



## Google Sheets for Realtime Assessment and Analysis of Less-Structured Problems

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## Abstract

Universities are under increasing pressures for efficiencies in education with declining budgets, increasing enrollments, and increasing expectations/accountability by students. A traditional approach with engineering or science computations is to parse the answers into a multiple choice selection. Grading of these problems is efficient and has evolved from Scantron systems to Clickers, to open source online solutions such as Moodle, Google Forms, or WebWORK. This method does have its limitations. An investment of time is required in identifying the array of possible answers. In addition, multiple choice questions allow a student to provide guesses when they might not have an idea how to approach the problem. In the grading that is performed as a batch, the instructor loses the temporal resolution which is most helpful in determining which areas are giving students particular issues.

The controlled sharing and import of individual data through Google Sheets provides educators an opportunity to utilize a spreadsheet for collecting and assessing answers real-time. This is easy to do in a manner where all students see all answers, but individual shared sheets can be setup to provide a private interaction with each student. There are several advantages to this system over many current approaches: students can continue to change their answers until the time that the instructor "grades" the assignment, the instructor has a real-time view of the student's answers and grades at any instant (with the opportunity to provide direction), tolerance values can be built in along with a median value of student answers, and sort features in Google provide real-time information on the students and concepts that are having the most issues.

This approach has been piloted in a Capstone Senior Design class for Chemical Engineering where structured concepts were taught and assessed (economics, relief sizing, etc.) and open-ended designs were utilized (where the instructor did not have a "right"/"wrong" answer, but significant deviations could be discerned).

## Introduction

Faculty and institutions are embracing technology to become more efficient in assessing student learning and providing feedback. Alaeddine *et. al.* 2015<sup>1</sup> discussed the opportunities in the context of increased student learning through technology, and their experience with an office of Educational Technology and Academic Affairs. Hogan and Cernusca 2012<sup>2</sup> wrote about the implementation of Clickers to increase or at least maintain student learning in the challenging environment of large enrollment (~50-60 that had increased to 170+) where the course was not in the primary major of a significant proportion of the students (a structural geology class with a large number of petroleum engineering students). In the recent history, most states have shifted a larger fraction of state general funding to institutional self-generated funding (primarily tuition

and fees). In this model, traditional institutional discounting or scholarships of tuition have a disproportionate negative impact on the net revenue. Therefore, total net funding per full-time equivalent (FTE) of student has been relatively stagnate or even declining for many institutions. The state of the study unfortunately leads the Southern Regional Education Board in lowest total funding per FTE student in a four year institution, with further calls by the legislature and much of the public to drive further efficiencies. It is within this context of increasing enrollment at a time of declining resources that the author has sought to implement a tool that can provide student feedback, in order to increase or at least maintain student learning, while reducing the time required per student, allowing the solution to scale larger more efficiently.

Engineering and science problems have often been posed with discrete multiple choices of solutions to facilitate grading. The ubiquitous Scantron has a history dating back to 1972<sup>3</sup>, but unfortunately required batch processing of the information with all the logistics of physical paper and scanner. Modern Classroom Response Systems (CRS) provide instantaneous feedback to the instructor and student. These solutions can range from propriety hardware such as Clickers<sup>4,5</sup> to online systems such as Top Hat<sup>6,7</sup> or PollAnywhere<sup>8,9</sup>. One can also use the survey/quiz features in the common Classroom Management software such as Moodle, or setup a Google Form.

In addition to the response systems above, there are automated computer based homework solutions, such as WeBWork<sup>10</sup>, that allows the student to work independently on a problem set. A significant advantage is that many of the variables can be randomized for the students to require a different numerical answer for each student, reducing the tendency of cheating. The disadvantage is that a significant investment by the faculty or institution must be invested to program the question sets.

The free cloud based service of Google Docs/Apps has opened up a number of opportunities for utilization in higher education. The Google Sheets/Apps Script described in this document bridges the gap between a Classroom Response System and some of the automated homework systems. Google forms have been discussed as a survey instrument for course engagement. The use of Google Docs and Google Sheets facilitates live collaboration on a single view. In the past, the author has employed Google Sheets as a means for discussions of open-ended design projects that students were performing cost optimizations. Although this platform was superior to prior efforts of having students emailing spreadsheets with pre-defined templates (because of the live interactive nature of Google Sheets), the lack of anonymity of individuals and groups was viewed as a significant drawback.

The “Importrange” function built into Google Sheets allows defined information to be passed from one spreadsheet to another, allowing the sheet creator (in this case, the instructor) to specify the workflow of information. Google Sheets also allows the “owner” to turn on and off sharing of worksheets (Figure 1). Using these two features, an instructor can create an individual worksheet for each student, where the information from each is consolidated into a single

instructor worksheet that only that person can view (Figure 2 and 3). Using macros created in Google Scripts, individual feedback can be provided to each of the students if the instructor wishes. The author has utilized this methodology in two types of problems, and believes that the open nature of Google Sheets offers potential advantages over existing software solutions:

1. Problems with closed form solutions (standard homework/exam problems)
2. Open-ended problems (i.e. design or optimizations)

As noted above, many solutions exist for closed form problems, including iClicker, Top Hat, etc. Using Google Sheets provides an environment that allows many Excel-based spreadsheets to be easily imported using copy/paste. The author has implemented a scoring system based on a tolerance to the solution ( $\pm x$  percent being correct, greater deviation but less than  $y$  percent being high or low respectively and greater than  $y$  percent being very high or very low). Figure 4 depicts how this is implemented in the Google Sheets to provide the grading real-time to facilitate live sorting for the instructor. With this system, different problems can be asked with very little modification of this type of Personal Response System. Large problems can be parsed into many smaller steps, allowing a live two-dimensional view of students versus progress on the problem. This is especially helpful in identifying conceptual issues by the class or particular students that need more individualized attention.

