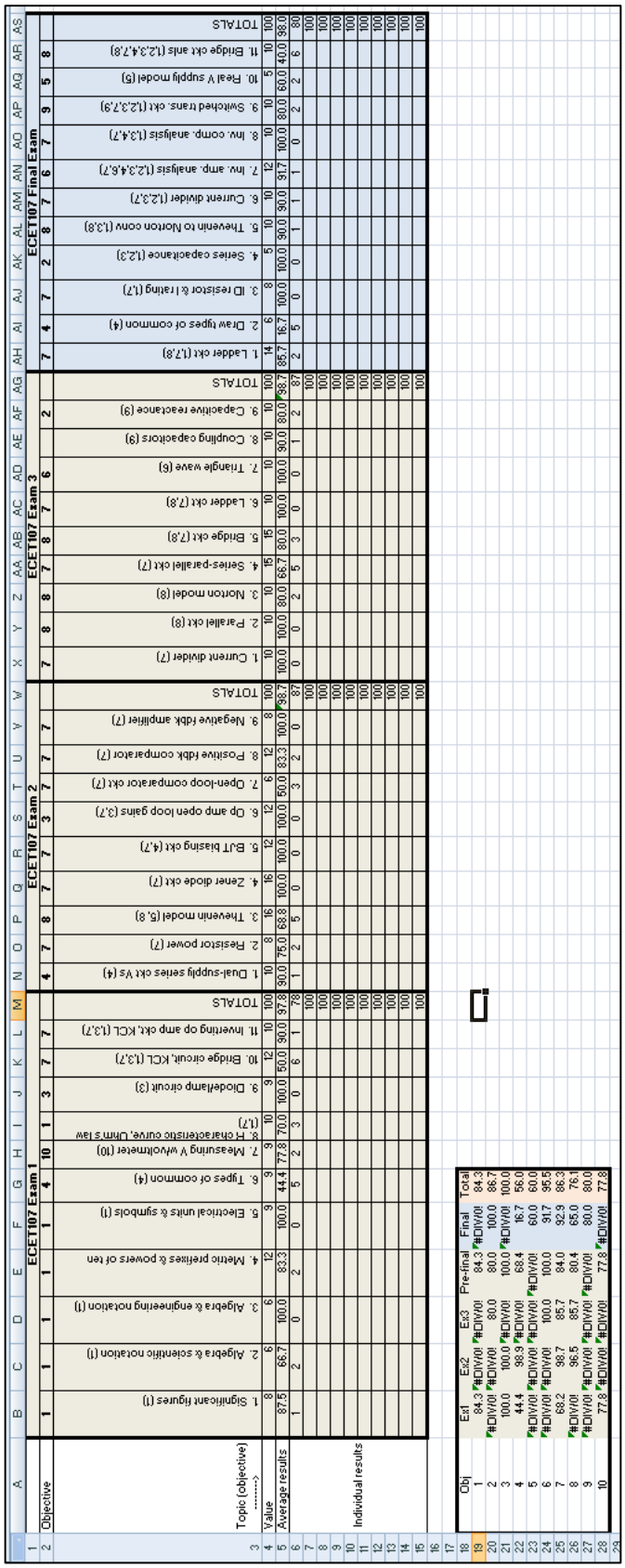
- Row 1 is a header that lists the title of each exam.
- Row 2 assigns course outcome to each question.
- Row 3 describes each question with a brief phrase.
- Row 4 assigns the point value for each question.
- Row 5 calculates the class average for each question.
- Rows 6-15 contain manually-entered scoring for each question of each student's exam. This is where the tedious work lies. The user records the *points missed* for each question of each exam. (That is what I mark by each question as I grade it.) I usually prefer to do it as I grade each page of each exam, although I have also occasionally graded all of the exams first, and then recorded the stats later.
- Columns M, W, AG, and AS verify the total points for each exam (row 4), calculate the class average for each exam (row 5), and total the individual score for each exam (rows 6-15). The latter serves as a double-check for the manual tally of each exam (as long as the exams are kept in order during the grading process).

Rows 19-28 calculate aggregate class performance on each course outcome:

- Row 18 is a header for the course outcome number (column A) and the exams (columns B-G).
- Rows 19-28, for ten course outcomes in this case, report class average for each outcome by mid-course exam (columns B-D), aggregate for all mid-course exams (column E), for the final exam (column F), and for all of the exams together (column G).

Next, the key worksheet cell formulas are described.

