

THE EFFECTS OF A FLIPPED CLASSROOM ON ACHIEVEMENT AND STUDENT
ATTITUDES IN SECONDARY CHEMISTRY

by

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TABLE OF CONTENTS

INTRODUCTION AND BACKGROUND	1
CONCEPTUAL FRAMEWORK	3
METHODOLOGY	7
DATA AND ANALYSIS	10
INTERPRETATION AND CONCLUSION	22
VALUE	25
REFERENCES CITED	27
APPENDICES	28
APPENDIX A: Unit 5 Test	29
APPENDIX B: Unit 6 Test	35
APPENDIX C: Class Time Log	43
APPENDIX D: Student Survey 1	45
APPENDIX E: Student Survey 2	47
APPENDIX F: Student Survey 3	50
APPENDIX G: Student Interviews	53
APPENDIX H: Unit Schedules	55

LIST OF TABLES

1. Class Demographics: Gender.....	7
2. Class Demographics: Ethnicity.....	7
3. Comparison of Class Time in traditional versus Flipped Classrooms.....	8
4. Data Triangulation Matrix	10

LIST OF FIGURES

1. Comparison of Unit Test Averages.....	11
2. Comparison of Unit Test Averages. Males and Females.....	12
3. Survey Question: Do you think the flipped classroom technique helped you learn chemistry more efficiently than what was done last semester?.....	13
4. Survey Question: Overall, my attitude toward chemistry class is positive. Males & Females.....	15
5. Survey Question: Overall, my attitude toward chemistry class is positive. Top and bottom halves of class.....	16
6. Survey Question: I prefer to listen to lecture face to face. Males and Females.....	17
7. Survey Question: I prefer to listen to lecture face to face. Top and bottom halves of class.....	19
8. Preferred Classroom Type.....	20
9. Survey Question: In terms of the amount of content that was flipped, would you prefer more or less?.....	21
10. Preferred Classroom Type on Block With One To One.....	25

ABSTRACT

In this investigation flipping was used to see if improvement occurred in achievement and with students' attitudes toward chemistry. Flipping means lecture content usually delivered in the classroom was instead presented through asynchronous videos via the internet in advance of class. This was done in a suburban high school chemistry course. Results from unit tests were analyzed to see the change in summative achievement; while student surveys and interviews were analyzed to see the change in students' attitudes toward chemistry. Results revealed no significant change in achievement with only marginal improvement in positive attitudes toward chemistry. Student comments and interviews showed that students did not have a positive response to using flipping to introduce new content but had a positive attitude towards using flipping in other roles.

INTRODUCTION AND BACKGROUND

Introduction

In an educational structure, where instructional minutes between student and teacher are limited, that time, in many classrooms, is spent on activities on the lowest levels of Bloom's taxonomy. When there is increased call to develop higher order thinking skills and to have students engage in authentic practice, much of the available instructional time is spent on disseminating information. The "flipped classroom" or "inverted classroom" is an instructional model in which lecture material typically covered during class is instead delivered online to the students—through the use of web-based courseware management systems (CMS) and vodcasting. Vodcasting is a technique where videos are made by the teacher, typically containing lecture content that students would watch, through the internet, before coming to class. The most notable early secondary science practitioners of the flipped classroom were Jonathan Bergman and Aaron Sams. They were using this practice when they were teaching together at Woodland Park High School in Woodland Park, Colorado.

I currently teach at Glenbrook South High School in Glenview, IL, just northwest of Chicago, one of two schools in District 225, a secondary only district. Glenbrook South or GBS has about 2700 students, while Glenbrook North, the other school in the district, is of comparable size. The community and the school are predominately white upper-middle class. There are many corporate headquarters in the area—Kraft, Allstate—and many of our students' parents work at them. Our largest minority population is Asian, specifically Korean. Our free and reduced lunch population is around 20%. There

is virtually no violence or gang activity. Academically, the school is very successful with a proactive administration working hard to address the few weak areas that we have. The school climate is excellent with a strong school culture and high level of involvement among students in extra-curricular activities of all types.

Focus Question

There is limited classroom time for teachers to work with students during class to clarify misconceptions and build depth of knowledge. Additionally, opportunities for students to work together in small groups outside of laboratory work are also limited. A classroom structured on a flipped model would increase the amount of time available for teachers to work directly with students during class, as well as increased opportunities and time for students to engage in more peer-to-peer work. Given these changes, students in a flipped classroom should show increased performance on summative assessments. With less time spent on lecture, students should be able to complete additional authentic activities which should increase students' performance on lab assessments. Given that less time is spent on lecture and more time spent on student-centered activities, as well as additional one-on-one time, these changes might result in a positive increase in students' attitudes toward chemistry.