Feedback is provided to the students using a macro created in Google Script (see Google app script at end of article). This feedback is only provided for cells where there is an attempt and only when the instructor runs the macro (to limit bisecting the answer by guessing). The fast and automated scoring has allowed the instructor to utilize this on homework assignments, to provide more than a single cycle of feedback (especially problematic in a Tuesday/Thursday course). Students can be required at some intermediate time to upload their answers, where the macro is read and scored (letting the students know which answers were incorrect).

Open-ended problems present the challenge that the macro described above cannot provide accurate feedback because the solution might not be known a-priori by the instructor. The spreadsheet can be set up to calculate the average or median of the solutions uploaded, which is very helpful in identifying outliers. The author implemented this process in a Chemical Plant Design class. The root cause of the error could have been in calculating the size of a specific unit operation or in the application of this size to a cost equation. Sizing errors of a unit operation (i.e. a pump, heat exchanger, tower, etc.) were most commonly attributed to improper application of justified variable in an equation (for instance, the heat transfer coefficient of an exchanger), unit conversion errors, and simple mathematical mistakes in applying the equation. Requiring students to upload most terms of the equations solved allowed the instructor to provide guidance on what to correct.

A much less complicated approach is to create a single Google Sheet, but unfortunately there is potential for students to abuse this system (uploading answers similar to others without a given

solution set). In addition, the lack of anonymity can create a less than ideal environment to students that are particularly struggling in the class. With the answers from the individual sheets being collected into a master sheet, results from the master sheet can be shared in class without any identifying information.

Different worksheets can provide sorted and/or filtered views of this data. The “Sort” command in Google Sheets is a live feature (Figure 5), therefore the data resorts itself as new information is entered or edited by the students. One can also transpose the data that is being sorted. This can be helpful if a scoring is assigned to a given column, therefore the areas with the highest or lowest overall scoring can be easily identified.

### **Instructional Context and Implementation**

The Google Sheet system has been used in three types of classroom scenarios: an in-class instruction/exercise, traditional homework, and open-ended projects. All three scenarios were carried out with seniors in Chemical Engineering, the first scenario was as part of a Spring course while the second two scenarios were part of a Fall course. Both are required classes for seniors in Chemical Engineering at the institution. Only one section of each of the courses are taught, so the results in the next section constitute the entire demographic of the graduating students in Chemical Engineering for the reported year (not a self-selected subsection, as would be the case for an elective).

The institution in this study is a public four year institution with an enrollment of approximately 11,000 students. From 2010 to 2015, many of the engineering programs have experienced significant growth (from 1211 to 1860 total of all engineering programs, and 169 to 333 in Chemical Engineering specifically). The demographics of the senior cohort has typically been approximately 24% women, 11% underrepresented minorities, and 18% international. The average Math ACT has been approximately 26.5 for the graduating seniors. Until the Spring 2015 graduating class, students were required to take the NCEES Fundamentals Engineering Exam (with points assessed in the plant design sequence to incentive passing). The 7 year average of FE performance for Chemical Engineering seniors that were required to take the FE was 100% of the national average in the subsection “Process Design & Economics” (aggregate performance of students reported by NCEES for the institution divided by the reported national average). Anecdotally, the prevailing job market can have an impact of student motivation during the senior year (interestingly, during times of high market demand where many students have signed offers prior to the start of the senior year, motivation appears to be more of a challenge as students begin looking past school and planning/preparing for the start of their career).

As discussed in the prior section, a separate sheet is created for every student in a course. This is actually made easier by the fact that the sharing in Google Sheets can be turned on/off by the creator. The identification for a given Google Sheet used for reading or writing information is a

large string that is visible in the web address of the browser. This string is independent of the name of the Google Sheet (so it can be retitled to the various students in the future) or sharing performed. Therefore, the same student Google Sheet can be recycled in future course offerings. Figure 6 and 7 depict the view by the highest and lowest performing student for the example problem. The different Google Sheet IDs' are visible along with how the student answers and grading are presented in separate tabs (student answers in tab labeled Sheet1, graded feedback in tab labeled Sheet2).

The combined master sheet requires some organization and programming of app scripts. A single page was created where student names, associated Sheet ID's, and tab names are provided (Figure 8). The rest of the Worksheet references this tab (so changes only have to be made in one place if a student needs to be added or deleted). Similarly, a single tab was created to define rules used throughout the worksheets such as what tolerance value to define as high/low versus very-high/very-low (Figure 9).

### **In-class exercise**

The first scenario was the instruction and testing of safety relief sizing using the Chemical Process Safety textbook by Crowl and Louvar. This instruction is carried out while the students are performing the American Institute of Chemical Engineers (AIChE) 30-day design competition outside of class. Under the terms of the competition, the students cannot receive help from the instructor or other students, so there is an opportunity to cover material that is useful to the students but not directly part of the project. Because students are focused on the project outside of class, the intention is to have the learning occur during the classroom time. In the past, there was instruction followed by in-class sample exercises. The instructor would walk around to help correct errors and ensure students were making progress on the sample problem. At some point after the 30-day project, a safety exam is conducted to assess student learning of these concepts.

Historically, the performance on this exam has been below desired levels. There are likely several confounding factors to this performance, including the relatively low portion of the grade (the project represents the primary portion with a fraction of 25% comprising the safety portion), the multiple choice format of the exam that limits awarding of partial credit and a cascading errors, and the timing of the exam (seniors where the majority have signed jobs with less than 3 weeks to graduation).

After the lecture of the material was provided, students were given an exercise to work in class. As the instructor walked around the class (prior to implementing the Google Sheet), it was difficult to gauge the extent of progress each was making. The Google Sheets solution, which originally had been developed to provide presentation feedback, was modified as described in this article. The same example problem was parsed into 16 sequential steps, and students were asked to upload answers as soon as possible on each item. Initially, there was no mechanism to

provide feedback to the students other than orally as it was identified by the instructor. This quickly became the rate limiting step even in a class as small as 23 people. Seeing the rates at which students progressed through the problem was very insightful, allowing the instructor to understand which students were having issues with specific concepts. The grading macro was developed and piloted in the next class period. The grading macro provided individualized feedback to whether the student was correct, high, low, very high or very low based on a tolerance value defined by the instructor.

