SUPPLEMENTARY INFORMATION

Appendix I: Formative survey items and rate of student response (given in %).

Table 1. Surveys were collected over two semesters (Fall 2011 and Spring 2012, N=712). All students enrolled in the first semester general chemistry laboratory were asked to participate in Fall 2011 and all students enrolled in both semesters of the general chemistry laboratory sequence participated in Spring 2012. Survey completion was performed at the close of the term, was voluntary, and in no way affected students grades in the course.

	Strongly Agree	**Agree**	**No Opinion**	**Disagree**	**Strongly Disagree**
I found it easy to record the video on my cell phone/camera/iPad.	34.70	38.81	10.05	6.39	9.13
After practice, I found it easy to edit the video.	20.09	32.42	26.94	13.24	7.31
I liked the video reports better than the written reports.	17.81	22.37	17.81	17.35	24.66
It was easy to turn in my assignments in BlackBoard Learn.	29.68	36.07	16.89	8.22	9.13
I feel that I will review my videos to refresh my technique in later courses.	8.68	9.59	26.03	26.03	29.68
I reviewed the rubrics provided in preparation for recording the videos.	31.51	42.92	11.42	4.57	9.59
The rubrics were easy to follow.	25.11	44.29	15.53	7.76	7.31
I knew what the TAs would be grading for because of the rubrics.	42.01	40.18	7.76	3.65	5.94
My grades on the videos were comparable to the written reports.	29.22	35.16	21.00	3.65	5.94

Appendix II: Video Grading Rubrics

Balance Video Grading Rubric (20 total points):

Lab Group Members:_____

TAs: The video should fall into one category under each of the following headings. Choose the category you feel best describes the submitted video. Items that have and underlined require every piece mentioned in the item.

____ (2 pts possible) General video quality:

____(2 pts) The video was shot in a manner that allows for clear observation of measured values, all close ups of notebooks and balance readout allow the viewer to read results, and explanations or definitions are audible.

____(1 pt)The students can all be seen performing the procedure (or the audio provides a reasonable description), but the video was not shot in a manner to allow the viewer to determine the accuracy of any measurements.

____(0 pts) The video does not allow for any determination of how the measurements were made.

____ (8 pts possible) Technique:

____(8 pts) Each student in the group can be seen taring the balance, obtaining the mass of their watch glass, adding sample away from the balance, and obtaining the mass of the watch glass and sample together. All of the previous, as well as what data must be recorded to obtain mass of sample, must be accompanied with explanations.

____(4 pts) Each student in the group can be seen performing the majority of the steps adequately, but not all of them. All of the previous must be accompanied with explanations.

____(2 pts) Each student in the group can be seen performing the majority of the steps adequately, but not all of them. Also, the previous items are not accompanied with explanations.

____(0 pts) The entire group is not seen in the video.

____(2 pts possible) Uncertainty question (completed as a group, once per video)

____(2 pts) The students describe where the uncertainty of the balance lies and describe that external effects cause the readout to shift. A description of what steps can be taken to minimize this effect are also described.

____(1 pt) The students mention the uncertainty and its effect on the readout, but fail to offer explanation of why this happens.

____(0 pts) This question is not addressed in the video.

____(2 pts possible) Consistently using the same balance(completed as a group, once per video)

____(2 pts) The students mention that it is important to consistently used the same balance throughout an entire experiment and provide sufficient example to support their claim.

____(1 pt) The students mention that they should use the same balance through an experiment, but fail to explain why.

____(0 pts) This question is not addressed in the video.

____ (2 pts possible) Notebook:

____(2 pt) The notebook is clearly shown in the video and includes: a 'named' or labeled sample, data for initial and final masses, and all decimals given by the balance have been recorded.

____(1 pt) The notebook is shown in the video, but data for initial and final mass are not shown or all decimals given by the balance have not been recorded .

____(0 pts) The notebook is not shown at all in the video or is shown in a way that makes it difficult to determine what was recorded.

