**Affordable Learning Georgia Textbook Transformation Grants**

**Final Report for Mini-Grants**

# General Information

Date: August 14, 2020

Grant Round: 14

Grant Number: M89

Institution Name(s): University of Georgia

Team Members: Donald Wayne Suggs

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Project Lead: Donald Wayne Suggs

Course Name(s) and Course Numbers: Quantitative Chemical Analysis (CHEM 2300L)

Final Semester of Project: Summer 2020

Average Number of Students Per Course Section: 15

Number of Course Sections Affected by Implementation of Revised Resources: 4

Total Number of Students Affected by Implementation of Revised Resources: ~50

# Project Narrative

The purpose of this grant was to develop a three laboratory experiments which would be more inquiry based. Moving to a more inquiry-based pedagogy would hopefully facilitate more effective learning and retention. This is especially true as the students grappled with Analytical Chemistry methodology for the first time.

However, the PI was hampered in completion of this project due to the coronavirus in the Spring 2020 semester and for the Summer 2020 semester. Conversion of the final three labs to virtual learning had priority and was to be performed late during Spring 2020. This was the scheduled time for the implementation of the newer labs. Summer found the PI performing a complete conversion of the lab to virtual learning. A new lab on EXCEL applied was added to get students ‘up and running’ building worksheets to perform their lab calculations (this lab is not included here as it is still in revision stages).

A new inquiry-based lab was developed in which tonic water samples from different manufacturers were analyzed for quinine content using fluorescence. The analytical methodology employed was the standard addition method. This lab was performed live once during the Fall 2019 semester. The PI has no hard data on student performance for this lab as it was the first time the developed methodology was tried in a ‘live’ setting. Observation and some student comments have led to the more inquiry-based lab presented in the next section. The lab has not been performed ice due to time constraints in the Spring semester and the summer semester. More modification need to be made, however to get it completely inquiry based.

The PI, however, did modify some of the weak acid titration labs we performed to be a bit more inquiry based, and to hook into the ideas developed in the aforementioned EXCEL lab. A lab was developed to examine two diprotic acids: one with the pKa values differing by at least 4 units and showing two distinct breaks and the second where the pKa values were less than 4 units apart and showed only one break. The students performed potentiometric titrations with a drop counter and used CurtiPlot to determine the endpoint volumes. From this data the molar mass of the acid could be calculated. They also extracted pKa values where possible (this is more difficult to do for the acid with the closer pKa values, and students struggle with this). As a point of comparison, students added three different indicators to the replicate solutions and were asked which indicator could be used for quantitative purposes.

This particular laboratory lead into the next which is a potentiometric titration to find the total acidity in fruit juices or wine. They had to take this knowledge from the diprotic acid lab (acids selected in that lab were ones found in fruit juice or wine) to confirm the major acid in the juice or wine. Since it is a mixture of acids, the titration curve does not exactly match the pure dominate acid.

Over the summer the PI changed the diprotic acid lab and made it more of an investigative lab using an EXCEL worksheet that I found that allows students to explore the behavior of diprotic acids (some of this is not included in the current materials as it needs some heavy revision. If you would like to see it you can e-mail me). Since they struggled with finding simple pKa values (even from straight forward diprotic acids), the PI added a lab that worksd to identify a monoprotic weak acid. This worked much better for the summer 2020, and will be implemented in the Fall of 2020. The progression of identifying a weak acid through a potentiometric titration followed by the diprotic lab makes more sense (in terms of time and cognitive load). All of these labs lead to the total acidity lab which has a much more complex titration curve. You will note that the instructions for this lab are sparse. The student is provided with industry SOPs for finding total acidity. They have to work things out for themselves. They are however given some guidance of the amounts to use since juices like lemon are have a much higher total acidity than apple or grape juice.

The PI did not have time to resurrect and update a lab involving the derivatization and titration of a polyethylene glycol polymer. This lab utilizes a back titration to determine the average molar mass of a polyethylene glycol sample. This is lab that was performed years ago, but in the current climate time funds could not be spent in spring or summer to update this lab to the inquiry level. This lab handout is NOT included in the materials.