Figure 1: Exam Stats worksheet

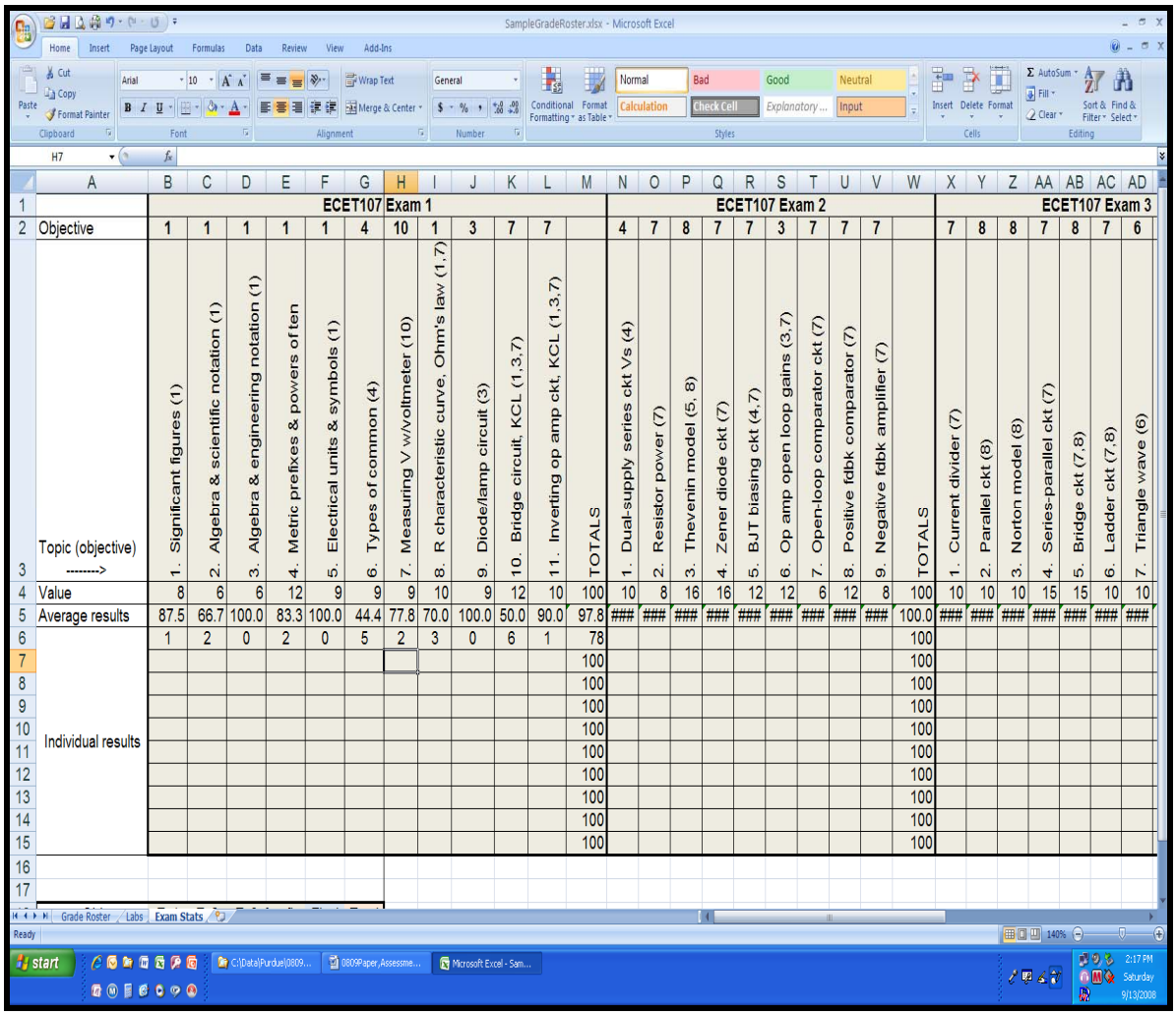


	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ	AK	AL	AM	AN	AO	AP	AQ	AR	AS
1		ECET107 Exam 1												ECET107 Exam 2										ECET107 Exam 3										ECET107 Final Exam									
2	Objective	1	1	1	1	1	4	10	1	3	7	7		4	7	8	7	7	3	7	7	7		7	8	8	7	8	7	6		2		7	4	7	2	8	7	6	7	8	5	8
3	Topic (objective) ------->	1. Significant figures (1)	2. Algebra & scientific notation (1)	3. Algebra & engineering notation (1)	4. Metric prefixes & powers of ten	5. Electrical units & symbols (1)	6. Types of common (4)	7. Measuring V w/voltmeter (10)	8. R characteristic curve, Ohm's law (1,7)	9. Diodeflamp circuit (3)	10. Bridge circuit, KCL (1,3,7)	11. Inverting op amp ckt, KCL (1,3,7)	TOTALS	1. Dual-supply series ckt Vs (4)	2. Resistor power (7)	3. Thevenin model (5, 8)	4. Zener diode ckt (7)	5. BJT biasing ckt (4,7)	6. Op amp open loop gains (3,7)	7. Open-loop comparator ckt (7)	8. Positive fdbk comparator (7)	9. Negative fdbk amplifier (7)	TOTALS	1. Current divider (7)	2. Parallel ckt (8)	3. Norton model (8)	4. Series-parallel ckt (7)	5. Bridge ckt (7,8)	6. Ladder ckt (7,8)	7. Triangle wave (6)	8. Coupling capacitors (3)	9. Capacitive reactance (9)	TOTALS	1. Ladder ckt (1,7,8)	2. Draw types of common (4)	3. ID resistor & rating (1,7)	4. Series capacitance (1,2,3)	5. Thevenin to Norton conv (1,3,8)	6. Current divider (1,2,3,7)	7. Inv. amp. analysis (1,2,3,4,6,7)	8. Inv. comp. analysis (1,3,4,7)	9. Switched trans. ckt (1,2,3,7,9)	10. Real V supply model (5)	11. Bridge ckt anls (1,2,3,4,7,8)	TOTALS
4	Value	8	6	6	12	9	9	10	10	9	12	10	100	10	8	16	16	12	12	6	12	8	100	10	10	10	15	15	10	10	10	10	14	6	8	5	10	10	12	10	10	10	5	10	100
5	Average results	87.5	66.7	100.0	83.3	100.0	44.4	77.8	70.0	100.0	50.0	90.0	97.8	90.0	75.0	68.8	100.0	100.0	100.0	50.0	83.3	100.0	98.7	100.0	100.0	80.0	66.7	80.0	100.0	100.0	90.0	80.0	98.7	85.7	16.7	100.0	100.0	90.0	90.0	91.7	100.0	80.0	60.0	40.0	98.0
6		1	2	0	2	0	5	2	3	0	6	1	78	1	2	5	0	0	0	3	2	0	97	0	0	2	5	3	0	0	1	2	100	2	5	0	0	1	1	1	0	2	2	6	80
7													100										100										100												100
8													100										100										100												100
9													100										100										100												100
10	Individual results												100										100										100												100
11													100										100										100												100
12													100										100										100												100
13													100										100										100												100
14													100										100										100												100
15													100										100										100												100
16																																													
17																																													
18	Obj	Ex1	Ex2	Ex3	Pre-final	Final	Total																																						
19	1	84.3	#DIV/0!	#DIV/0!	84.3	#DIV/0!	84.3																																						
20	2	#DIV/0!	#DIV/0!	80.0	80.0	#DIV/0!	80.0																																						
21	3	100.0	100.0	#DIV/0!	100.0	#DIV/0!	100.0																																						
22	4	44.4	98.9	#DIV/0!	68.4	16.7	56.0																																						
23	5	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	60.0	60.0																																						
24	6	#DIV/0!	#DIV/0!	100.0	100.0	91.7	95.5																																						
25	7	68.2	98.7	85.7	84.0	92.9	86.3																																						
26	8	#DIV/0!	96.5	85.7	80.4	65.0	76.1																																						
27	9	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	80.0	80.0																																						
28	10	77.8	#DIV/0!	#DIV/0!	77.8	#DIV/0!	77.8																																						
29																																													

Figure 2 shows the portion of the worksheet that covers Exam 1, zoomed in for better viewing. The first exam has been graded, and the points missed have been recorded in row 6 (columns B-L). The average results, shown in row 5, reflect the scores recorded in row 6. For example, cell B5 indicates an average of 87.5 percent, or 7 of 8 points correct. The formula used for this function is:

$$=(B4-AVERAGE(B6:B15))/B4*100 \qquad (1)$$

which is a standard percent calculation. It subtracts the average points missed for all of the students (AVERAGE(B6:B15)) from the total points possible (B4), then divides by the total points possible (B4) and multiplies by 100 to convert to a percentage.



