Chemistry Education Research and Practice

Chemistry Education Research and Practice RSCPublishing

ARTICLE

Cite this: DOI: 10.1039/x0xx00000x
Received 00th January 2012,
Accepted 00th January 2012
DOI: 10.1039/x0xx00000x
www.rsc.org/

Video Reports as a Novel Alternate Assessment in the Undergraduate Chemistry Laboratory

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The increased use of video capable cellular phones to document everyday life presents educators with an exciting opportunity to extend this capability into the introductory laboratory. The study assessed whether students enrolled in a southeastern U.S. university's first-year laboratory course retained technical information at a higher rate after creating a technique video. These videos were created on hand-held video capable devices that students owned prior to enrolling in the course, eliminating additional cost to students. Pre-/post-test analysis (N=509) was performed to determine short- and long-term learning gains regarding reporting the volume of graduated glassware to the proper number of significant figures. Though both groups used various graduated glassware throughout the term, chi-square analysis showed that students who created a video detailing use of a Mohr pipet reported the volume of graduated glassware correctly on the final exam and laboratory practical at a significantly higher rate than those students who received only verbal instruction on the technique.

Introduction

Laboratory instruction has been considered an essential component of chemistry instruction since 1927 (DeMeo, 2001). The goals for general chemistry laboratory courses are generally a balance between training students in proper laboratory techniques and the development of research (critical thinking) skills (Lloyd, 1992). Even courses that are focused on critical thinking skills require students to take measurements in order to collect data that will allow them to draw accurate conclusions. While proper technique is implied and often demonstrated in these approaches, there is opportunity for error to be introduced the first time a student performs a technique.

The explosion of social media in the past 5 years including Facebook, YouTube, and Twitter, along with the development of personal electronic devices, has resulted in a generation that has new and different technology available for use in their own learning than previous generations. Personal phones are widely popular and a large number of devices are manufactured and purchased annually (Global Mobile Statistics, 2013). Williams and Pence propose that the use of cellular phones or portable devices will impact chemical education (and society) in greater ways than the introduction of the personal computer (Williams & Pence, 2011). Additionally, the Horizon Report, an annual report that summarizes research and discussion on current issues in technology and education from publications and the internet, recognized cellular phones as an emerging technology for teaching and learning because of these wide ranging capabilities including video capture and data transfer. (Johnson *et al.*, 2011).

A survey of currently available cellular phones shows that even the most low-tech of these devices is capable of capturing video. This video can be transferred as a data file by either docking the phone with a computer, accessing an internal memory card, or through wireless data transfer. For those students who do not own an adequate phone or have difficulty transferring data from its storage device, inexpensive point and shoot cameras are an easy and readily available option. Our institution offers students video equipment on short-term loan, though no student in the study took advantage of this opportunity.

Technology has long been a part of the chemistry laboratory curriculum (March *et al.*, 2000; Winberg & Berg, 2007). Specifically, video technology has been used for everything from training (Pantaleo, 1975) and demonstrations (Fortman & Battino, 1990) to self-reflection (Veal *et al.*, 2009). Videos have been used extensively for in-laboratory instruction for a variety of chemistry courses, including upper level courses in physical (Rouda, 1973) and analytical chemistry (Williams, 1989). Searches through YouTube's internal search engine for standard laboratory techniques result in a number of useful tutorial videos (MIT, 2013; ChemLab, 2013). These videos are largely instructor/institution produced, with little to no student involvement. Instructor-produced pre-laboratory videos are a valuable asset in the classroom and have been shown to improve laboratory techniques and retention of information (DeMeo, 2001).

Despite this literature demonstrating the effectiveness of instructor-generated videos as a teaching and learning tool, the chemical education literature provides only a few descriptions of student-generated videos. Initial studies involving multimedia laboratory reports indicate that students are willing to report their results via less conventional means (Jenkinson & Fraiman, 1999). Student-authored videos on biochemistry topics were used in a second year undergraduate course to engage students in their own learning (Ryan, 2013). This study found that the students were more engaged in their own learning, perceived deeper learning, and enjoyed working in groups. Lancaster describes the effectiveness of student authored vignettes where students use Camtasia Studio to prepare short review presentations on topics required on a final examination (Lancaster, 2014). Passing marks suggest a positive relationship between the introduction of the vignettes and the passing rate. A conference paper describes how student-generated videos allow the instructor to identify student's knowledge gaps and misconceptions (Niemczik *et al*, 2013). An additional paper shows that having teachers (as students in a professional development program) prepare videos improves their self-efficacy (Blonder *et al*, 2013). These results are consistent with observations in disciplines outside of chemistry (Hirschel *et al.*, 2012; McCullagh, 2012) where the impact of the video is increased when the student reviews themselves performing the task. Thus, student-created videos have been shown to have positive effects on student learning, but none of these studies have focused on laboratory techniques or instruction.