The intent of this study is to see what effects the implementation of a flipped methodology might have on aspects of the classroom focused on the following questions—Is there an increase in achievement after the implementation of a flipped classroom; is there an increase in the amount of time spent on guided and independent practice and lab activities and demonstrations; and finally, is there an increase in positive

attitudes toward chemistry class among students after the implementation of a flipped classroom?

CONCEPTUAL FRAMEWORK

“Research has supported that active learning strategies result in higher student engagement and greater learning gains as compared to traditional instructor-centered methods such as lecture” (Zappe, Leicht, Messner, Litzinger, & Lee, 2009, p. 3). One method of decreasing the amount of classroom time spent on teacher-centered lecture without cutting content is to “flip” the classroom. The “flipped classroom” or “inverted classroom” is an instructional model in which lecture material typically covered during class is instead delivery online to the students before they arrive in order to increase the amount of time available for practice and application. Baker (2000) developed an early set of goals for teachers to consider when implementing a flipped classroom:

- Find an approach that would make it possible for faculty to move from sage to guide.
- Reduce the amount of time spent in class on lecturing, opening up class time for the use of active learning strategies.
- Focus more on understanding and application (critical and creative thinking) than on recall of facts (content/basic thinking), while not sacrificing presentation of the factual base.
- Provide students with more control over their own learning.
- Give students a greater sense of their own responsibility for their learning.
- Provide students with more opportunities to learn from their peers.

The first two of Baker’s (2000) flipped model goals relate to changing the role of the instructors and the manner of instruction in the classroom. In a traditional, lecture-heavy setting, the instructor is the “sage on the stage,” whereas in a flipped classroom, the instructor’s role is more of the guide on the side. Many science classrooms follow the traditional lecture-homework cycle in which the instructor serves as the sage on the stage;

the classroom is teacher-centered, with the teacher serving as the disseminator of information. If the previous night's assignment was to read the appropriate passages in the textbook, the student might have some understanding of the day's lesson. However, repeated research studies have shown that only 20-30% of students actually do that reading (Carlisle, 2010). Even with overhead projectors and PowerPoint presentations, most of the material in the lecture will be presented verbally by the instructor. This is at odds with the fact that most students, some 75% to 83%, are in fact visual, not auditory learners (Carlisle). As the lecture proceeds, the instructor will more than likely pace the lesson to the ability of the middle of the class, meaning that there will be students who are not engaged by the material because the pace is too slow, as well as students who are left behind because they might not understand the material after only the initial presentation. Lecture could take anywhere from a third to half of the instructional time before the students are able to engage in an activity or some experiential learning (Begmann & Sams, 2009).

Instructors have noted that the flipped classroom was more enjoyable to teach in (Carlisle; Lage, Platt, & Treglia, 2000). Compared with a traditional 'chalk and talk' classroom, there is an increased opportunity for student- teacher interaction, providing opportunity for the instructor to identify and clarify misconceptions, as well as time to work one on one with students who need the most help (Lage et al., 2000).

Additionally, research has shown that a mismatch between an instructor's teaching style and a student's learning style can result in the students learning less and being less interested in the subject matter (Lage et al., 2000). Through the use of a flipped model, there is more time available for an increased variety in instructional methods, a

greater menu of instructional options. Studies have shown that the greater the divergence between teaching style and learning style the worse the student's performance (Klemz, Murphy, & Young, 2003; Lage et al.). Regardless of the system used to classify learning styles, whether it is the Grasha-Reichmann, Keirse-Bates, or Kolb, a flipped classroom provides an increased opportunity for a greater range of instructional methods that are more likely to appeal to all learners (Lage et al.).

The flipped model's third goal is to focus more on learning objectives on the upper portion of Bloom's taxonomy without sacrificing the factual base. Additional class time provides opportunity for more group project-based learning which encourages collaborative learning which can further shift the class setting from instructor-centered to student-centered (Klemz et al., 2003). A flipped model also provides the additional time that can be spent on higher-order questioning and problem solving, learning objectives higher on Bloom's taxonomy, as well as exposing students to all four stages of Kolb's learning cycle—concrete experience, abstract conceptualization, reflective observation, and active experimentation (Klemz et al.). The use of educational technology to flip the classroom allows for greater opportunities for learning through experiential or active learning (Begmann & Sams, 2009; Strayer, 2007; Zappe, Leicht, Messner, Litzinger, & Lee, 2009). The National Research Council has stated that "...the new science of learning is beginning to provide knowledge to improve significantly people's abilities to become active learners who seek to understand complex subject matter and are better prepared to transfer what they have to new problems and settings" (NRC, 2000, p. 13).