	A	B	C	D	E	F	G	H	I	J	K	L	M
1		ECET107 Exam 1											
2	Objective	1	1	1	1	1	4	10	1	3	7	7	
3	Topic (objective) -------->	1. Significant figures (1)	2. Algebra & scientific notation (1)	3. Algebra & engineering notation (1)	4. Metric prefixes & powers of ten	5. Electrical units & symbols (1)	6. Types of common (4)	7. Measuring V w/voltmeter (10)	8. R characteristic curve, Ohm's law (1,7)	9. Diode/lamp circuit (3)	10. Bridge circuit, KCL (1,3,7)	11. Inverting op amp ckt, KCL (1,3,7)	TOTALS
4	Value	8	6	6	12	9	9	9	10	9	12	10	100
5	Average results	87.5	66.7	100.0	83.3	100.0	44.4	77.8	70.0	100.0	50.0	90.0	97.8
6	Individual results	1	2	0	2	0	5	2	3	0	6	1	78
7													100
8													100
9													100
10													100
11													100
12													100
13													100
14													100
15													100
16													
17													

	N	O	P	Q	R	S	T	U	V	W
1	ECET107 Exam 2									
2	4	7	8	7	7	3	7	7	7	
3	1. Dual-supply series ckt Vs (4)	2. Resistor power (7)	3. Thevenin model (5, 8)	4. Zener diode ckt (7)	5. BJT biasing ckt (4,7)	6. Op amp open loop gains (3,7)	7. Open-loop comparator ckt (7)	8. Positive fdbk comparator (7)	9. Negative fdbk amplifier (7)	TOTALS
4	10	8	16	16	12	12	6	12	8	100
5	###	###	###	###	###	###	###	###	###	100.0
6										100
7										100
8										100
9										100
10										100
11										100
12										100
13										100
14										100
15										100

	X	Y	Z	AA	AB	AC	AD
1	ECET107 Exam 3						
2	7	8	8	7	8	7	6
3	1. Current divider (7)	2. Parallel ckt (8)	3. Norton model (8)	4. Series-parallel ckt (7)	5. Bridge ckt (7,8)	6. Ladder ckt (7,8)	7. Triangle wave (6)
4	10	10	10	15	15	10	10
5	###	###	###	###	###	###	###

Figure 2: Exam 1 portion of Exam Stats worksheet

The exam score for each person is tallied in column M (M6 – M15). The formula in cell M6 is:

=M$4-SUM(B6:L6) (2)

where the total of the points missed (SUM(B6:L6)) is subtracted from the total points possible (M$4). Note that the dollar sign ($) precedes the number "4." This keeps the number "4" from incrementing in the formula so it could be copied down the column to cells M7 – M15 (when the worksheet was originally constructed). I use the numbers in this column to check my manual tally of each exam. If the numbers do not match, it generally either means I made a mistake tallying the grade manually, or that I made a mistake with one of the "missed point" entries (columns B – L).

Cell M5 computes the exam average for the entire class. Its formula is simply:

=AVERAGE(M6:M15) (3)

The only remaining section of the Exam Stats worksheet is at the lower left, where the course outcome results are reported. A larger view of this area is shown in Figure 3. Note that the divide-by-zero errors (#DIV/0!) indicate a course outcome not covered by the corresponding exam(s).

	A	B	C	D	E	F	G
17							
18	Obj	Ex1	Ex2	Ex3	Pre-final	Final	Total
19	1	84.6	#DIV/0!	#DIV/0!	84.6	#DIV/0!	84.6
20	2	#DIV/0!	#DIV/0!	80.0	80.0	100.0	90.0
21	3	100.0	100.0	#DIV/0!	100.0	#DIV/0!	100.0
22	4	44.4	90.0	#DIV/0!	67.2	16.7	50.4
23	5	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	60.0	60.0
24	6	#DIV/0!	#DIV/0!	100.0	100.0	91.7	95.8
25	7	70.0	84.7	88.9	83.2	93.9	86.0
26	8	#DIV/0!	68.8	86.7	82.2	65.0	76.5
27	9	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	80.0	80.0
28	10	77.8	#DIV/0!	#DIV/0!	77.8	#DIV/0!	77.8

Figure 3: Course outcome statistics

The formula in cell B19 calculates the class average for all of the questions from exam 1 that tested course outcome 1:

= (SUMIF($B$2:$L$2,$A19,$B$4:$L$4) -
SUMIF($B$2:$L$2,$A19,$B$6:$L$15)/COUNT($B$6:$B$15)) (4)
/ SUMIF($B$2:$L$2,$A19,$B$4:$L$4)*100

This equation deserves more explanation. The first SUMIF statement in the numerator totals the possible points for course outcome 1 on Exam 1. In other words, for each column in row 2

($B$2 – $L$2) where the course outcome is equal to "1" (the value in cell $A19), add the value in row 4 ($B$4 – $L$4) to the sum. The second SUMIF statement and the COUNT statement, still in the numerator, total the points missed on the exam by the entire class (SUMIF($B$2:$L$2,$A19,$B$6:$L$15)) for course outcome 1 and divides it by the number of students who took the exam (COUNT($B$6:$B$15)). The third SUMIF statement divides this number by the total possible points for course outcome 1 on Exam 1. Then it is multiplied by 100 to make it a percentage. A simplified version of the formula, minus some of the MS Excel syntax, is shown in Equation (5):

$$\frac{(exam1, obj1\ pts\ possible) - \frac{(exam1, obj1\ pts\ missed)}{\#\ students\ taking\ exam}}{(exam1, obj1\ pts\ possible)} * 100\% \tag{5}$$

Although at first it might appear that the same thing could be accomplished by merely averaging the course outcome 1 result scores in row 4, columns B – F and I, this is not the case. The result would not give a weighted average. In other words, the result from cell D5 would be given the same weight in the average as the result from cell E5, even though the latter was worth twice as many points. The approach taken in Equations (4) and (5) gives proper weighting to each exam question.

The formulas for Exam 2, Exam 3, and the Final Exam, in cells C19, D19, and F19, respectively, are done in the same way.

The formulas to compute performance for the three mid-term exams and for all four exams (including the final exam) are more complex. The issue is that the student count may change as the course progresses, so the divisor into the points missed must be calculated separately for each exam. This time we will look at the simplified version of each formula first, then the formula in MS Excel syntax form. Starting with the Pre-final formula in cell E19, the simplified version looks like this:

$$\frac{(exams1,2,\&3\ obj1\ pts\ possible) - \left\{ \begin{array}{l} \left[\frac{(exam1, obj1\ pts\ missed)}{\#\ students\ taking\ exam1}\right] \\ + \left[\frac{(exam2, obj1\ pts\ missed)}{\#\ students\ taking\ exam2}\right] \\ + \left[\frac{(exam3, obj1\ pts\ missed)}{\#\ students\ taking\ exam3}\right] \end{array} \right\}}{(exams1,2,\&3\ obj1\ pts\ possible)} * 100\% \tag{6}$$

Converting Equation (6) into proper syntax in MS Excel gives the following. Note that the indentation and alignment of parentheses have been added for clarity, but in MS Excel the entire formula is typed as a contiguous block of text.

```
= (SUMIF($B$2:$AF$2,$A19,$B$4:$AF$4) -
    (SUMIF($B$2:$L$2,$A19,$B$6:$L$15)/COUNT($B$6:$B$15)
      +SUMIF($N$2:$V$2,$A19,$N$6:$V$15)/COUNT($N$6:$N$15)
      +SUMIF($X$2:$AF$2,$A19,$X$6:$AF$15)/COUNT($X$6:$X$15)
    )
  )
 /SUMIF($B$2:$AF$2,$A19,$B$4:$AF$4)*100
```

(7)

The next worksheet tracks grading for the lab-related portions of the course.

IV. Labs Worksheet

This section provides an overview of the purpose of the Labs worksheet and its general construction, a detailed functional description of its layout, and an explanation of the formulas used.