Context and Rationale for This Study

Students' ability to correctly report significant figures when reading a meniscus has traditionally been poor at the authors' institution. Analysis of laboratory final exams collected over a number of semesters indicate that students have difficulty understanding the need to estimate between the graduations (only 30% of students report the volume using the proper significant figures on final examinations). The frequent use of laboratory glassware that requires such a skill offered an opportunity to relate a laboratory technique with the creation of technique videos. Moreover, these videos could be created alongside laboratory activities that were already a part of the curriculum. The introductory exercise in our laboratory sequence requires students to develop an experimental procedure to determine the density of an unknown liquid (guidelines are provided and the instructor demonstrates the use of the equipment, but a detailed step-by-step procedure is not presented to students). The expected procedure requires the transfer of the liquid using glassware that has graduated volumetric marks and a mass measurement using an electronic balance. The glassware provided includes a 10-mL Mohr pipet, a 100-mL graduated cylinder, and a beaker. Class data and discussion of standard deviation and error analysis is expected to lead students to select the pipet when transferring small volumes of liquid. Because of this, the proper use of the Mohr pipet was chosen as the first video topic.

The Research Question

The work presented in this paper seeks to determine whether the data support the hypothesis that students who create a video detailing the proper use of a Mohr pipet as part of a laboratory exercise report a volume accurately and to the correct number of significant figures more frequently than students who complete the same laboratory exercise without preparing the pipet video (having prepared a video on using a balance instead).

Methods

To answer the research question, we integrated the creation of videos into the existing laboratory curriculum and used a pre-/post-test research design to analyze how students reported the significant figures associated with reading a volume. Assessment items were included on written quizzes or exams and direct observation made during a laboratory practical. All students enrolled in the course participated in the study. Informed consent was explained to all participants, though signed forms were not collected in an effort to maintain anonymity. Students were assigned to either the balance video (control) group or pipet video (experimental) group based on lab section. Test items and observation rubrics were collected and coded and statistical analysis was performed.

Formative Surveys

A formative survey was developed to identify possible barriers to implementing a video requirement in the laboratory. All students enrolled in the introductory course during the summer 2011, fall 2011 and spring 2012 semesters were asked to complete a formative survey related to the availability of video cameras and their perceived self-efficacy with video capture, editing, and transferring (N=799). Students completing the formative survey are not included in the current study because we did not wish to place a graded requirement in the syllabus that could not be completed by a significant number of students. These surveys were collected after informed consent was given. Students were also asked to indicate their preference for video assignments over more traditional assignments (written reports, exams, etc.). The results of these surveys indicated that the students were willing and able to prepare videos as part of the course requirements. Survey items and results can be found in the supplementary information. (see Appendix I)

Subjects

Data were collected in the fall 2012 semester at a public university in the southeastern United States. All students in the study were enrolled in the first part of a two-term introductory chemistry laboratory sequence. The majority of students (95%) enrolled were STEM or pre-health majors. The course is a stand-alone laboratory course requiring students to master both conceptual and technical items. Students are not required to be co-registered in a lecture course, but most (98%) are co-registered for or have completed the corresponding first semester lecture. Students were instructed to prepare for the laboratory activities by reviewing a laboratory manual custom-published by the authors (March, 2012) and by reviewing texts and online resources associated with a list of suggested topics. The laboratory met for a three-hour block once-a-week twelve weeks of a fifteen-week semester[†]. In the fall of 2012, 16 sections were offered with an initial enrollment of 619 students (5.5% of the university student body). Each section has 39:2 student to instructor ratio. All sections were led by at least one graduate teaching assistant, and occasionally upper-level undergraduate students who had performed exceptionally well in the laboratory were assigned to assist as the second instructor. Only those students completing all components of the study (pre-test, post-test, written final exam, and laboratory practical exam) were included in the final analysis. Of the 619 students initially enrolled, 509 were present for all four of these testing periods.