The instructor felt that this tool provided information (specifically temporal resolution on the class exercise) that was otherwise difficult to determine. Students provided positive comments in the final course outcomes and assessment survey, however a survey of student learning on the relief sizing concept was not demonstrably different than the prior three years ( $p=0.13$ ). Student performance on the exam was also not statistically different than the prior three years ( $p=0.96$ ).

### **Homework**

In the second setting, the Google Sheet was used as a means of collecting and grading homework for the Fall senior plant design course in Chemical Engineering. Similar to the format above, the problems were parsed into many subsections to isolate specific areas that the students were missing. The course was taught on a Tuesday/Thursday schedule. Because of the length of time between the Thursday to Tuesday homework, the instructor asked students to upload initial solutions by 5 pm on Sunday evenings. The grading macro was run and individualized feedback was provided to each student. The grades were saved and made up a portion of the homework grade (1/3). Students were allowed to correct and change any mistakes until the beginning of the class period when the final grading macro would be run and saved (comprising the other 2/3 of the homework grade for that assignment).

The use of the Google Sheets for homework had a very significant positive impact on performance ( $p = 1.4E-6$ ). The immediate feedback appeared to engage the students more readily, especially with larger class sizes where traditional grading was relatively slow. Over the prior four years, students did not turn in approximately 11% of the opportunities for homework. With the Google Sheet, only 1% of the homework opportunities were missed by the students. The average grade rose with the Google Sheet, but it was largely due to the higher participation rate among the students. The possible motivation of rapid feedback is in contrast with survey findings by Vandebussche *et. al.* 2013. In that study, students taking math classes were asked to respond to a survey on possible reasons for not completing their homework. “You had too much work from other courses” was the top reason, while “you knew it wouldn’t be graded” was relegated to among the lowest reasons cited (tied for sixth place among four other reasons out of only ten). It is possible that the core disciplinary class provided in the current study provided a different motivation environment than the prior work (reflecting a prioritization of work by the students when responding “..too much work from other courses”).

## **Projects**

Students in the first quarter plant design class are required to optimize the Net Present Value of a single distillation column and then a combination of two distillation columns for their project grade (using the process simulator ChemCAD and Excel sheets for cost modeling). As students' progress through the optimization process, all students are required to provide detailed information on the sizing of equipment and costs for the system at a base case condition. Prior years used a single shared Google Sheet for students to enter data (since 2010), and prior to that students were required to fill out an Excel template that was consolidated by the instructor and presented to the class. The information provided to the students using the system outlined in this paper were not fundamentally different, so it was not a surprise that there was only a very weak statistical difference in project performance ( $p=0.056$ ). The single shared Google Sheet was easy to implement but unfortunately did not allow for anonymous feedback. The instructor was concerned that this would create an unnecessarily uncomfortable atmosphere for the students that were having difficulty with the material. Compiling the individual Excel templates created an anonymous environment; however, it did place a significant burden on the instructor that was not sustainable as enrollment increased. The current individualized Google Sheet input allows the instructor to anonymously highlight areas to the class that appear to be issues. The live sort function was particularly valuable in identifying areas where students might be deviating significantly from the average (prompting the student to check those areas closer).

## **Conclusions**

The Google Sheet system described in this paper provides an effective means of anonymous, real-time monitoring of student progress. Homework is an area that this appears to be especially effective, allowing feedback to be provided at intermediate points prior to turning in the assessment. The feedback appears to increase student engagement, without a linearly increasing burden of grading on the instructor or graduate teaching assistants (allowing these resources to be used for other purposes). For more open ended assignments that cannot be graded to a single numeric value, the Google Sheet provides an efficient way of collecting information that can be presented in an anonymous manner to the student population.

## **Bibliography**

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Inputs Live via "importrange"