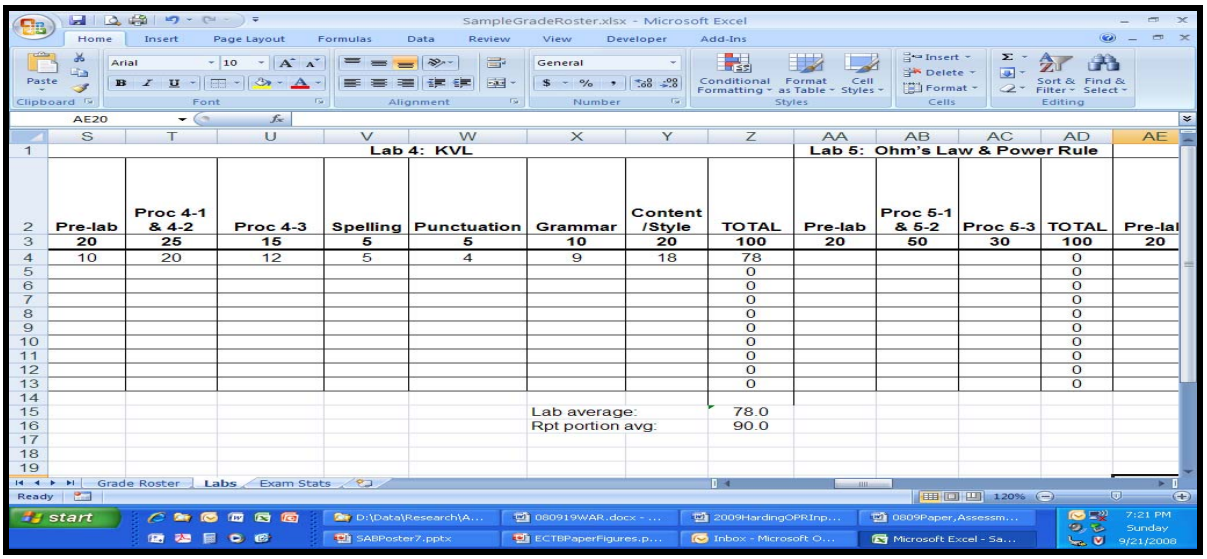
The Labs worksheet tallies points for each individual lab, including the pre-lab, in-lab procedures, and lab reports. In the course used for this example there are three written lab reports during the semester, so the point breakdown is different for those than it is for the other individual labs. Also, there are two lab practical exams and one oral presentation. This worksheet tracks the grading for all of them, and reports a separate *average* for each of the following:

- lab scores for labs *with a report*;
- score for *lab report portion* of labs with a report;
- *oral presentation* lab reports;
- effectiveness of *presentation slides* for oral presentations;
- effectiveness of *circuit schematic(s)* used in oral presentation slides.

The first three rows of this worksheet are header rows. Figure 4 shows a section of the Labs worksheet for Lab 4, which has a report, and Lab 5, which does not. Row 1 lists lab number and title for each lab, row 2 contains the sub-title for each portion of the labs (pre-lab, procedure number, etc.), and row 3 holds their respective point values. Rows 4-13 contain the manually entered scoring, plus the individual totals for each lab under the headings labeled TOTAL. The formula for the TOTAL columns is a simple sum; Equation (8) shows an example for cell Z4.

```
=SUM(S4:Y4)
```

(8)



	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE
1					Lab 4: KVL				Lab 5: Ohm's Law & Power Rule				
2	Pre-lab	Proc 4-1 & 4-2	Proc 4-3	Spelling	Punctuation	Grammar	Content /Style	TOTAL	Pre-lab	Proc 5-1 & 5-2	Proc 5-3	TOTAL	Pre-lal
3	20	25	15	5	5	10	20	100	20	50	30	100	20
4	10	20	12	5	4	9	18	78				0	
5								0				0	
6								0				0	
7								0				0	
8								0				0	
9								0				0	
10								0				0	
11								0				0	
12								0				0	
13								0				0	
14													
15						Lab average:		78.0					
16						Rpt portion avg:		90.0					
17													
18													
19													

Figure 4: Labs worksheet sections for Lab 4, which has a report, and Lab 5, which does not

There are also two additional scores for each lab with a report. The first one tallies the overall average of the lab, as shown in the Lab 4 formula for cell Z15:

=SUM(Z4:Z13)/COUNT(S4:S13) (9)

The purpose of the COUNT function in this formula is to account for the possibility that someone may have dropped the course. In that case, the corresponding row entry in column Z will be a zero, which would skew the average. The COUNT function returns the number of numeric entries from column S, effectively counting the number of students who actually performed the lab. Note that if someone did not attend the lab and a zero score is recorded in that row of column S, the zero will be included in the average for cell Z15.

The other additional score for Lab 4 is the average for the report *portion* of the lab, which is useful for tracking success of the program outcome concerning writing skills. The formula for cell Z16 is an example:

=SUM(V4:Y13)/(SUM(V3:Y3))/COUNT(V4:V13)*100 (10)

This formula sums all of the points for the report *portion* of the lab (cells V4 – Y13), divides it by the total points possible for the report *portion* of the lab (cells V3 – Y3) to normalize it, then divides it by the COUNT of students who did the report (numeric entries in cells V4 – V13) to get the average.

At the far left side of this worksheet, in columns A and B, are the overall course averages for the labs with reports and the lab *report portion* of those labs, which in this case includes three different labs that required formal reports. These values are contained in rows 18-19, as shown in Figure 5.

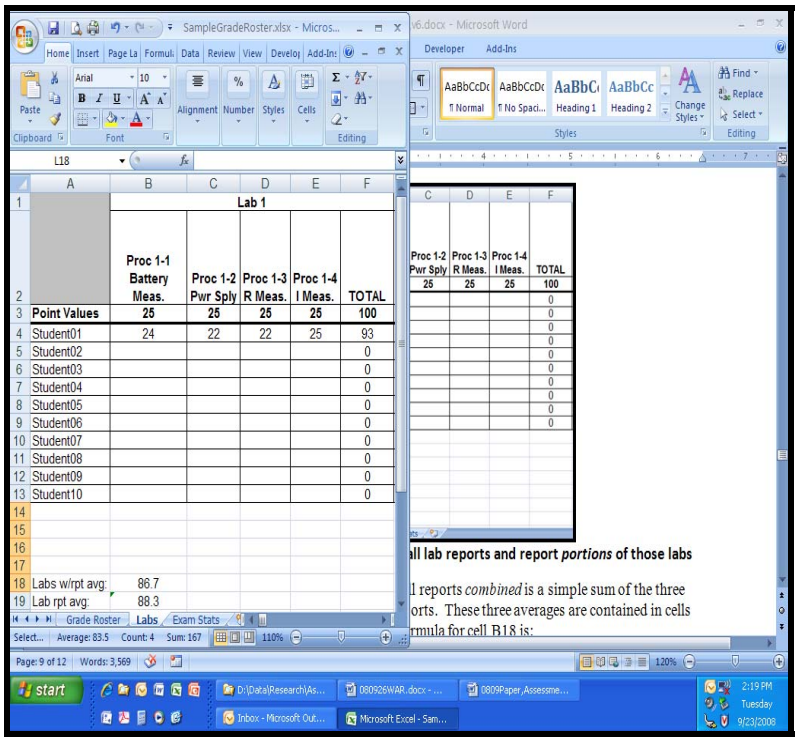


Figure 5: Overall class average for all lab reports and report *portions* of those labs