Both the control and experimental groups created a video during the same week of the study during their scheduled laboratory period, but the technique chosen to be described differed between the groups. The videos were not stand-alone assignments, and both of the video topics chosen were necessary to complete the laboratory assignment for the week. Despite the creation of the video, students in both groups were expected to use the equipment the same number of times throughout the semseter. The 16 sections offered in fall 2012 were divided into two groups; 9 sections were in the control group (N=276) which created an analytical balance video and 7 sections were in the treatment group (N=233) which created a

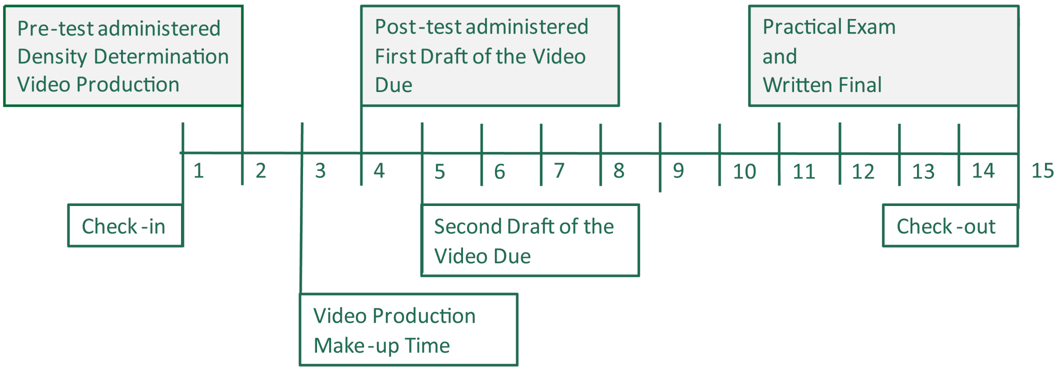


Figure 1. Project timeline. The 15-week fall 2012 semester indicating key events relative to the project.

Mohr pipet video. Group assignments were made on the basis of the day/time that the laboratory section met, so students were not able to choose the content of the video they recorded. Assigning treatment/control on the basis of the day/time of the week resulted in some teaching assistants leading both groups.

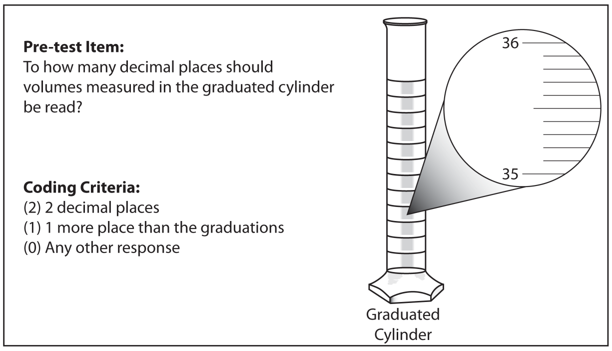
Video Production and Submission

Detailed grading rubrics, video recording, and editing tutorials were provided to students via the course management website at the start of the term (see Appendices II and III). Students were instructed to review these materials as their pre-laboratory assignment in the week prior to video production. Student groups created videos in parallel to a standard laboratory exercise, and the creation of the video was presented to students as a complementary activity to the standard laboratory assignment. The laboratory exercise required students to determine the density of an aqueous solution using an analytical balance and volumetric glassware; including a Mohr pipet. The assignment offered an equipment list to students but did not give them explicit instruction on determining the density. Videos were recorded in groups of 3-4 students. Though formation of laboratory groups is at the discretion of the TAs, the majority of students are allowed to choose their laboratory partners. Each student had to perform the technique and it had to be obvious that each student was present in the video (*i.e.*, simply showing the students' hand was not sufficient). Make-up periods were provided in the event that students later realized they needed additional footage. Editing requirements were minimal, but time limits were placed on the video both to avoid lengthy segments where students are simply standing around and to limit the amount of time teaching assistants spent grading videos. Students were instructed to perform any edits outside of class time, and they had two weeks to edit the first version of their video.(Figure 1)

Students published their videos to YouTube. Students that did not wish to make their video public were instructed to choose YouTube's 'unlisted' option, which allows the video to be published but only those individuals with a link directly to the videos are able to view it. We did accommodate a student that was concerned with privacy issues by viewing the video from a personal laptop during office hours. YouTube was selected as a submission platform because it converts a large number of file types to a player that our teaching assistants were familiar with and offers help with file types and uploading. Thus, teaching assistants did not have to learn how to use multiple video players. Videos were graded by one of the section's teaching assistants the week after submission. Feedback was provided to the students during the next laboratory meeting via a scored rubric. Students submitting a video with gross technical errors received a rubric with additional written comments from their TA and were encouraged to edit their video, reshooting if necessary, and to submit it for re-grading.