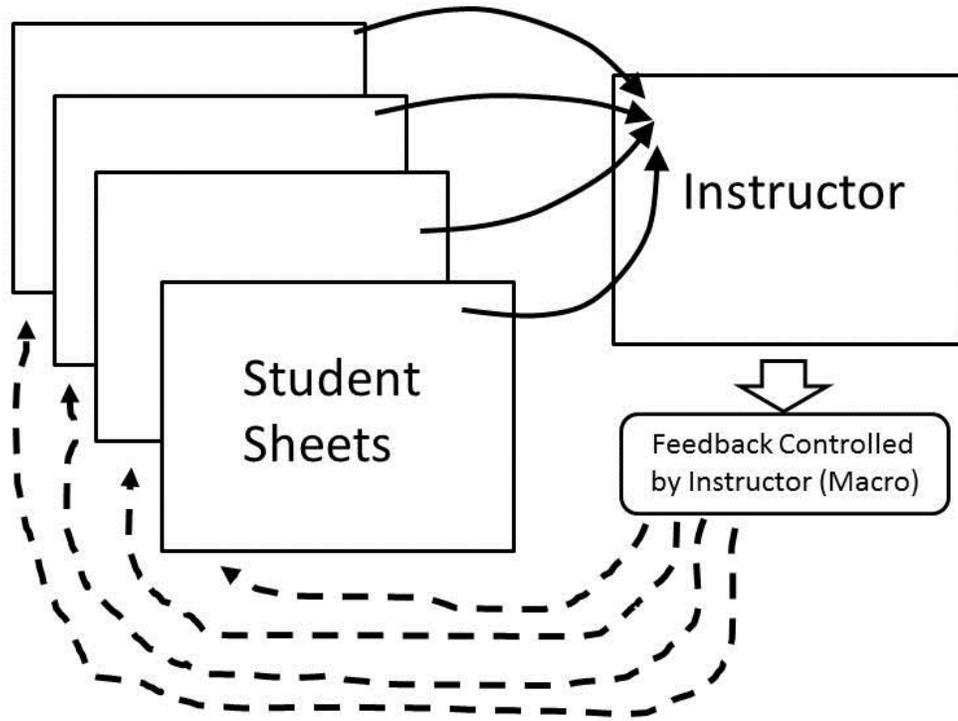


Figure 1 – Overview of Information flow of student to instructor sheets

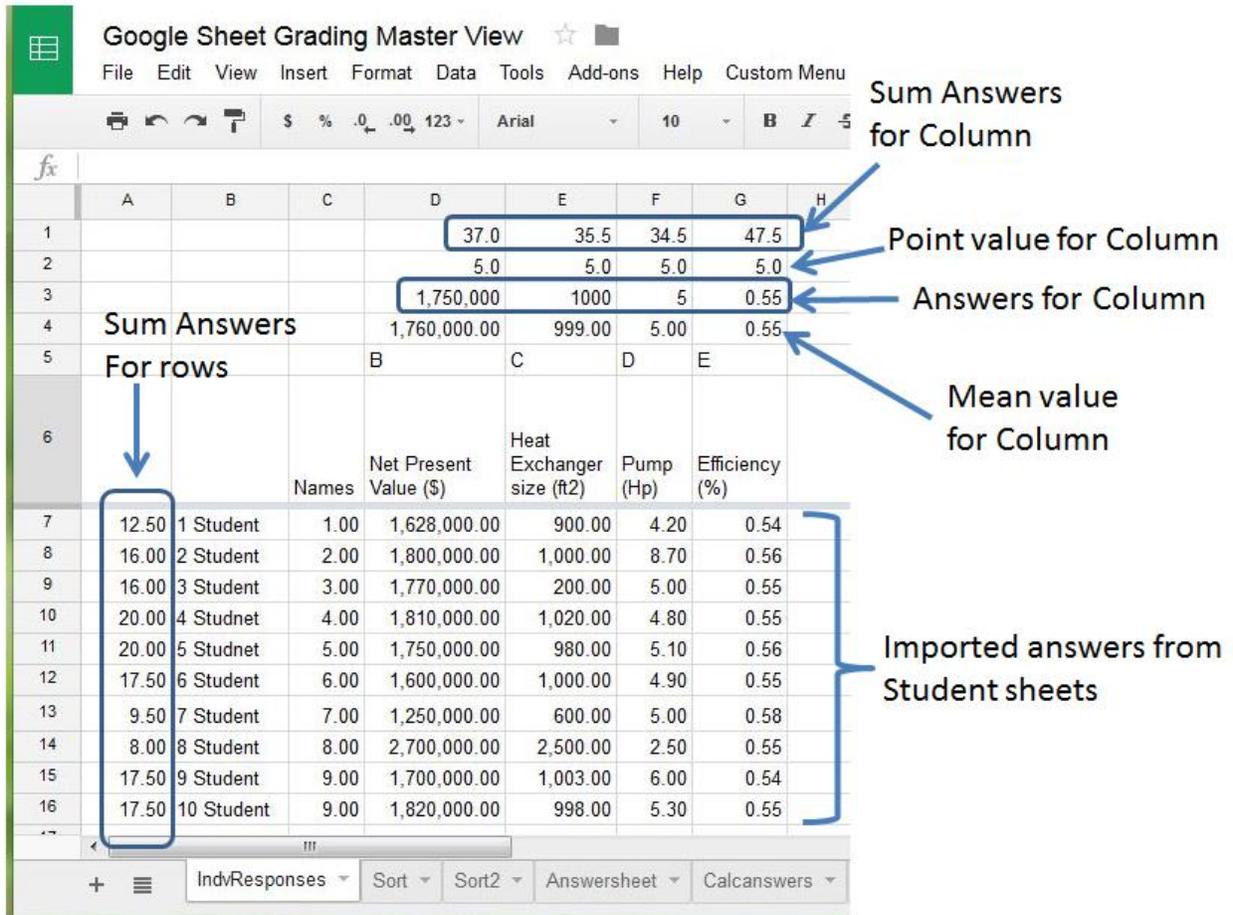


Figure 2 – Instructor master sheet consolidating information from students

Google Sheet Grading Master View jpalmer@email.latech.edu

File Edit View Insert Format Data Tools Add-ons Help Custom Menu All changes saved in Drive Comments Share

fx =importrange(Definitions!C2,Rules!\$B\$8)

	A	B	C	D	E	F	G
1				=sum(Calcpoins!D:D)	=sum(Calcpoins!E:E)	=sum(Calcpoins!F:F)	=sum(Calcpoins!G:G)
2				5.0	5.0	5.0	5.0
3				1,750,000	1000	5	0.55
4				=median(D7:D16)	=median(E7:E16)	=median(F7:F16)	=median(G7:G16)
5				=REGEXTRACT(ADDRESS(ROW(), COLUMN()-2), "[A-Z]+")	=REGEXTRACT(ADDRESS(ROW(), COLUMN()-2), "[A-Z]+")	=REGEXTRACT(ADDRESS(ROW(), COLUMN()-2), "[A-Z]+")	=REGEXTRACT(ADDRESS(ROW(), COLUMN()-2), "[A-Z]+")
6			=Template!A1	=Template!B1	=Template!C1	=Template!D1	=Template!E1
7	=sum(Calcpoins!D7:BE7)	=Definitions!B1&"&Definitions!A1"	=importrange(Definitions!C1,Rules!\$B\$8)	1,628,000.00	900.00	4.20	0.54
8	=sum(Calcpoins!D8:BE8)	=Definitions!B2&"&Definitions!A2"	=importrange(Definitions!C2,Rules!\$B\$8)	1,800,000.00	1,000.00	8.70	0.56