The formula to compute the class average for all reports *combined* is a simple average of the three class averages for the labs requiring written reports. A simple average works here because the number of possible points is the same for the three labs. These three averages are contained in cells N15, Z15, and AR15, and the corresponding formula for cell B18 is:

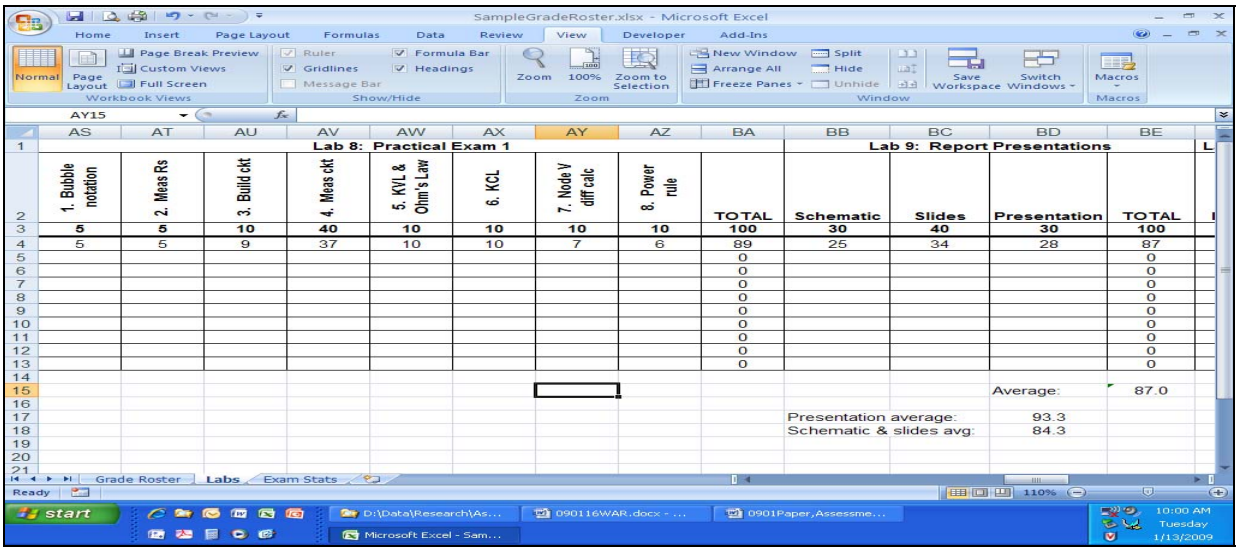
=AVERAGE(N15,Z15,AR15) (11)

The formula to calculate the class average for the combined lab *report portion* of the grades is a bit longer. This computation requires a weighted average, in case the number of points allocated to the report portions of the labs is not always the same (which occurs sometimes for my labs):

=(N16*SUM(J3:M3)+Z16*SUM(V3:Y3)+AR16*SUM(AN3:AQ3))/SUM(J3:M3,V3:Y3,AN3:AQ3) (12)

The difference here is that each average (N16, Z16, and AR16, respectively) is multiplied by the corresponding number of points possible for that lab (SUM(J3:M3), SUM(V3:Y3), and SUM(AN3:AQ3), respectively), then that number is divided by the total points possible for all three of the reports (SUM(J3:M3,V3:Y3,AN3:AQ3)).

Next, Figure 6 shows the worksheet sections for grading the first practical exam and the oral presentations. Rows 4-13 total the individual grades in column BA for the practical exam and column BE for the presentations. Calculation of these totals is the same as for the other lab sections.



	AS	AT	AU	AV	AW	AX	AY	AZ	BA	BB	BC	BD	BE
1	Lab 8: Practical Exam 1									Lab 9: Report Presentations			
2	1. Bubble notation	2. Meas Rs	3. Build ckt	4. Meas ckt	5. KVL & Ohm's Law	6. KCL	7. Node V diff calc	8. Power rule	TOTAL	Schematic	Slides	Presentation	TOTAL
3	5	5	10	40	10	10	10	10	100	30	40	30	100
4	5	5	9	37	10	10	7	6	89	25	34	28	87
5									0				0
6									0				0
7									0				0
8									0				0
9									0				0
10									0				0
11									0				0
12									0				0
13									0				0
14													
15												Average:	87.0
16													
17										Presentation average:		93.3	
18										Schematic & slides avg:		84.3	
19													
20													
21													

Figure 6: Labs worksheet sections for first practical exam and oral presentations

In addition to the individual lab totals, there are three other scores tallied (lower right part of Figure 6). The first is for the overall presentation average, which is a simple average of the individual scores. This formula, for cell BE15, is:

$$=\text{SUM(BE4:BE13)/COUNT(BD4:BD13)} \qquad (13)$$

This formula is essentially the same as Equation (9). It calculates the class average for everyone who *did* a presentation.

The second tally, in cell BD17 of Figure 6, is for the *presentation portion*, which is used to track a program outcome regarding verbal communication skills. Its formula is:

$$=\text{AVERAGE(BD4:BD13)/BD3*100} \qquad (14)$$

This formula is a just an average of the student points scored for the oral presentation (AVERAGE(BD4:BD13), divided by the number of points possible (BD3), multiplied by 100 to convert it to a percentage.

The third tally assesses the quality of the circuit schematics and presentation slides. It relates to a program outcome covering visual and graphical communications. The formula, contained in cell BD18, is:

$$=\text{SUM(BB4:BC13)/COUNT(BB4:BB13)/(BB3+BC3)*100} \qquad (15)$$

where SUM(BB4:BC13) is the total of all points scored for the schematic and slide portions of the grade, COUNT(BB4:BB13) is the number of students who did it, and (BB3+BC3) is the number of points possible for those portions.

The last worksheet is the Grade Roster, which is covered next.

V. Grade Roster Worksheet

The Grade Roster ties everything together. Its purposes are to:

- track each student's progress throughout the semester;
- calculate each student's overall course grade;
- compute class performance (high, low, and average scores) for each part of the course;
- report the class averages for labs with a report and for the *report portion* of those labs.

The Grade Roster worksheet is depicted in Figure 7. The major sections, working from left to right, contain data for: labs without reports; labs with reports, plus the oral presentation; lab practical exams; quizzes and/or homework (I sometimes also use this section to record homework grades, if applicable); exams; and the overall course grades. The row-by-row breakdown is as follows:

- Row 1 contains the section headings.
- Row 2 contains headings for each activity within the sections.
- Rows 3-12 contain the individual scores, section averages, and course grades for each student.
- Rows 13-16 report statistical information for each course activity: mean scores in row 13, high scores in row 15, and low scores in row 16. Row 14 is reserved for what I call "averages without outliers." There are times when one or more students miss an activity (unexcused) and receive a zero grade(s) that would skew the class average. Since it is often useful feedback to know the average of students who *participated* in a lab, quiz, etc., this row allows entry of a custom formula, when applicable, to calculate the class average without including those "outlier" grades.
- Cells B17 – B21 tally the number of each letter grade (A – F) received in the class.
- Cells B23 and B24 report the average of labs with lab reports and the average of the report portions of those labs. These cells merely point to the corresponding cells in the Labs worksheet, described in the previous section of this paper.