____ (4 pts possible) Usefulness:

____(4 pts) The video is an excellent resource and could be used in the future as a teaching tool.

____(2 pts) The video has limited use in the future due to significant errors in technique and/or description. It is evident that students had only a limited grasp of the concepts at hand.

____(0 pts) The video will have no future use and should not be used as a review of technique.

____ (20 pts possible) Overall Grade
(15 of 20 points required to earn extra credit)

Your video should be **5 minutes** or less. Videos between 5 and 7 minutes will earn a **4 point deduction**. Videos between 7 and 9 minutes will earn an **8 point deduction**. Videos longer than 9 minutes **will not be graded**.

Pipette Video Grading Rubric (20 total points):

Lab Group Members:_____

TAs: The video should fall into one category under each of the following headings. Choose the category you feel best describes the submitted video. Items that have and underlined require every piece mentioned in the item.

____ (2 pts possible) General video quality:

____(2 pts) The video was shot in a manner that allows for clear observation of measured values, all close ups of notebooks and meniscus allow the viewer to view the results, and explanations or definitions are audible.

____(1 pt)The students can all be seen performing the procedure (or the audio provides a reasonable description), but the video was not shot in a manner to allow the viewer to determine the accuracy of any measurements.

____(0 pts) The video does not allow for any determination of how the measurements were made.

____ (2 pts possible) Definitions of meniscus:
(Completed as a group, once per video.)

____(2 pts) The students describe what a meniscus is, why a meniscus occurs, how to read a volume (the bottom of the meniscus), and an example of a meniscus in their pipette (a detailed drawing may also be included).

____(1 pt) The students adequately describe how to read a meniscus but fail to provide an example (or the video is shot in a manner that does not allow the viewer to read it) or the students provide a visible example but lack a detailed definition.

____(0 pts) The meniscus is not mentioned in the video.

____ (2 pts possible) Definitions of Priming (cleaning) the Pipette (Note: the actual action doesn't need to be included in the video and explanation may be included as a group, once per video.)

____(2 pts) The students mention that the pipette was rinsed with water and solution 3x each before use.

____(1 pt) The students mention that the pipette needs to be cleaned prior to use but do not give details how.

____(0 pts) Priming is not mentioned in the video.

____ (8 pts possible) Technique:

____(8 pts) Each student in the group can be seen drawing up a volume, determining the initial volume, transferring from the pipette to the reaction vessel properly, and determining the final volume. All of the previous must be accompanied with explanations.

____(4 pts) Each student in the group can be seen drawing up a volume and transferring to the reaction vessel, but it is difficult to determine whether the students are determining the initial and final volumes. All of the previous must be accompanied with explanations.

____(2 pts) Each student in the group can be seen drawing up a volume and transferring to the reaction vessel, but it is difficult to determine whether the students are determining the initial and final volumes. Also, the previous items are not accompanied with explanations.

____(0 pts) The entire group is not seen in the video.

____ (2 pts possible) Notebook:

____(2 pts) The notebook is clearly shown in the video and includes: a 'named' or labeled sample, data for initial and final volumes, and all volume data is recorded to two decimal places.

____(1 pt) The notebook is shown in the video, but data for initial and final volume are not shown or the data is not recorded to two decimal places.

____(0 pts) The notebook is not shown at all in the video or is shown in a way that makes it difficult to determine what was recorded.

____ (4 pts possible) Usefulness:

____(4 pts) The video is an excellent resource and could be used in the future as a teaching tool.

____(2 pts) The video will be useful to those who made it in the future, but will likely not be used as a teaching tool.

____(0 pts) The video will have no future use and should not be used as a review of technique.

____ (20 pts possible) Overall Grade
(15 of 20 points required to earn extra credit)
Your video should be **5 minutes** or less. Videos between 5 and 7 minutes will earn a **4 point deduction**. Videos between 7 and 9 minutes will earn an **8 point deduction**. Videos longer than 9 minutes **will not be graded**.

Appendix III: Chemistry Video—Filming Guidelines

Consumer-level digital video cameras, digital still cameras, and phones have the capability to record video and audio at a quality to satisfy this assignment.