9	=sum(Calcpoins!D9:BE9)	=Definitions!B3&"&Definitions!A3"	=importrange(Definitions!C3,Rules!\$B\$8)	1,770,000.00	200.00	5.00	0.55
10	=sum(Calcpoins!D10:BE10)	=Definitions!B4&"&Definitions!A4"	=importrange(Definitions!C4,Rules!\$B\$8)	1,810,000.00	1,020.00	4.80	0.55
11	=sum(Calcpoins!D11:BE11)	=Definitions!B5&"&Definitions!A5"	=importrange(Definitions!C5,Rules!\$B\$8)	1,750,000.00	980.00	5.10	0.56
12	=sum(Calcpoins!D12:BE12)	=Definitions!B6&"&Definitions!A6"	=importrange(Definitions!C6,Rules!\$B\$8)	1,600,000.00	1,000.00	4.90	0.55
13	=sum(Calcpoins!D13:BE13)	=Definitions!B7&"&Definitions!A7"	=importrange(Definitions!C7,Rules!\$B\$8)	1,250,000.00	600.00	5.00	0.58
14	=sum(Calcpoins!D14:BE14)	=Definitions!B8&"&Definitions!A8"	=importrange(Definitions!C8,Rules!\$B\$8)	2,700,000.00	2,500.00	2.50	0.55
15	=sum(Calcpoins!D15:BE15)	=Definitions!B9&"&Definitions!A9"	=importrange(Definitions!C9,Rules!\$B\$8)	1,700,000.00	1,003.00	6.00	0.54
16	=sum(Calcpoins!D16:BE16)	=Definitions!B10&"&Definitions!A10"	=importrange(Definitions!C10,Rules!\$B\$8)	1,820,000.00	998.00	5.30	0.55
17							