The key formulas used in this worksheet are described next.

The first formula captures the individual lab grades and is the same type of formula for all three lab sections (labs with reports, labs without reports and lab presentations, and practical exams). Each of these cells refers to a cell in the Labs worksheet, where the corresponding grade is tallied. For instance, consider Lab 1, which is column D in the Grade Roster worksheet. The formula for cell D3 is:

=Labs!F4 (16)

which refers to cell F4 within the Labs worksheet.

Once the formula for cell D3 is entered, it can be copied and pasted down the column into cells D4 – D12, which will then reflect the numbers in cells F5 – F13 from the Labs worksheet. During the semester I typically enter the formulas into the corresponding column after lab each week, instead of doing them all at the start of the semester. If all of them were entered at the start of the semester, those cells would contain zero values until the labs were completed, which would skew the section averages in columns L, Q, and T. By leaving the cells empty until the labs are completed, they are not included in the section average calculation, which provides an accurate running total of the student grades as the semester progresses.

The second formula computes the average for the labs that do not require reports. Before describing this equation, it should be noted that a "drop rule" applies to the labs with no reports and the quizzes. The "drop rule" simply ignores the lowest individual grade when calculating the section average. (The intent of this rule is to provide some accommodation for a student missing class because of a required business trip, illness, or just having a bad day in lab.) This rule makes the formula more complex than a simple average. For example, the formula for cell L3 is:

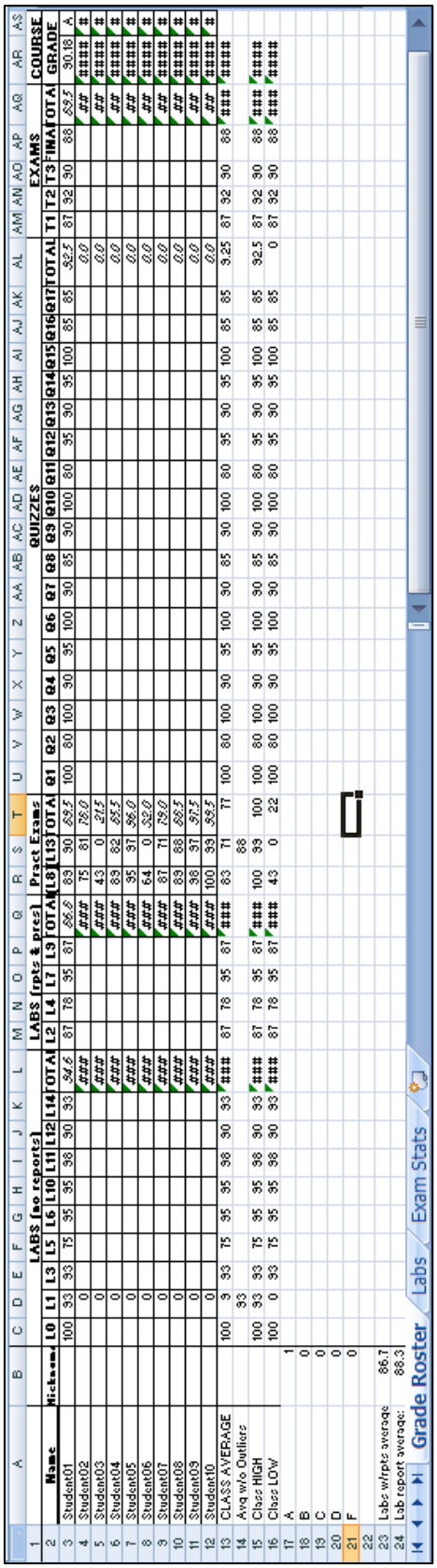
=(SUM(C3:K3)-MIN(C3:K3))/(COUNT(C3:K3)-1) (17)

The SUM function totals the grades for the section, then the MIN function subtracts the lowest grade, i.e., the one to be "dropped." The COUNT function is decreased by one before being divided into the modified sum to compute the average.

A straightforward average is used for the labs with reports and the presentation (students are not allowed to drop any of those). For instance, the definition for cell Q3 just averages the values in cells M3 – P3:

=AVERAGE(M3:P3) (18)

Figure 7: Grade Roster worksheet



	Name	Nickname	L0	L1	L3	L5	L6	L10	L11	L12	L14	TOTAL	L2	L4	L7	L9	TOTAL	L8	L13	TOTAL	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16	Q17	TOTAL	T1	T2	T3	FINAL	TOTAL	GRADE
			LABS (no reports)										LABS (rpts & pres)					Pract Exams			QUIZZES																		EXAMS					COURSE
3	Student01		100	33	33	75	35	35	38	30	33	54.6	87	78	35	87	85.8	83	30	68.5	100	80	100	90	35	100	90	85	30	100	80	35	30	35	100	85	85	52.5	87	32	90	88	68.5	30.18	A
4	Student02			0								###					###	75	81	78.0																		0.0					###	###	#
5	Student03			0								###					###	43	0	21.5																		0.0					###	###	#
6	Student04			0								###					###	83	82	83.5																		0.0					###	###	#
7	Student05			0								###					###	35	37	36.0																		0.0					###	###	#
8	Student06			0								###					###	64	0	32.0																		0.0					###	###	#
9	Student07			0								###					###	87	71	78.0																		0.0					###	###	#
10	Student08			0								###					###	83	88	85.5																		0.0					###	###	#
11	Student09			0								###					###	38	37	37.5																		0.0					###	###	#
12	Student10			0								###					###	100	33	66.5																		0.0					###	###	#
13	CLASS AVERAGE		100	9	33	75	35	35	38	30	33	###	87	78	35	87	###	83	71	77	100	80	100	90	35	100	90	85	30	100	80	35	30	35	100	85	85	9.25	87	32	90	88	###	###
14	Avg w/o Outliers			33															88																										
15	Class HIGH		100	33	33	75	35	35	38	30	33	###	87	78	35	87	###	100	99	100	100	100	100	90	35	100	90	85	90	100	80	35	30	35	100	85	85	32.5	87	32	90	88	###	###
16	Class LOW		100	0	33	75	35	35	38	30	33	###	87	78	35	87	###	43	0	22	100	80	100	90	35	100	90	85	30	100	80	35	30	35	100	85	85	0	87	32	90	88	###	###
17	A	1																																										
18	B	0																																										
19	C	0																																										
20	D	0																																										
21	F	0																																										
22																																												
23	Labs w/rpts average	86.7																																										
24	Lab report average:	88.3																																										

Grade Roster / Labs / Exam Stats

There is an issue with the average for the lab practical exams. Since it is several weeks into the semester before the first exam, a normal mean calculation will result in a divide-by-zero error and prevent calculation of an overall course grade anytime before the first lab practical exam. A conditional formula is used to address the problem. The formula in cell T3 for calculating the practical exam average uses an IF statement:

=IF(COUNT(R3:S3)>0,AVERAGE(R3:S3),L3) (19)

The IF statement syntax is: IF (condition, action if true, action if false). This formula does the following. If there is a value for either practical exam [COUNT(R3:S3)>0] then use the section average [AVERAGE(R3:S3)] to compute the value. Otherwise, use the average of the individual labs (L3). The average of the individual labs in cell L3 is a reasonable estimate of what the practical exam score will be, and allows computation of a course grade.