You want to make sure the device you choose has the following recording capability:

- Record for at least 3 minutes long at a take or shot
- Record video AND audio
- Can export the recording to a computer for basic editing

Workflow:

- Understand the lab assignment and write a brief script or outline of what you will say. Three minute time length.
- Rehearse your script.
- Make sure all your lab items are prepared and in reach
- Analyze your location for light and sound
- Set up the camera and do a run-through:
    - Can you see the presenter and the lab equipment clearly? Do they fill up most of the frame? If not, reframe the shot by moving in closer or zooming in.
    - Can you hear the presenter speaking? Play back your rehearsal recording and if you cannot hear, move the camera and internal microphone closer.
- Film the entire lab start to finish in a wide shot
- Re-shoot the elements of the lab that are most technical in close-up. When you edit, you can cut in these close up shots to point out the specific techniques you are describing.
- Export the footage to your computer and use editing software to cut a three-minute video from your footage. Most computers come loaded with Windows Moviemaker or Apple iMovie.
- Export you finished video and upload to YouTube
- Link your YouTube video to your class Blackboard Learn site

Composition

The goal of this assignment is to demonstrate your mastery of chemistry lab techniques. You need to make sure your work fills the frame of the video. If the camera is too far away, you and your work will be too small to assess for a grade. Use the compositional frame well and think about filling the space. **Always shoot so that your frame is horiontal (longest part of the rectangle is horizontal)!**

Your Widest Shot:

• The lab presenter occupies almost entire top to bottom of frame.
• Her arm and balance occupy almost entire length (left to right) of frame.
• You will shoot your entire lab start-to-Finish in this framing.

Close up Shots:

• For the more technical elements, shoot in close up. You can drop in these close-up shots in the editing.
• You will shoot these select close-ups after you have shot the entire lab in wide shot

You want to minimize your time editing, so make sure you have a start-to-finish take of your entire lab that can used as the main narrative of your finished video. You can cut away to a close-up shot to illustrate a certain point or cut way to a different take to hide a mistake or omission. You do not want to be in a position where you have to piece the lab together after the fact with bits and pieces of random shots.

Audio
The microphones on consumer cameras and phones are designed to be close. Try to shoot within conversational distance for clear audio (~3-5 feet). Listen to a rehearsal recording to make sure your audio is clear. If you are too far away, move closer. If the background noise is too loud or distracting, move to a quieter place or wait until the room is less crowded.

If your audio is not clear, you may have the option of recording a voiceover track separately which you can add in to your edited video. In your editing software, you will have the option to delete your audio track recorded in the lab and you can insert your new voiceover recording.

Lighting
Make sure your image is well-lit so that you can clearly see your presenter and the lab equipment. If you are in a dark or dim area, move to a brighter area. Do not shoot with a bright window behind you. You will look silhouetted because the camera cannot compensate for the bright sunlight coming in behind you. Film with the window behind you, or move to a more interior location in the room.

Steadiness
Holding a small camera or phone steady is difficult to do. If you do not have a tripod, use a stack of books to prop the camera up or brace your arm against a wall or table or even bending it to brace against your body to minimize camera motion.

Editing
Transfer your footage to a computer and open your video editing software (for many of you, Windows Moviemaker or iMovie). Select your best start to finish take and lay that clip down in your movie sequence. You can add your close up shots when appropriate: the rule of thumb is SEE and SAY. When the lab presenter SAYS something, you can cut to your close-up so that we can SEE it. When the presenter moves on to the next point, the close up shot can end. You do not need to fade or dissolve to and from these cuts.

Troubleshooting: If your recorded audio is unusable, you can separately edit the audio and video from your clips. You are able to keep your video track and delete the audio track. You can record a new audio voiceover track from your script, import it into the computer and lay it down under your video picture.

You are welcome to add text or fades to black at the beginning or end of the video, but do not exceed three minutes.

When you are done, you will export your video in one of the accepted YouTube formats (.mov, .wav., .mp4, for example) to prepare for upload.