IndvResponses Sort Sort2 Answersheet Calcanswers Wordanswers Calcpoins Definitions Rules

Figure 3 – Instructor master sheet, view of equations

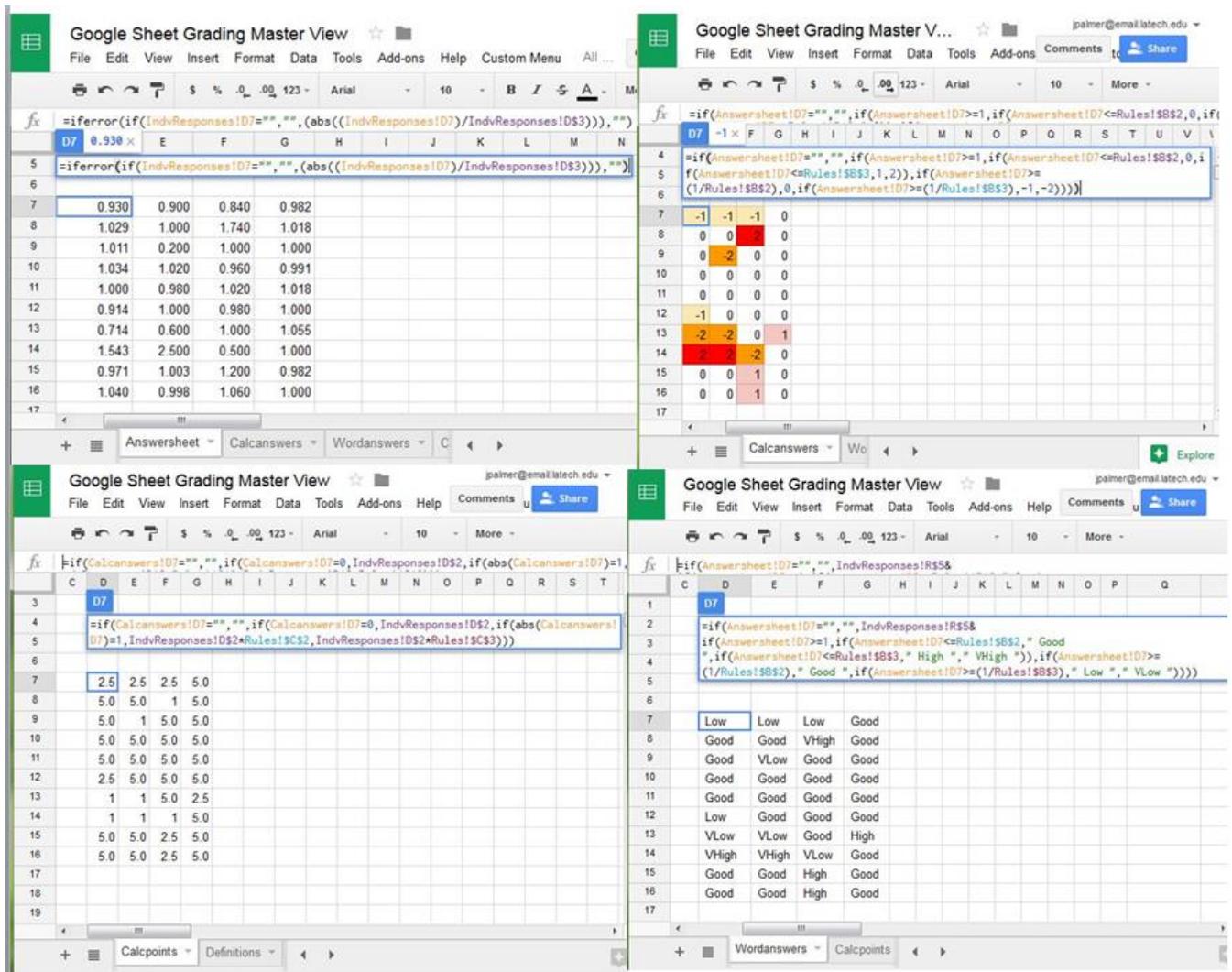


Figure 4 – 4 tabs to calculate grades for live sorting

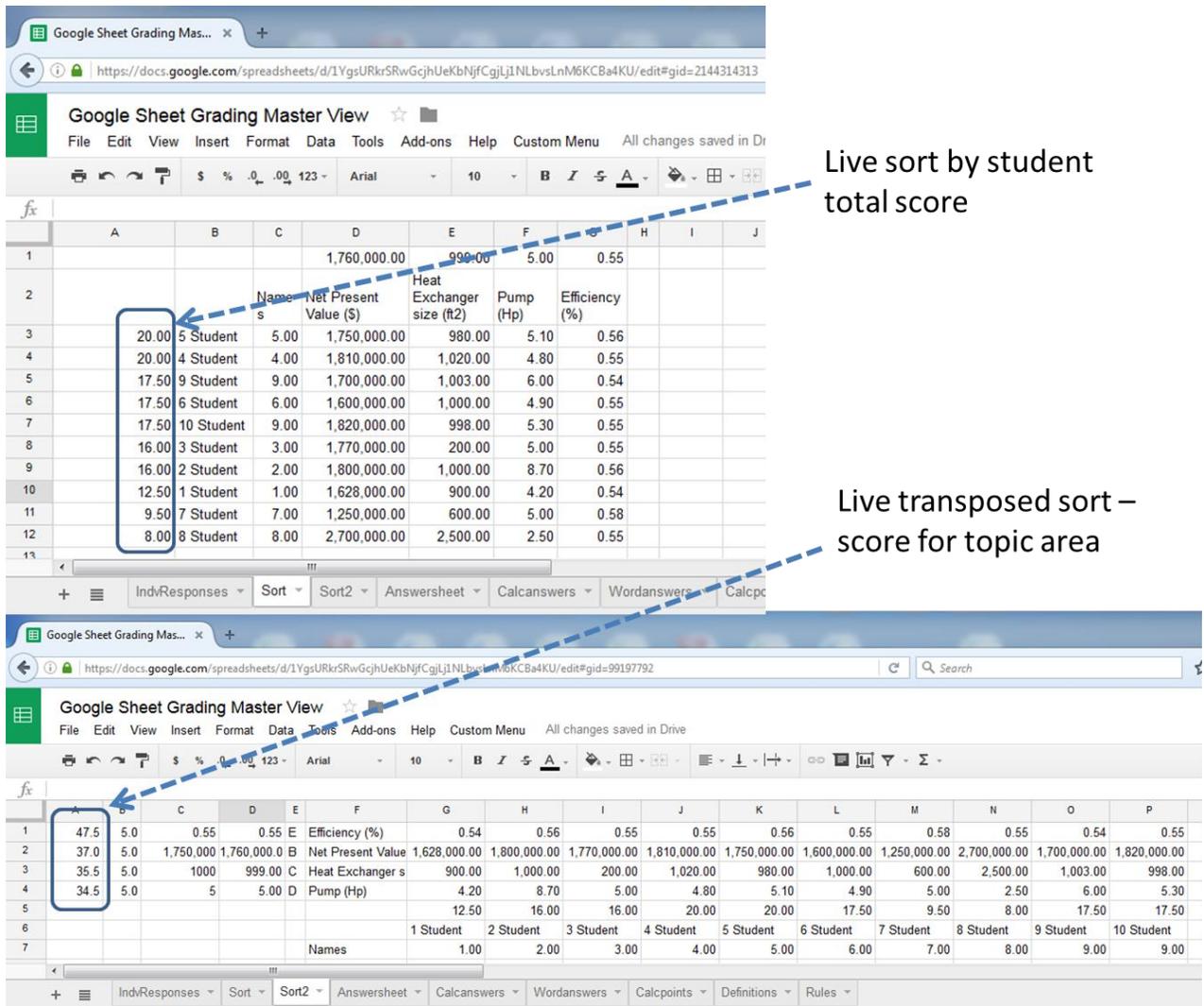


Figure 5 – Instructor live sort view

Google ID of sheet for Student 5

Student 5 (top student)

Names	Net Present Value (\$)	Heat Exchanger size (ft2)	Pump (Hp)	Efficiency (%)
5	1750000	980	5.10	0.56