The last three goals focus on changing the role and responsibilities of the student in the classroom as well as student-to-student interactions. Instructors have noted that

students seemed more motivated, possibly because the flipped model demanded that students take more ownership for their own learning (Carlisle, 2010; Kingsley & Putman, 2009; Lage et al., 2000; Peña, Jr., 2011; Strayer, 2007; Zappe et al., 2009). Either as a function of increased engagement, or additional time spent with the material, or both, students who spend more time with online resources tend to score higher when assessed versus traditional preparation only. However, the increase was not always significant (Carlisle; Kingsley & Putman; Peña; Skylar, 2009). Students whose instructors reduced lecture time the most, not only spent more time with online resources, but also spent more time reading class materials and did better on the assessment (Carlisle). Studies have shown that there is increased satisfaction among students with the learning environment when interactivity of lessons within a course increases (Kingsley & Putman; Skylar). Multiple studies have shown that online material such as podcasts and vodcasts increase student engagement (Lage et al.). There was an additional statistically measurable improvement when students created their own podcasts, screencasts, and vodcasts, rather than just watching premade ones (Peña).

Students have responded favorably on Likert scale surveys to group work, both enjoying group work as an instructional method and the effectiveness of group work in support of learning (Klemz et al., 2003; Lage et al., 2000). Interestingly, instructors have noted that female students are more active participants in the flipped classroom than in the traditional classroom (Lage et al.). Students in multiple studies were clear that while online resources increased their understanding, the entire course should not be flipped (Kingsley & Putman, 2009; Lage et al.; Strayer, 2007; Zappe et al., 2009). Some students

expressed feeling unsettled or being “lost” initially working in a flipped environment. This experience was not reported by students in a traditional classroom (Strayer).

METHODOLOGY

My intervention studied a flip of my regular level chemistry classroom. The “flipped classroom” or “inverted classroom” is an instructional model in which lecture material typically covered during class is instead delivered online to students before they arrive to class, in order to increase the amount of class time available for practice and application.

The intervention was carried out in two periods of general chemistry taught by myself. Both periods contained 46 students with 24 males and 22 females. The course is organized into two-unit quarters, for a total of eight units. The last week of each quarter has been set aside to provide time for multi-day, summative lab projects, so that in any quarter, two units typically take nine weeks to teach.

The specific demographic breakdown of the two periods involved is as follows.

Table 1
Class Demographics: Gender

Gender	Male	Female
1 st Period n=24	12	12
3 rd Period n=22	12	10
Total n=46	24	22

Table 2
Class Demographics: Ethnicity

Race	Latino	African American	Caucasian	Asian	Other
1 st Period n =24	0%	0%	79%	21%	0%
3 rd Period n=22	0%	0%	83%	17%	0%
Total n=46	0%	0%	82%	18%	0%

Starting during the last half of 2nd quarter, and continuing throughout the intervention, I asked one student, per period, to keep a daily time log (Appendix E) to establish a baseline of what the distribution of activities were before the intervention. Table 3, is a comparison of the time distribution in Aaron Sams' traditional AP chemistry as it was originally structured and after the implementation of the flipped model (Bergmann & Sams, p.15, 2012). I used Bergmann and Sams' activities structure to track the shift in my classroom throughout the intervention.

Table 3

Comparison of Class Time in traditional versus Flipped Classrooms (Bergmann & Sams, p.15, 2012)

Traditional Classroom		Flipped Classroom	
Activity	Time	Activity	Time
Warm-up activity	5 min.	Warm-up activity	5 min.
Go over previous night's homework	20 min.	Q & A time on video	10 min.
Lecture new content	30-45 min.	Guided and independent practice and/or lab activity	75 min.
Guided and independent practice and/or lab activity	20-35 min.		

During 2nd quarter, I administered Survey 1 (Appendix F), Student Response to Flipped Classroom, to each period via a Google form at the start of 2nd semester. This was done to establish a baseline of student attitudes toward the structure of the class, types of activities, and chemistry in general.