The PI has learned much about lab writing and implementation during this entire process. Especially over the summer 2020 semester when the PI had to review all labs and provide data for students to analyze. I have also learned that students do not read everything you write, nor do they go through all of the inquiry-based material you provide to help them understand what is going on (unless it’s for a grade). I do not have any quantitative data, but anecdotally it seems that my students do much better on data interpretation when they use inquiry based materials.

It was discovered (during the online transition) that for some of the more complicated quantitative method labs we do, a guided inquiry taking the student through the calculation steps (different that the experimental data) was of positive benefit. This allowed students to have confidence in the calculations for their respective lab report and allowed them to focus on presenting and interpreting results. Unfortunately, there is not any quantitative data to present at this time.

# Materials Description

The quinine experiment involves the students taking spectra of a diluted tonic water sample to determine the best dilution to use for the analysis. This requires a good signal but one that is not near the quenching zone for quinine. Once they know the dilution level, students add aliquots of a standard directly to the diluted tonic water in the fluorimeter cuvette which is **already** in the fluorimeter. After each addition of standard using a micropipet, the florescence intensity is recorded and the mean of three replicate values determined. A standard addition plot is constructed and the concentration of the quinine in the diluted tonic water is found along with its uncertainty. The uncertainty is based on the regression statistics. Students then find the concentration in the tonic water and use propagation of error to find the error in that concentration. Students compare tonic water concentration by manufacturer by sharing results and then comparing them to known ranges. Confidence intervals are used to check for accuracy.

The weak acid lab begins by describing the shape and chemistry behind the titration of a weak acid with a strong base (or vice versa). Students review the dominate species (alpha values) for each conjugate during the titration curve to learn the type of solution created at each point. This leads to an understanding of how to find the pKa values of the acid. Methods of find the endpoint volume are also discussed as they relate to quantitative analytical work. NOTE: This works in conjunction with the acid titration guided inquiry that was developed for lecture (See proposal M90’s report). The student is presented with a solid weak acid. They must figure out in one potentiometric titrations (using a drop counter and pH probe) what the approximate molar mass is. Then they determine the mass or volume (if they dissolve it to make a solution) needed to titrate the sample completely using 10 mL of the standard NaOH provided. They add different indicators to each sample an determine when they change color. They find the inflection point from the second derivative in CurtiPlot. They then find the pKa at 25%, 50% and 75% titrated. All means of the molar mass and pKa is given along with 95% confidence intervals. This allows them to try and identify their acid. Students also report the best indicator to use for the analysis.

As part of the weak acid lab and leading up to the total acidity lab, the student is directed to look at a provided EXCEL file (sometimes I use CurtiPlot) which allows them to explore diprotic acid behavior in light of the experience with weak acids.

The PI has included the Total Acidity lab as it is pretty much self-explanatory and open ended.

Guided inquiries were added to the External calibration Lab (Determination of Iron in Natural Waters) and to the Internal calibration lab (Gas Chromatography of a Xylene Mixture). These files are self-explanatory and have a matching EXCEL file where student can enter answers and have a template to do calculations. These inquiries are collected in GradeScope by scanning in a pdf document.

# Materials Links

# Future Plans

The fluorescence lab will need to be further modified to make it friendlier. After this lab is executed live again, student feedback will be used to modify the lab.

Further guided inquiry pre-labs will be developed for ***all*** labs. This is especially true for the diprotic acid inquiry. The simple inquiry currently used will be developed to include simulated titrations using Curtiplot so the student can gain a better understanding of real diprotic and polyprotic acids.

Currently, there are several labs that switch in and out of the rotation each semester. There is must work to be done. There was not time to develop videos for the labs since they were either not performed or access to the lab was restricted during the spring when they would have been done. This will be corrected this Fall and the PI can provide these as soon as they are done.