Test Items

A pre-test was administered as a single item (Box 1) on a five-question pre-laboratory quiz during week 2, the week that the pipet was used for the first time (Figure 1). Students were provided information in the laboratory manual related to the meniscus, graduations, and estimation, but the quiz was administered prior to the pre-laboratory lecture or demonstration. Students were given 10 minutes to complete the quiz.



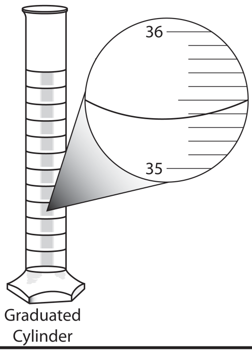
Box 1. Pre-test item and coding criteria.

Two post-tests were administered to measure short- and long-term learning gains. The short-term post-test was given in week 4 (two weeks after treatment). The post-test item was included as a single item on a multi-item pre-laboratory activity quiz (Box 2, Post-test Item). Again, students were given 10 minutes to complete the entire quiz. Longer-term gains were measured as a single item on the written final exam (Box 2, Final Examination Item) and direct observation as part of a laboratory practical exam in week 15 (thirteen weeks after treatment). Students were instructed to review both the laboratory manual and their notes to prepare for both the written exam and practical exam. All students completed the written exam prior to starting the practical exam.

Post-test Item:
Report the volume from the cylinder.

Final Examination Item:
Use the drawing to the right to determine the volume contained in the graduated cylinder.

Coding Criteria:
(2) 2 decimal places and the correct volume
(1) 2 decimal places but the incorrect volume
(0) Any other response



Box 2. Post-test and final exam items and coding criteria. The same image was presented for both prompts.

For the laboratory practical exam, students were instructed that they would need to determine the density of a solution and provide data concerning both the accuracy and precision of their measurements. They were not allowed to bring their notebook or other notes. Stations were set up to mimic the week 2 density determination activity and included a balance, a 10-mL Mohr pipet, a 100-mL graduated cylinder, and beakers. Each laboratory section had outside proctors (also known as supervisors or monitors), who had been trained to monitor technique through a series of training videos. Proctors were not placed in observation positions until their scores on training videos met calibrated scores established by three different instructors. Proctors were assigned to laboratory sections, but were not told which video the students had prepared. These proctors used a rubric to monitor whether students chose to use the Mohr pipet and whether they used whatever glassware they chose and the balance correctly. Students were given a worksheet on which they recorded data and performed calculations. Proper use of significant figures was based on the data recorded on the student worksheet and the observation of the proctors. All laboratory practical exam materials can be found in Appendix IV of the supplementary information.

Data Collection and Analysis

Written quizzes and the written final exam were administered and collected by the teaching assistants for the individual laboratory sections. Materials were scanned into PDF form by the teaching assistants and sent to the authors before being graded. Electronic copies of all test items were stored in a password protected folder. Each student was given an alphanumeric code so that individual student progress could be followed. Student data presented here was collected under the guidance of the University's Institutional Review Board for Human Use (Erdmann, 2011).

For the pre- and post-test, each response was coded using a 2/1/0 score. As the task required in the pre- and post-test items differed slightly, the skills required in each item were classified according to a revised Bloom's Taxonomy domains: (2) Remember and Apply/Analyze, (1) Remember, and (0) Incorrect (other responses) (Anderson et al, 2001; Krathwohl, 2002). As part of the practical, selecting the most accurate glassware (the Mohr pipet) and reporting the proper number of significant figures was scored as (2) used the pipet and recorded the volume to 2 decimal places or (1) used the pipet recorded the volume incorrectly (incorrect number of significant figures or the beginning/final meniscus was outside the graduation marks) or (0) used the incorrect glassware.