Appendix IV: Appendix VII: Laboratory Practical Documents
Instructions to Teaching Assistants
Primary responsibilities:

- Ensure each station is prepped prior to each session (see supply list below)
- Observe student technique
- Collect student worksheets and grading rubrics to be graded

Students should sign up for a session on the sign-up sheet posted on the door after finishing their written final. Sessions will begin promptly every twenty minutes. During these 20 minutes students will need to get set-up, collect all data they feel is necessary, and complete all calculations. **ABSOLUTELY NO EXTRA TIME WILL BE GIVEN DURING ANY SESSION.** You will need to kick them out if they are not done.

Students are only allowed **(1)** a calculator and **(2)** a writing utensil with them at their station. Phones may not be used as calculators. Bookbags, notebooks, etc. should be left in the hallway, but if students do bring them in, please have them leave these under the whiteboard.

Each station should be given all of the following at the start of each session:

- Instructions with station number taped beside the balance
- Student worksheet
- Grading rubric (taped and folded)
- Labeled sample bottle
- Dry 50-mL beaker
- 2 dry 150-mL beakers
- Dry 100-mL graduated cylinder
- Dry 10-mL Mohr pipet
- Balance cleaning brush
- Weighing paper
- Paper Towels

Be sure to carefully keep time.

- Students should be given warning when there are 5 minutes and 2 minutes left in their session.
- Students should be given instructions to begin turning in their worksheets at the 2 minute warning.

Each proctor will have no less than 3 students to observe during each session. Use the provided rubric to assess student technique. The rubric should be easy enough to follow, but some things to keep in mind are:

- The entire practical is worth 35 points.
- The Technique Items (section 1) will be graded while students are in the lab. The Data Collection and Data Reporting Items will be graded by the section TAs once students have left.
- The first four rows of the grading rubric are redundant. Students who use a beaker or cylinder will lose 5 points automatically (line 1). Students who use the pipet should be graded based on lines 2-4.
- The correct number of decimal places (in Data Collection Items) should be graded based on the glassware they chose, whether it was correct or not. No double jeopardy, please.

DO NOT ACCEPT ANY PRACTICAL FROM A STUDENT WITHOUT CONFIRMING THE DATA THEY GRAPHED IS THEIR OWN!

Instructions to Students

Please sign up for a session on the sign-up sheet to the right of these instructions.

- Sessions will begin every twenty minutes, starting at the time indicated for each section in the chart below.
- During these 20 minutes you will need to get set-up, collect all data you feel is necessary, graph your results, and complete all calculations.
- You will be given a warning when five minutes are remaining for your session. At 2 minutes, you will be asked to begin cleaning and turning in your belongings.
- **NO NOTEBOOKS ARE ALLOWED IN THE PRACTICAL!**
- **ABSOLUTELY NO EXTRA TIME WILL BE GIVEN DURING ANY SESSION!**

Section (meeting time)	Session 1	Session 2	Session 3	Session 4	Session 5	Session 6
T3 (M 11:15)	12:15	12:35	12:55	1:15	1:35	1:55
5X (T 8:00)	9:00	9:20	9:40	10:00	10:20	10:40
J2 (T 11:00)	12:00	12:20	12:40	1:00	1:20	1:40
J3 (T 2:00)	3:00	3:20	3:40	4:00	4:20	4:40
N9 (T 5:00)	6:00	6:20	6:40	7:00	7:20	7:40
J7 (W 8:00)	9:00	9:20	9:40	10:00	10:20	10:40
7G (W 11:15)	12:15	12:35	12:55	1:15	1:35	1:55
2Q (W 2:30)	3:30	3:50	4:10	4:30	4:50	5:10
M2 (W 5:45)	6:45	7:05	7:25	7:45	8:05	8:25
Y3 (R 8:00)	9:00	9:20	9:40	10:00	10:20	10:40
M3 (R 11:00)	12:00	12:20	12:40	1:00	1:20	1:40
M4 (R 2:00)	3:00	3:20	3:40	4:00	4:20	4:40
Y6 (R 5:00)	6:00	6:20	6:40	7:00	7:20	7:40
P1 (F 8:00)	9:00	9:20	9:40	10:00	10:20	10:40
P5 (F 11:15)	12:15	12:35	12:55	1:15	1:35	1:55
P3 (F 2:30)	3:30	3:50	4:10	4:30	4:50	5:10

You are only allowed **(1)** a calculator and **(2)** a writing utensil at your station.