Imports from instructor master sheet

Overall score

Figure 6 – Student 5 view, top student

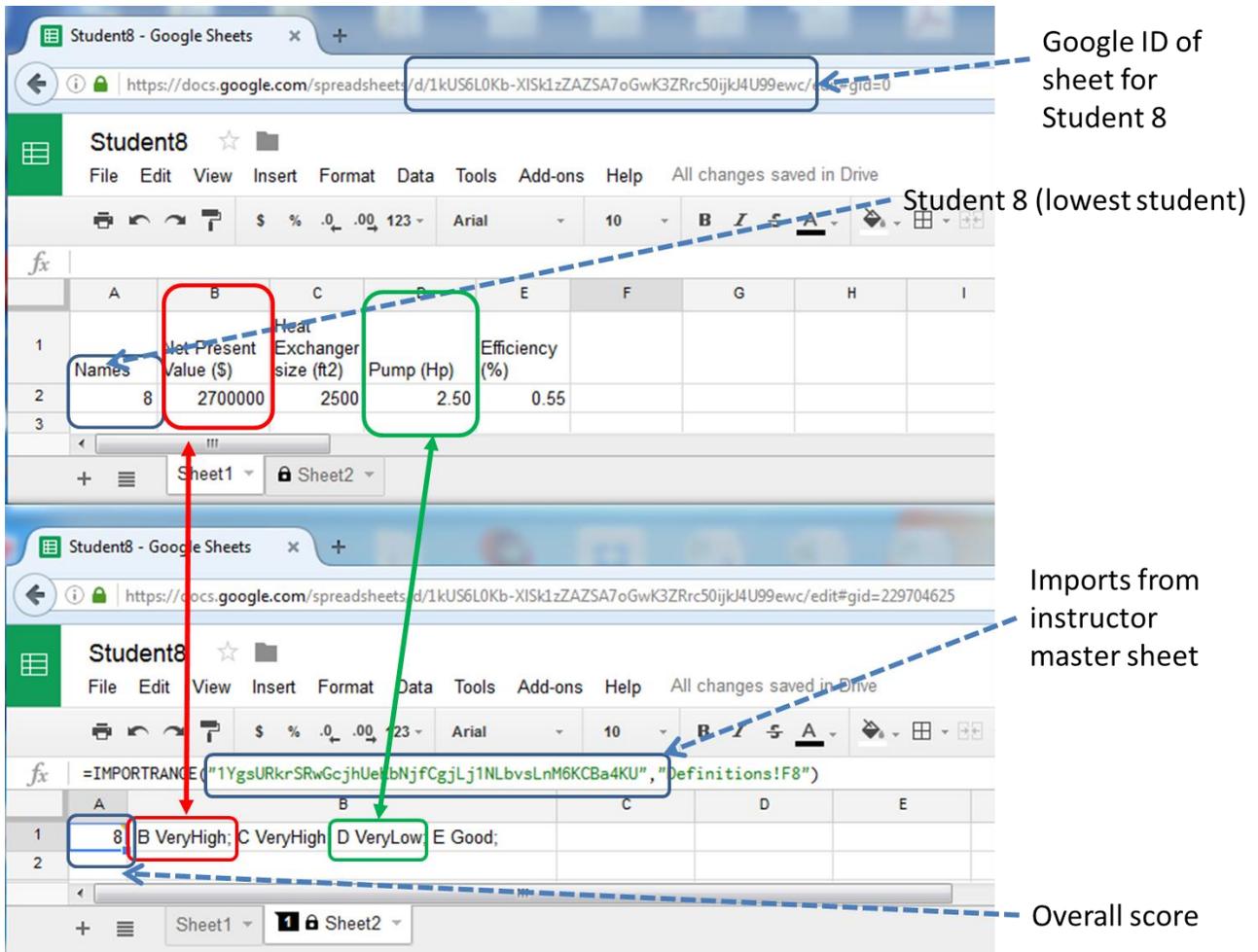


Figure 7 – Student 8 view, lowest student

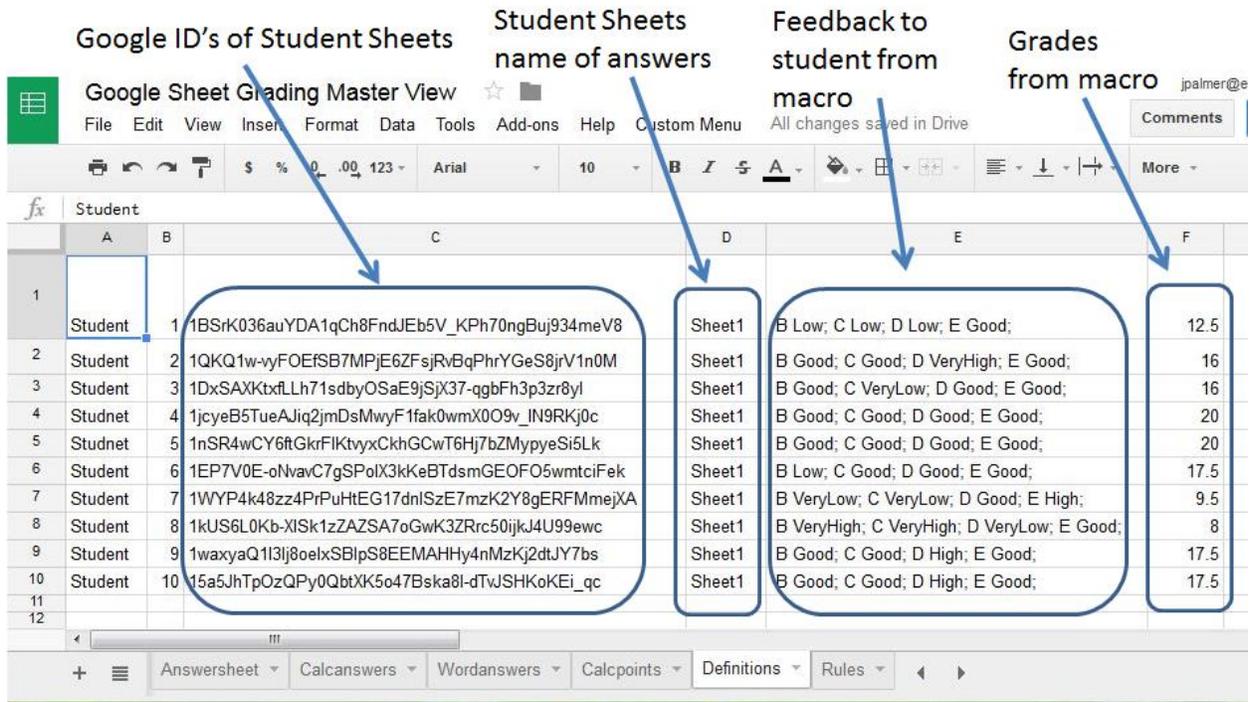


Figure 8 – Definitions page of instructor sheet

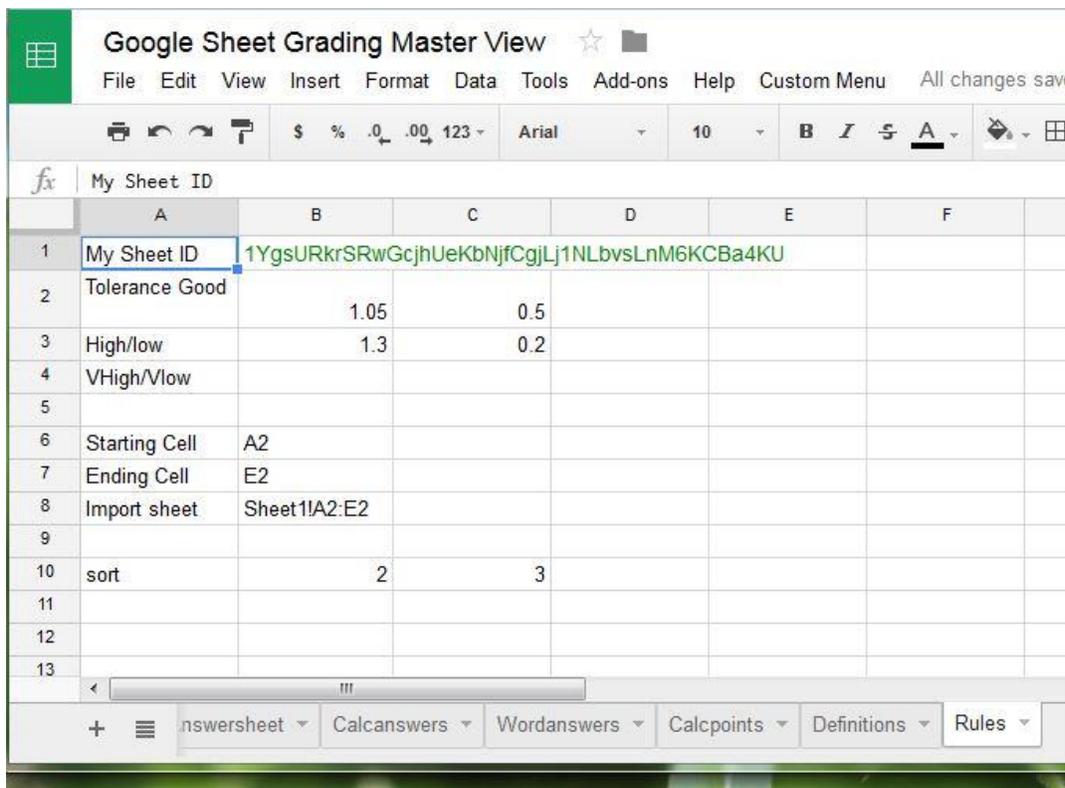


Figure 9 – Rules for instructor sheet

Google Scripts to push templates to student sheets and to grade student sheets

Note that to use this without modification requires a sheet labeled Template, IndvResponses, and Definitions that is laid out in the same manner as defined previously

```
function onOpen() {
  var ss = SpreadsheetApp.getActive();
  var items = [
    {name: 'PushTemplate', functionName: 'menuItem1'},
    null, // Results in a line separator.
    {name: 'Results', functionName: 'menuItem2'},
  ];
  ss.addMenu('Custom Menu', items);
}

function menuItem1() {
  // pushes template out to each student worksheet
  var ss=SpreadsheetApp.getActiveSpreadsheet();
  var template=ss.getSheetByName("Template");
  var templength=template.getLastRow();
  var tempwidth=template.getLastColumn();
  var temprange=template.getRange(1,1,templength,tempwidth);
  var tempx=template.getDataRange().getValues();
  var rules=ss.getSheetByName("Rules");
  var rulesx=rules.getDataRange().getValues();
  var definitions=ss.getSheetByName("Definitions");
  var deflength=definitions.getLastRow();
  var defsx = definitions.getDataRange().getValues();
  for (var i = 0; i < deflength; i++) {
    var ssxt=SpreadsheetApp.openById(defsx[i][2]);
    var sheetxt=ssxt.getSheetByName(defsx[i][3]);
    var strng = '=IMPORTRANGE(""+rulesx[1][0]+", "Definitions!F"+(i+1)+"");
    sheetxt.clear();
    var sheetxtrng=sheetxt.getRange(1,1,templength,tempwidth);
    sheetxtrng.setValues(tempx);
  }
}

function menuItem2() {
  // grades the responses
  var ss=SpreadsheetApp.getActiveSpreadsheet();