Each student enrolled in the course was expected to spend similar time on task and as such both the control and experimental groups were expected to show improvement in reporting the proper number of significant figures. Thus, McNemar's chi square and odds ratios were calculated within each group to evaluate any differences in performance within the groups. This statistic is commonly used in pre-/post-test design to compare and determine significance between the number of students whose scores have increased, decreased or remained the same (Elliott & Woodward, 2007). Between groups analysis was analyzed using chi-square (χ^2) determinations between the pre-/post-test, pre-test/written final exam, and post-test/written final exam. The chi-square statistic was selected since this statistic uses the frequency data from a sample to evaluate the relationship between the variables in a population and is the one of the most common nonparametric statistical values (Gravetter & Wallnau, 2009). Chi-square calculations were performed using a 3x2 contingency table to assess whether the increase in number of students that use the pipet and record the proper number of significant figures was different between the groups as a result of the treatment. Due to the size of the data pool and the degrees of freedom, minimal requirements for all cells of the contingency tables were met and the correction for continuity was not necessary and thus ignored. Statistical analyses were conducted using the Statistical Package for the Social Sciences (SPSS version 20 for Windows). Tabulated statistical data can be found in the Supplementary Information (see Appendices V, VI, and VII).

Key points regarding data collection along the semester are presented in the timeline shown in Figure 1. During week 2, the pre-test was administered prior to all students filming videos detailing the use of either a Mohr pipet or an analytical balance. The post-test was administered during week 4, after students had edited and submitted the first draft of their videos. The longitudinal post-test data point (the written final exam) was administered the last week of the semester (week 15) along with the practical examination.

Of the 10 labs performed during the course, 8 of them required estimating the last decimal place when reading a volume. Mohr pipets were used to transfer solutions 3 of the 10 weeks, but students also used burets (2 of 10 weeks) or graduated cylinders (at least 5 of 10 weeks) throughout the course. Teaching assistants demonstrated the proper use of each piece of glassware at least once during the term, though the rigor in the presentation admittedly varied among TAs. The large sample size is expected to address this variable treatment.

Results and Discussion

Between group analysis of the pre-test results from the balance/pipet groups show that there is no significant difference (χ^2=0.6051, p=0.739) in prior knowledge of volume measurements or significant figures between the two groups, and corrections for *a priori* knowledge were not performed. As both groups performed identical tasks throughout the semester, it is not surprising that within group analysis indicate that both groups showed improved performance on the post-test and the final exam. The post-test odds ratios (OR) (Table 1) indicate that the preparation of the pipet video does have some influence on the experimental group's performance even though the percent correct is similar. Students who created a pipet video were 4.6-fold more likely (McNemar's χ^2=43.2) to increase their performance between the pre-test and post-test while students who created a balance video are only 2.6-fold more likely (McNemar's χ^2=25.3). It is important to note that the difference between the two ORs does not indicate the magnitude of this influence (*i.e.*, it is not a doubling effect).

The influence of the pipet video is tempered between the post-test and the written final examination (OR=2.6, McNemar's χ^2=13.3 (pipet) and OR=3.1, McNemar's χ^2=23.3 (balance)). These odds ratios indicate that the number of students providing correct answers increased for both groups by the end of the semester. This observation is not unexpected since both groups used graduated glassware throughout the semester.

Study Period	Statistical Test	Pipet Group (N=233)	Balance Group (N=276)
Pre-test to Post-test	McNemar's χ^2	43.2	25.3
	Odds Ratio	4.6	2.6
Pre-test to Final	McNemar's χ^2	82.6	84.8
	Odds Ratio	11.1	9.8
Post-test to Final	McNemar's χ^2	13.3	23.3
	Odds Ratio	2.6	3.1
Pre-test to Practical	McNemar's χ^2	21.3	8.8
	Odds Ratio	2.5	0.6
Final to Practical	McNemar's χ^2	31.6	*130.5*
	Odds Ratio	5.1	*36.0*

Table 1. McNemar's Chi Square analysis within groups for the Pre-, Post- and Final Examination data points. All probabilities are statistically significant at the 99% confidence interval (p<0.01).

Figure 2 shows the number of students who were able to improve their performance from an incorrect to a correct answer between the pretest and subsequent tests (*i.e.*, the number of students who fell into the 'no/yes' category in the McNemar's chi-square table).