I flipped the lecture material during the 3rd quarter, which ran from late January to late March. Flipped lectures were distributed through Moodle and YouTube. The remaining class time was spent in guided and independent practice and/or lab activity. The two units comprising that quarter are Unit 5 Gaseous Matter: Gases & Equilibrium and Unit 6 Aqueous Matter: Solutions and Acids & Bases. I did both units to provide an

opportunity to make adjustments between units 5 and 6, as well as allow students to become familiar with the flipped classroom process during unit 5, so that by unit 6, the data gathered might be less impacted by the implementation process. I used test data for Units 1 through 6, from the previous year's classes as a baseline to assess the impact of the intervention. At the end of both Units 5 and 6, I administered the unit exam (Appendix A and C) and was able to measure the deviation during the intervention by comparing test data from this year's students with the previous year.

During the intervention, Student Surveys 2 & 3 (Appendix G & H) were administered, again via Google forms, after the assessments in each unit were completed. At the beginning of 4th quarter, student interviews (Appendix I) were conducted with select students. Six students were interviewed, three female and three males, with one student of each gender in the A, B and C range respectively.

The research methodology for this project received an exemption by Montana State University's Institutional Review Board and compliance for working with human subjects was maintained. The data collected was used to answer the focus questions of my action research project according the Data Triangulation Matrix (Table 4).

Table 4
Triangulation Matrix

Focus Question	Data Source 1	Data Source 2	Data Source 3
<i>Primary Question:</i> Is there an increase in achievement after the implementation of a flipped classroom?	Summative unit tests	Student surveys	Teacher observations
<i>Secondary Questions:</i> Is there an increase in the amount of time spent on guided and independent practice and lab activities & demonstrations?	Class time logs	Teacher observations	
Is there an increase in positive attitudes toward chemistry class among students after the implementation of a flipped classroom?	Student surveys	Student interviews	Teacher observations

DATA AND ANALYSIS

Summative unit tests were the primary source of data analyzed to determine if the flipped classroom intervention had any impact on student achievement. In addition to comparing data from this year to last year, I also compared male to female scores, as well as comparing scores between students in the top half of the sample, based on total course average, to students in the lower half. I made similar comparisons between the groups mentioned above while analyzing student survey data.

Unit test averages were collected during the 2011-2012 school year from two sections of regular chemistry covering the first six of eight units. Test averages were collected during this school year over the same six units. During both school years, the first four units were taught in appreciably the same manner with no significant deviations

in time per unit or content covered. For the 2012-2013 school year, only the scores for students who took all six tests were included resulting in a sample size of 46 in two sections. The scores of students who transferred in or out of the sections were not counted. Test scores from the flipped intervention group, 2012-2013, were compared against the traditional group from 2011-2012, in *Figure 1*. Students in the intervention scored slightly, but not significantly higher, on three of the four units test taught to both groups in a traditional manner. The flipped classroom was implemented during units 5 and 6. Two Unit tests from the 2011-2012 school year, Unit 5 ($M = 40$, $SD = 13.0$) and Unit 6 ($M = 37$, $SD = 12.0$), were compared against the same two unit tests from the intervention period, Unit 5 ($M = 46$, $SD = 11.7$) and Unit 6 ($M = 46$, $SD = 12.0$). An unpaired t -test was run on both unit tests. Neither Unit test 5, $t(84) = 0.0751$, $p = 0.9403$, nor Unit test 6, $t(81) = 0.2642$, $p = 0.7923$, showed statistically significant difference. No effect of the flipped intervention could be shown through the two pertinent unit summative assessments.