The formula to compute the quiz average uses a similar kind of conditional expression. The reason for this is: When I teach a course the first time and am developing the materials, quizzes usually get lowest priority of my development time. Thus, it is possible to get into the course a few weeks and only have one quiz, or none, recorded. In order to allow for computation of a course grade, the Quizzes section is tallied using an IF statement. For example, cell AL3 is:

=IF(COUNT(U3:AK3)>1,(SUM(U3:AK3)-MIN(U3:AK3))/(COUNT(U3:AK3)-1),U3) (20)

Thus, if there is more than one score in the section [COUNT(U3:AK3)>1] it computes the average using the "drop rule" as in Equation (17) [(SUM(U3:AK3)-MIN(U3:AK3))/(COUNT(U3:AK3)-1)]. If there is not more than one quiz score recorded, it uses the first value in the section, which is in cell U3. Note that this approach will result in a value of zero for the average if the first cell (U3) is empty.

The next section tallies the exam averages using a modified version of the drop rule. A total of 400 points are counted for the three mid-course exams, each worth 100 points, and the final exam, worth 200 points. If the student's lowest exam score is one of the mid-course exams, then that exam is dropped, same as for the quizzes and labs without reports. If, on the other hand, the final exam is the lowest grade, it counts for 100 instead of 200 points when computing the mean. In other words, a student cannot drop the final exam completely, but it does have less impact on their course grade if it is the lowest exam score. A sample formula from cell AQ3 is shown below:

=IF(AP3>MIN(AM3:AO3),
(SUM(AM3:AO3)-MIN(AM3:AO3)+2*AP3)/COUNT(AM3:AP3), (21)
AVERAGE(AM3:AP3))

The IF statement of Equation (21) basically says: if the final exam grade is greater than the lowest mid-course exam grade [AP3>MIN(AM3:AO3)] then subtract the lowest score from the

sum of the three mid-course exam grades [SUM(AM3:AO3)-MIN(AM3:AO3)], add twice the final exam grade [2*AP3], and divide by the total number of course exams [COUNT(AM3:AP3)]. If the exam grade is the lowest score, then take a simple average of the four exams [AVERAGE(AM3:AP3)].

The right-most section in the Grade Roster worksheet computes each student's overall course grade. The numeric grade, in cells AR3 – AR12, is calculated by applying a weight to each of the section scores. The weighting used in this example is shown in Table 1, below.

Table 1: Allocation of points for course grade computation

Assessment Type	Portion of Grade
Labs without reports	10%
Labs with reports and oral presentation	5%
Lab practical exams	25%
Quizzes	10%
Exams	50%

The formula in cell AR3 is:

$$=L3*0.1+Q3*0.05+T3*0.25+AL3*0.1+AQ3*0.5 \qquad (22)$$

where L3*0.1 multiplies Student01's average score in labs with no reports by the weighting factor of 0.1, Q3*0.05 adds the portion for labs with reports and oral presentations, T3*0.25 includes the practical exams' contribution, AL3*0.1 counts the quizzes, and AQ3*0.5 accounts for the exams.

This course is set up to apply a straight letter-grade system with no plus or minus grades, using the lookup table shown in Figure 8.

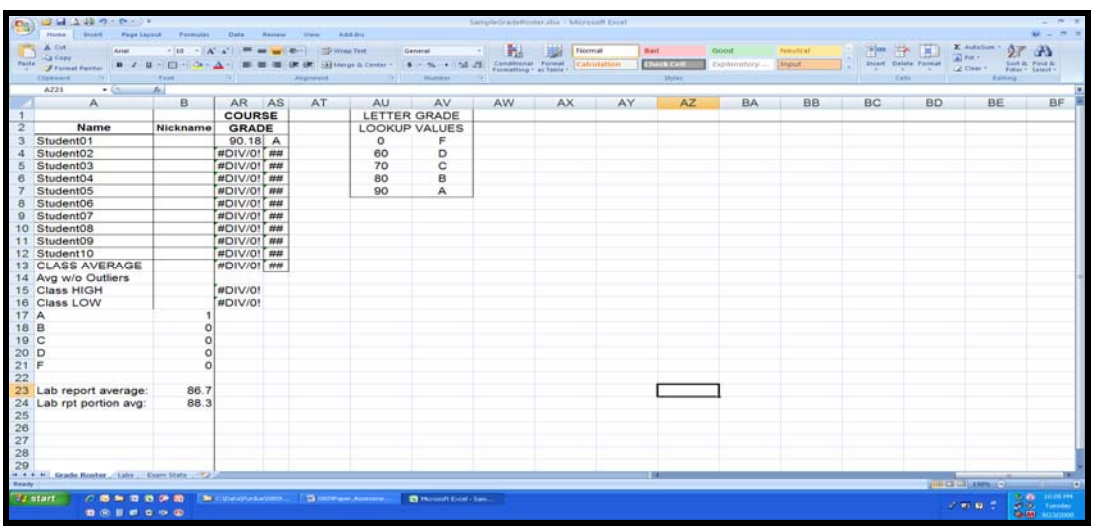


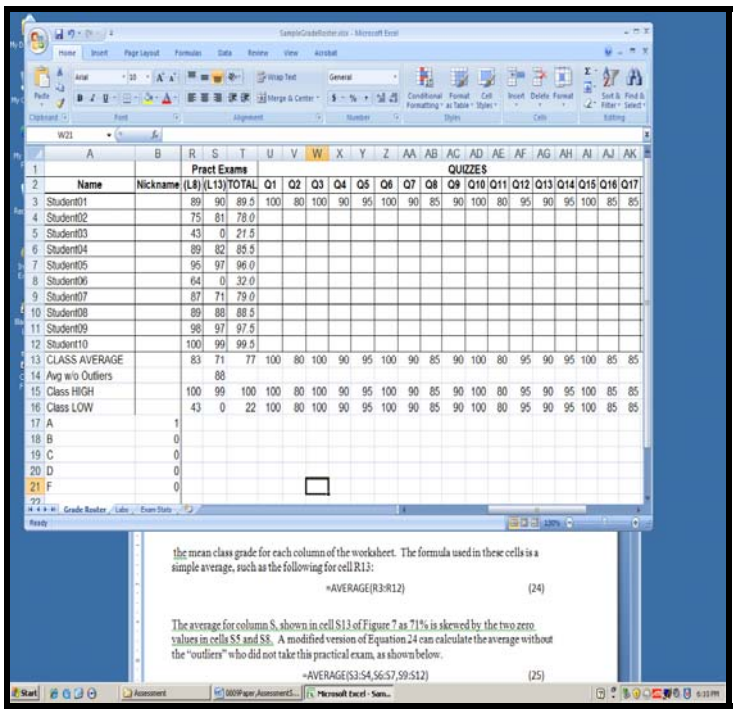
Figure 8: Letter grade lookup table

The formula for cell AS3 illustrates how the lookup table is used:

=LOOKUP(AR3, AU$3:AU$7, AV$3:AV$7) (23)

The LOOKUP statement finds the cell in array AU3 – AU7 that has the largest value less than or equal to the value in cell AR3, then assigns the corresponding cell value in array AV3 – AV7 to cell AS3. In this case, the value in AR3 is 90.18. The largest number less than that in AU3 – AU7 is 90, which is in the 5th cell. AS3 then receives the value in the 5th cell of the array AV3 – AV7, which is "A." The table can easily be expanded for letter grade systems using plus/minus grading. One must keep in mind, however, that the values in the first array must be placed in ascending order. Also, note the $ preceding the numbers in each array, which prevents the numbers from being incremented when the formula is copied from cell AS3 to cells AS4 – AS12.