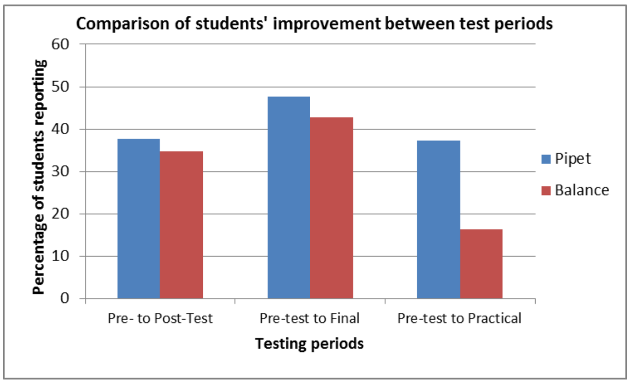


Figure 2. The number of students who answered incorrectly on the pretest but correctly on a subsequent test. All results are statistically significant, but the increase in correct answers between the pre-test and practical are particularly striking.

Between group analyses of short-term learning gains showed that creation of a technique video had a marginal effect on student performance on the post-test. The χ^2 statistic of 3.29 (p=0.193) implies that there is a little over an 80% chance that the videos led to an increase in student performance on the post-test. However, given that this assessment method appeals to a group of learners that is often overlooked in the chemistry laboratory environment (i.e., bodily/kinesthetic learners) (Gardner, 1983), the positive correlation between assessment and learning gains provides opportunities for further studies that include learning style preferences as another variable.

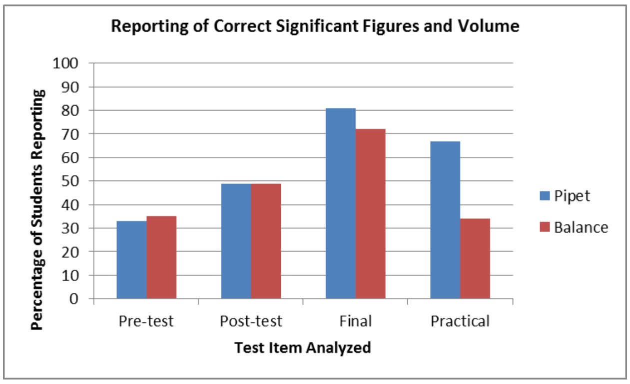


Figure 3. Comparison of student performance on all of the test items analyzed. Statistically significant differences are starred. Particular attention should be paid to the results of the practical.

Additional between group analyses show that the pipet group answered the assessment item correctly on the written final exam at a higher rate the balance group (81% versus 72%, χ^2=9.78, p=0.008). Though this finding is encouraging, the performance on the laboratory practical exam is the important observation. The item on the written final exam was similar to the post-test item, so responses on the written final exam could be influenced by the availability of the graded quiz as a study guide. During the practical exam, students in the pipet group used a Mohr pipet to transfer the solution at a higher rate (91%) than those students in the balance group (75%) (χ^2=50.53, p<0.001). Thus, though both groups spent the same amount of time using the pipet earlier in the term to determine the density, those students that made a pipet video selected the intended piece of glassware at a significantly higher rate. Additionally, students who used the Mohr pipet for volume determination also reported the correct significant digits at a much higher rate in the pipet group (74%) than the balance group (46%) (χ^2=34.77, p<0.001), indicating that creation of the video leads to an increase in proper application of the techniques the video details.

In addition to the data collected regarding significant figures related to volume, items were included on the pre- and post-tests probing students' familiarity with the significant figures associated with the analytical balance. As with the volume data, no differences in *a priori* knowledge were found between the groups. Additionally, there was no significant difference in growth between the groups on items related to using an analytical balance, which is likely attributed to the fact that the balances in question do not require estimation on the students' part as the mass readout is digital.

Though the majority of student groups submitting videos were able to successfully demonstrate proper technique with their initial submission, a potential limitation of the results lies in requiring these groups to re-shoot their videos or portions of video when gross technical errors were observed. The collection of this additional footage requires additional practice with the pipet that students in the control (balance) group would not have performed and time on task between the groups is not equivalent. The improved performance on the practical may be attributed to the instructor's feedback and student corrective action, and not simply from making the video. However, asynchronous monitoring is not possible without the video, so this corrective action would likely not ever have occurred. Thus, there could be an indirect benefit from the video preparation.