  var response=ss.getSheetByName("IndvResponses");
  var reslength=response.getLastRow();
  var reswidth=response.getLastColumn();
  var resdat = response.getDataRange().getValues();
  var lengthadd = 6;
  var widthadd = 0;
```

```

var idrow = 4
var answerrow=2;
var graderow=1;
var definitions=ss.getSheetByName("Definitions");
var deflength=definitions.getLastRow();
var defsx = definitions.getDataRange().getValues();
var rules=ss.getSheetByName("Rules");
var rulesx=rules.getDataRange().getValues();
var output="";
var grade1=0;
var grade2=0;
var checktot=0;
var criteriaH1=rulesx[1][1];
var criteriaH2=rulesx[2][1];
var criteriaL1=1/rulesx[1][1];
var criteriaL2=1/rulesx[2][1];
for (var x = 0; x < (reslength-lengthadd); x++) {
  for (var y = 0; y < (reswidth-widthadd); y++) {
    if (resdat[answerrow][y+widthadd]!="") {
      var checktot = (resdat[x+lengthadd][y+widthadd]/resdat[answerrow][y+widthadd]);
      var check3 = Math.abs(checktot);
      if (resdat[x+lengthadd][y+widthadd]==="") { var output=output+"
else if (check3>=criteriaL1 && check3<=criteriaH1) {var output=output+'
'+resdat[idrow][y+widthadd]+' Good;'; grade1=grade1+resdat[graderow][y+widthadd]}
else if (check3>=criteriaH1 && check3<=criteriaH2) {var output=output+'
'+resdat[idrow][y+widthadd]+' High;';
grade1=grade1+resdat[graderow][y+widthadd]*rulesx[1][2]}
else if (check3>criteriaH2) {var output=output+' '+resdat[idrow][y+widthadd]+' VeryHigh;';
grade1=grade1+resdat[graderow][y+widthadd]*rulesx[2][2]}
else if (check3<criteriaL1 && check3>criteriaL2) {var output=output+'
'+resdat[idrow][y+widthadd]+' Low;';
grade1=grade1+resdat[graderow][y+widthadd]*rulesx[1][2]}
else if (check3<criteriaL2) {var output=output+' '+resdat[idrow][y+widthadd]+' VeryLow;';
grade1=grade1+resdat[graderow][y+widthadd]*rulesx[2][2]};
definitions.getRange((x+1),5).setValue(output);
}
}
var output="";
definitions.getRange((x+1),6).setValue(grade1);
var grade1=0
}
}
}

```