Rows 13 – 16 contain: average, average without "outliers," high score, and low score for each column of this worksheet. Columns R and S will be used to illustrate the expressions used here, as shown in Figure 9.



	A	B	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ	AK
1			Pract Exams											QUIZZES								
2	Name	Nickname	(L8)	(L13)	TOTAL	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16	Q17
3	Student01		89	90	89.5	100	80	100	90	95	100	90	85	90	100	80	95	90	95	100	85	85
4	Student02		75	81	78.0																	
5	Student03		43	0	21.5																	
6	Student04		89	82	85.5																	
7	Student05		95	97	96.0																	
8	Student06		64	0	32.0																	
9	Student07		87	71	79.0																	
10	Student08		89	88	88.5																	
11	Student09		98	97	97.5																	
12	Student10		100	99	99.5																	
13	CLASS AVERAGE		83	71	77	100	80	100	90	95	100	90	85	90	100	80	95	90	95	100	85	85
14	Avg w/o Outliers			88																		
15	Class HIGH		100	99	100	100	80	100	90	95	100	90	85	90	100	80	95	90	95	100	85	85
16	Class LOW		43	0	22	100	80	100	90	95	100	90	85	90	100	80	95	90	95	100	85	85
17	A	1																				
18	B	0																				
19	C	0																				
20	D	0																				
21	F	0																				

the mean class grade for each column of the worksheet. The formula used in these cells is a simple average, such as the following for cell R13:

=AVERAGE(R3:R12) (24)

The average for column S, shown in cell S13 of Figure 7 as 71% is skewed by the two zero values in cells S5 and S8. A modified version of Equation 24 can calculate the average without the "outliers" who did not take this practical exam, as shown below.

=AVERAGE(S3:S4,S6:S7,S9:S12) (25)

Figure 9: Practical exam scores by individual; plus class high, low, and average values

The formula used in cell R13 is a simple average, and is representative of the expression used for each cell of row 13:

=AVERAGE(R3:R12) (24)

The average for column S, shown in cell S13 of Figure 9 as 71%, is skewed by the two zero values in cells S5 and S8. A modified version of Equation (24) calculates the average without the "outliers" who did not take this practical exam, as shown below.

=AVERAGE(S3:S4,S6:S7,S9:S12) (25)

where S5 and S8 have been omitted from the expression.
The average score for students who took the second practical exam, as reflected in cell S14, is 88% instead of 71%. The expressions in row 14 require the user to determine which cells qualify as outliers, so each one must be defined as it is needed throughout the semester.

Rows 15 and 16 contain the class high and low scores, respectively, for each column of student scores. The class high score for each column is computed using the MAX function. For example, the expression used to compute the high grade for practical exam 2, shown in cell S15, is:

=MAX(S3:S12) (26)

and the expression to calculate the low grade for practical exam 2, shown in cell S16, is:

=MIN(S3:S12) (27)

At the left side of the Grade Roster worksheet, near the bottom, cells B17 – B21 show the number of students receiving each of the various letter grades in the course. Figure 10 shows a close-up of this area.

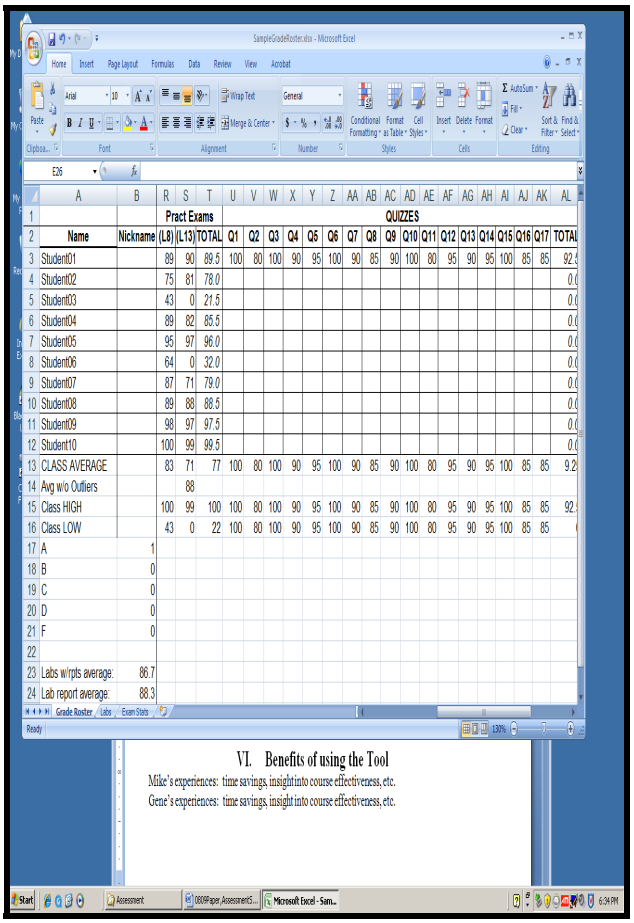


Figure 10: Course letter grade counts and lab report averages

A COUNTIF function is used to count the course letter grades in column AS. (The letter grade computation was discussed above and illustrated in Figure 8). For example, the number of As in the course is summed in cell B17:

=COUNTIF($AS$3:$AS$12,"A") (28)

This expression counts the number of "A" values in cells AS3 – AS12 and places the result into B17. The formulas for cells B18 – B21 are exactly the same, except that the letter A is replaced with B, C, D, and F respectively, to compute the corresponding count of each letter grade.

The final two numbers reflect the overall course average for labs with reports and the *report portion* of those labs. These numbers are calculated on the Labs spreadsheet, as discussed in the previous section of this paper, and are included on the Grade Roster worksheet for convenience. Cell B23 simply points to the corresponding cell, B18, in the Labs worksheet:

=AVERAGE(Labs!B18) (29)

The expression for cell B24 is the same, except "B18" is replaced with "B19."

That completes the explanation of the three worksheets.

VI. Conclusion

The author has found the assessment tool described above to be an invaluable aid for assessing courses. It quantifies student and overall class performance from a number of different perspectives. These include course activities, such as exams, quizzes, and labs; course outcomes; and program outcomes. Instructors interested in using the spreadsheet can contact the author at glhardin@purdue.edu.

Acknowledgements

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