Implications for Practice

The results of this study can be useful in many classroom situations. Using student-created videos offers an improved method for monitoring student technique by moving from a synchronous to an asynchronous evaluation model, and has uses in large-enrolment courses and distance-learning environments.

Student-created video assessments offer instructors the ability to observe technique and offer critique asynchronously, thus ensuring that the instructor can observe and provide feedback to all students in the laboratory. Jones *et al* state that feedback can be seen as 'the end of a cycle of learning and the beginning of the next" and describe a method of assessment using screen capture digital video to provide feedback (Jones *et al.*, 2012). In this method, students receive instructor feedback on their assignments via short screen capture videos created by the instructor. Thus, videos could be potentially useful in large enrolment laboratory courses, with the additional benefit of requiring equipment that the student already owns and software that can be obtained free of charge.

Many laboratory course designs require students to perform tasks in small groups. One potential problem in any such cooperative learning setting is that of the 'hitch hiker', or the individuals who defer to the 'good' student to complete the work (Cooper, 1995). In the laboratory, this hitch hiker problem often leads to the most technically astute member of the group taking responsibility for the majority of the data collection. Ensuring student involvement and equal participation among all group members in the laboratory is difficult due to the extent of the observation of the group required. This difficulty is exacerbated when graduate teaching assistants are responsible since they have limited experience with classroom management. The use of video could potentially be used to address the "hitch hiker" issue. Requiring all students to be seen in the video requires a minimum level of participation that is often difficult to monitor in a normal classroom environment.

An exciting potential application of student-created videos is in the distance-learning laboratory course setting. At the author's institution and others, enrolment is ever increasing while infrastructure remains largely unchanged. This phenomenon has led a number of institutions to increase their offerings of online courses (Phipps, 2013). Despite these growing pains, the contentious issue of the laboratory experience remains one of the largest obstacles to implementing online chemistry courses (Pienta, 2013). Safety, expense, retention and academic rigor further complicate the online laboratory course environment (Casanova *et al*, 2006; Hoole and Sithambaresan, 2003; Patterson, 2000; Boschmann, 2003). Provided safety precautions are in place, video reports may have value in distance learning environments where the instructor is not physically present, as they provide an active learning method of assessment. Instructors of these courses could ensure that off campus students are performing their own experiments by requiring them to create videos of themselves safely performing laboratory activities. In this model, the student-created video would be used for more than just analysing technique, it would be used to ensure students are individually performing their tasks. In this way instructors could monitor that the technical aspect of the laboratory experience is met. The author's data, specifically the high chi squared value associated with the application of technique, imply that creating a video could lead to increased retention and more meaningful learning in the online laboratory setting, thus alleviating some of the academic rigor concerns.

This study also allows us to consider the development of a list of techniques that could be included in a student's personal electronic library for use in other laboratory courses or in the research laboratory. These techniques could be as simple as the proper use of a piece of glassware or much more technical, such as the use of a HPLC. A number of techniques and instruments are common across scientific fields, and these videos on these techniques could be retrieved from the student's e-portfolio when needed.

Conclusions

Student-created technique videos were successfully integrated into the general chemistry laboratory curriculum as an alternate assessment. Formative surveys indicate that students are able to create and edit videos with little difficulty. Though the project required additional training of teaching assistants and the occasional need to address the hitch hiker problem (Cooper, 1995), the videos proved to be a worthwhile addition to the laboratory course. The short- and long-term measurements indicate an increase in students' ability to correctly report a volume to the correct number of significant figures after having prepared a video describing the proper technique. These results suggest that instructors can consider the use of video laboratory reports to improve retention of proper laboratory technique. Further studies should probe whether the important step in the learning gain is the preparation of the video or the process of reviewing oneself in the video after its preparation.

Acknowledgements

The authors would like to acknowledge Michele Foreman for the excellent video tutorials that she created for this project and Dr. Julia Austin for graciously agreeing to review this paper. Special thanks also go out to the teaching assistants of the course for their patience and assistance during the course of the study.

Notes and References

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† Laboratory courses met only during the 5 day weeks of the semester. Students were not asked to meet during holiday weeks or during the week of final exams.

Electronic Supplementary Information (ESI) available: Survey results, statistical information, grading rubrics and the Chemistry video shooting guide are available in the supplementary information.