Please do not bring anything else in the room with you, including your notebook or your phone. Phones may not be used as calculators and the time will be kept for you. Computers with graphing software will be provided. Please leave all items other than your calculator and writing utensil in the hallway.

No instruction will be given once you are in the room. Also, please be advised that proctors will not answer any questions during this practical. Follow the procedure below:

- Review your notebook pages regarding finding the density of a solution as well as the technique videos you created during the semester prior to your session. Please note that graphing software will be set up for you, so you will not need to know how to create the graph.
- Proceed directly to your assigned station and write your name on both the student worksheet and the grading rubric. **Do not begin data collection until you have given the proctor for your station the grading rubric.**
- Collect data to answer the problem given to you on the student worksheet.
- Complete all calculations on the student worksheet.
- Graph your results on one of the provided computers.
- Clean your station and turn in your worksheet to your proctor.

Name:_____ Station Number_____
Lab Section:_____

		Always	Sometimes	Never
	TECHNICAL ITEMS			
	The student uses the Mohr pipet.	5		0
	The student avoids pipetting directly from the bottle.	1	0.5	0
	The student reads the pipet at eye level.	2	1	0
	The student stops draining the pipet with the meniscus in the graduations.	2	1	0
	Indicate choice of glassware if not pipet:			
	The student avoids returning excess reagent to the bottle and disposes of it properly.	1	0.5	0
	The student tares the balance before adding the weighing vessel.	2	1	0
	The student uses an empty weighing vessel that fits inside the balance.	2	1	0
	The student closes the balance doors when obtaining the mass (student should not lose points if there are not doors to close).	2	1	0
	The student waits for the balance to equilibrate before recording the mass.	1	0.5	0
	The student removes the weighing vessel from the balance to add sample.	2	1	0
	The student maintains a clean workspace.	2		0
	DATA COLLECTION ITEMS			
	The student records volume data to the correct number of decimal places for their glassware.	2	1	0
	The student records all of the digits presented on the balance	2	1	0
	The student uses the mass by difference method	2	1	0
	SAFETY			
	The student has taken appropriate safety precautions (goggles, pants, shoes, etc)	**3 - Wore goggles and had on pants and proper shoes**	**2 - Wore goggles but had on shorts a/o sandals**	**0 - didn't wear goggles and wore shorts a/o sandals**
	DATA REPORTING ITEMS	**3 points**	**2 points**	**1 points**
	The student's average was within the following range:	**10%**	**15%**	**20-40%**
	The student's standard deviation was **X%** of their average:	**10%**	**20%**	**30-50%**
	The student's R^2 value was within the following range:	**>0.95**	**0.90-.0949**	**0.85-0.899**

Proctor:_____

Name_____ Lab section_____

Date_____ Station number_____

Determine the density of the provided solution using the MOST ACCURATE piece of glassware.
Refer to the instructions taped around your station if you need guidance. Complete all data collection and calculations on this sheet. You may use the back of this page if necessary. BE SURE TO CLEARLY LABEL DATA AND CALCULATIONS SO YOUR WORKSHEET WILL BE EASY TO GRADE!

Bottle ID_____ Density with precision (include units)_____

Best fit equation_____ R^2 value_____

Your instructor must verify that the data you graphed matches the data on this worksheet! Do not leave a computer without having your instructor initial that the data above has not been falsified.

Brief instructions and helpful tips

Station 1

Choose the piece of glassware the gives the most accurate results.

Collect data that will allow you to calculate the density of the provided solution.

Organize your data in a manner that the proctor can easily grade.

Record data to the proper number of significant figures.

Graph your results on one of the provided computers.

Record the results (including a rough sketch of your graph) on your worksheet.

Turn in your assignment and exit the room quietly.