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Appendices

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 <u>and</u> 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, <u>and</u> 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), <u>and</u> 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) <u>or</u> 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) <u>Each</u> student in the group can be seen drawing up a volume, determining the initial volume, transferring from the pipette to the reaction vessel properly, <u>and</u> 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, <u>and</u> 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 <u>or</u> the data is not recorded to two decimal places.

____(0 pts) The notebook is not shown at all in the video <u>or</u> 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	[redacted]	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	[redacted]	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.

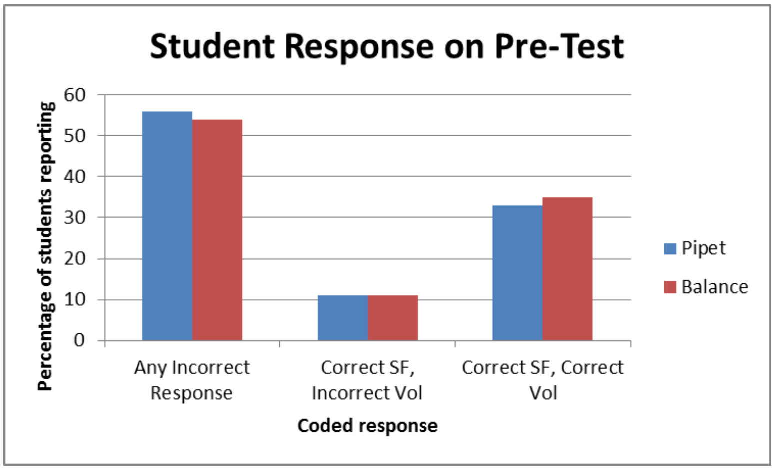


Figure 2. Comparison of post-test responses between the pipet and balance groups.

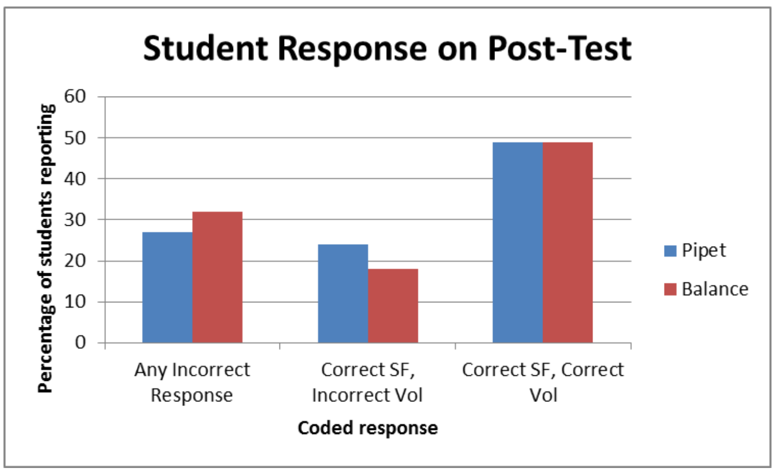
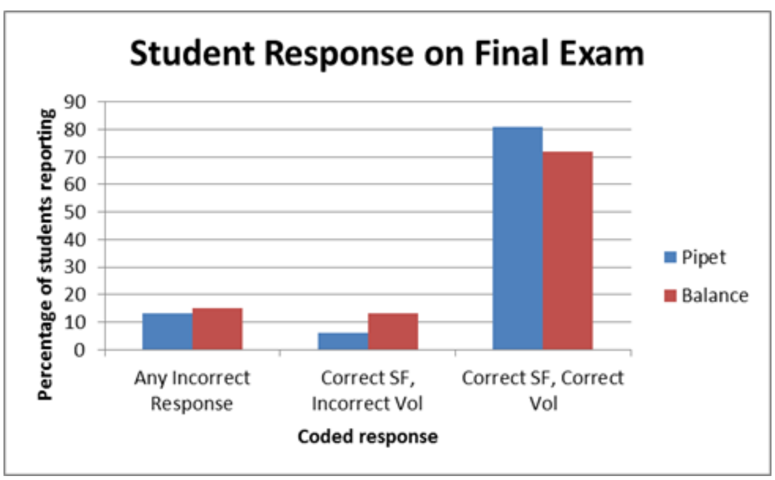


Figure 3. Comparison of final exam responses between the pipet and balance groups.



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.