Brief instructions and helpful tips

Station 2

Choose the piece of glassware the gives the most accurate results.

Collect data that will allow you to calculate the density of the provided solution.

Organize your data in a manner that the proctor can easily grade.

Record data to the proper number of significant figures.

Graph your results on one of the provided computers.

Record the results (including a rough sketch of your graph) on your worksheet.

Turn in your assignment and exit the room quietly.

Appendix V: Student response data for the pre-test, post-test, final examination, and laboratory practical (McNemar's Chi Square).

Table 2. Counts were used in 2x2 contingency tables for within group analysis (McNemar's $\chi 2$ values and Odds Ratios (OR)) to determine differences in student performance on the various test items.

	Pipet (N=233)	**Balance (N=276)**
Pre and post right (Yes/Yes)	82	91
Pre right, post wrong (Yes/No)	19	37
Pre wrong, post right (No/Yes)	88	96
Pre and post wrong (No/No)	44	52
McNemar's χ^2 (OR)	**43.2 (4.6)**	**25.3 (2.6)**
Pre and final right (Yes/Yes)	91	116
Pre right, final wrong (Yes/No)	10	12
Pre wrong, final right (No/Yes)	111	118
Pre and final wrong (No/No)	21	30
McNemar's χ^2 (OR)	**82.6 (11.1)**	**84.8 (9.8)**
Post and final right (Yes/Yes)	150	165
Post right, final wrong (Yes/No)	20	22
Post wrong, final right (No/Yes)	52	69
Post and final wrong (No/No)	11	20
McNemar's χ^2 (OR)	**13.3 (2.6)**	**23.3 (3.1)**
Pre and practical right (Yes/Yes)	66	49
Pre right, practical wrong (Yes/No)	35	79
Pre wrong, practical right (No/Yes)	87	45
Pre and practical wrong (No/No)	45	103
McNemar's χ^2 (OR)	**21.3 (2.5)**	**8.8 (0.6)**
Practical and final right (Yes/Yes)	141	90
Pract right, final wrong (Yes/No)	12	4
Pract wrong, final right (No/Yes)	61	144
Pract and final wrong (No/No)	19	38
McNemar's χ^2 (OR)	**31.6 (5.1)**	**130.5 (36.0)**

Appendix VI: Student response data for the pre-test, post-test, final examination, and laboratory practical (Chi Square).

Table 3. Student response data for the pre-test, post-test, and final examination, presented in both counts and percentages (listed in parentheses). This data was used for between group analysis (χ^2 values) to determine differences in student performance on the various test items.

Table 1a. Student Response Data for the Pre-test			
	2 Decimal Places # of students (%)	**+1 Graduations** # of students (%)	**Any other response** # of students (%)
Control (Balance)	97 (35.1)	30 (10.8)	149 (54.0)
Treat (Pipet)	76 (32.6)	27 (11.6)	130 (55.8)
χ^2 = 0.605 (*p*=0.739)			
Table 1b. Student Response Data for the Post-test			
	Correct SF, Correct Vol # of students (%)	**Correct SF, Inc Vol** # of students (%)	**Any other response** # of students (%)
Control (Balance)	135 (48.9)	50 (18.1)	91 (33.0)
Treat (Pipet)	114 (48.9)	56 (24.0)	63 (27.0)
χ^2 = 3.285 (*p*=0.193)			
Table 1c. Student Response Data for the Final Examination			
	Correct SF, Correct Vol # of students (%)	**Correct SF, Inc Vol** # of students (%)	**Any other response** # of students (%)
Control (Balance)	199 (72.1)	36 (13.0)	41 (14.9)
Treat (Pipet)	189 (81.1)	14 (6.0)	30 (12.9)
χ^2 = 9.781 (*p*=0.008)			

Figure 1. Comparison of pre-test responses between the experimental and treatment groups.

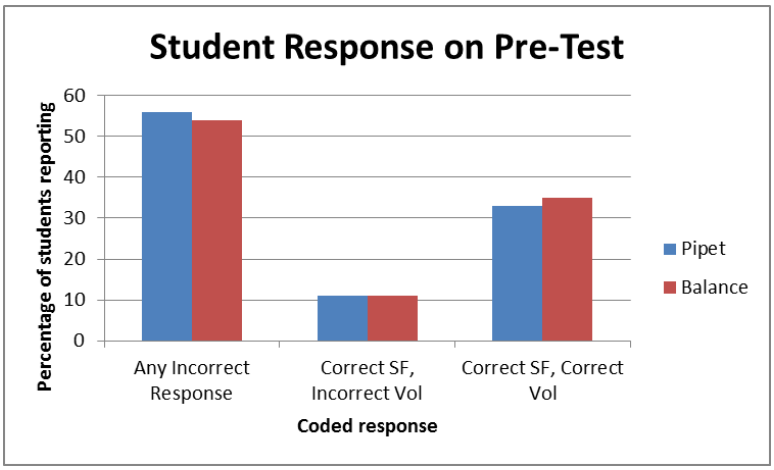


Figure 2. Comparison of post-test responses between the pipet and balance groups.

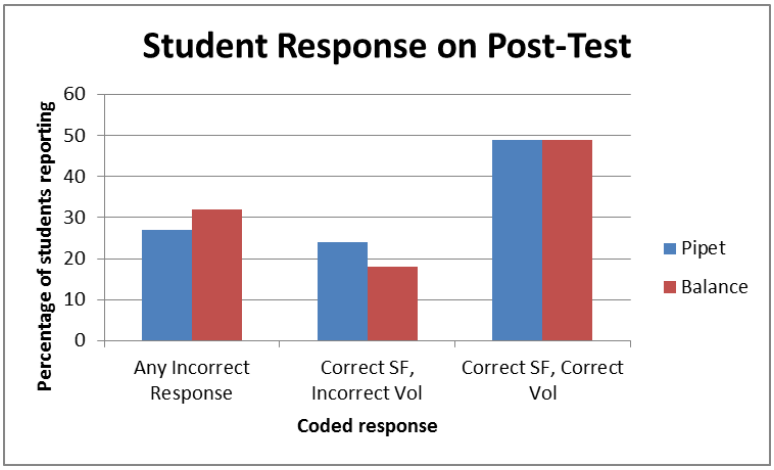
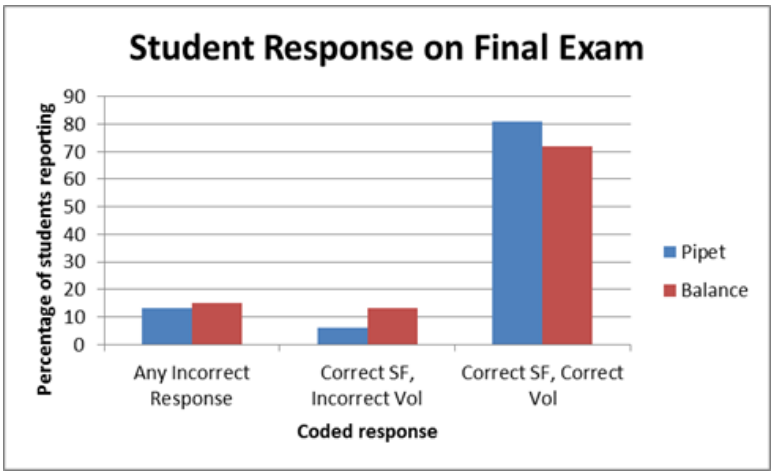


Figure 3. Comparison of final exam responses between the pipet and balance groups.



Appendix VII: Comparison of practical exam performance.

Table 4. Practical exam data was made through direct observation by trained proctors and by review of student data worksheets.

	Used the pipet and reported correct SF # of students (%)	**Used the pipet but reported incorrect SF** # of students (%)	**Used any other glassware** # of students (%)
Pipet Group	156 (67)	56 (24)	21 (9)
Balance Group	94 (34)	113 (41)	69 (25)
χ^2=34.773 (p<0.001)			

Figure 4.. Comparison of practical responses between the experimental and treatment groups.