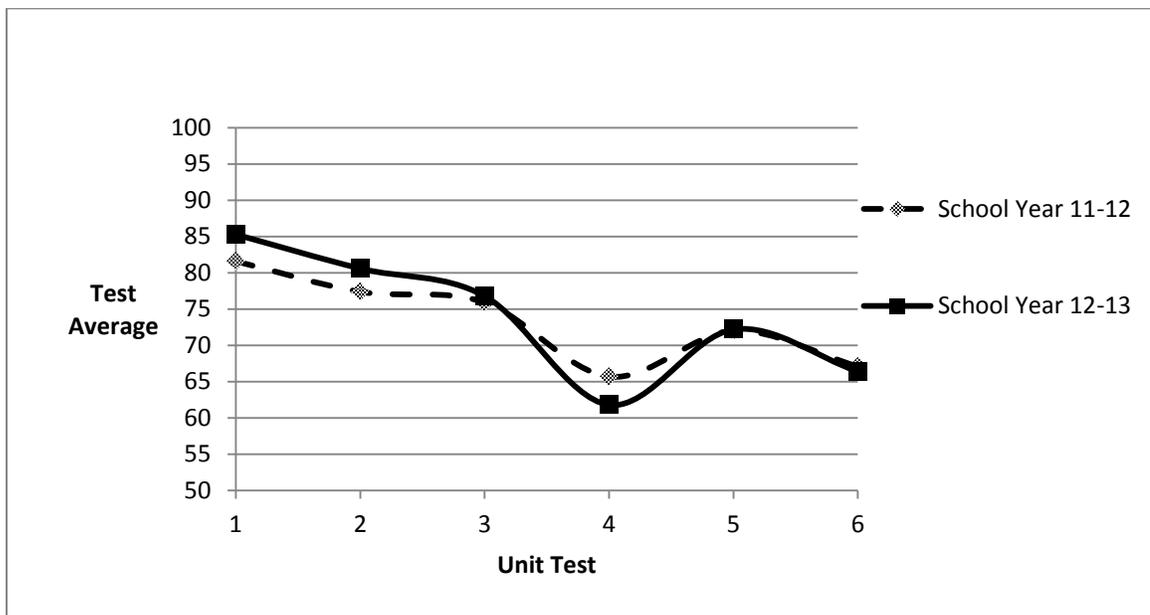


Figure 1. Comparison of unit test averages, ($N=46$).

In *Figure 2*, test scores were analyzed to compare the performance of males ($N = 24$) versus females ($N = 22$) in the implementation group. There was no deviation in test scores between genders for either unit test based on an unpaired t test—Unit test 5, females ($M = 84.5$, $SD = 10.0$) and males ($M = 86.0$, $SD = 7.8$), resulted in $t(44) = 0.5699$, $p = 0.5717$, while Unit test 6, females ($M = 79.8$, $SD = 10.9$) and males ($M = 81.3$, $SD = 11.$), resulted in $t(44) = 0.4574$, $p = 0.6496$.

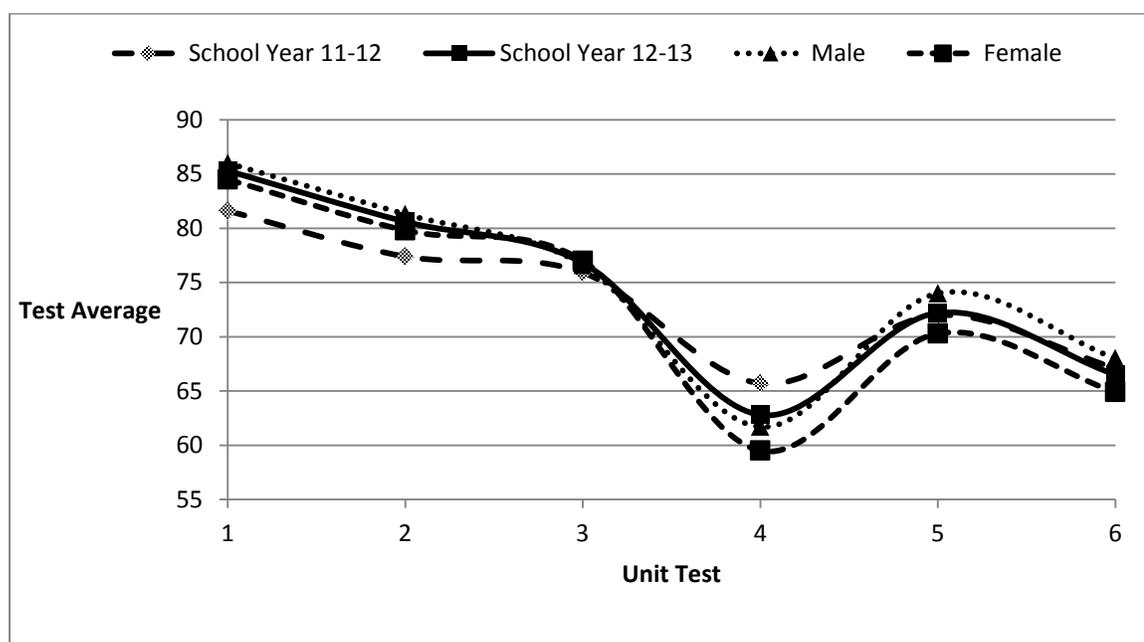


Figure 2. Comparison of unit test averages. males and females, ($N=46$).

The impact the flipped classroom had on students' self-reported sense of learning chemistry was addressed in the last survey, after the conclusion of the flipped intervention. Only 39 of the 46 students in the sample were willing, or able, to complete all three surveys. In *Figure 3*, of those 39, 23 students, or 59%, reported that they felt that the flipped intervention helped them learn chemistry more efficiently to some degree. Students were given the option of answering “Yes, but” and qualifying their responses. The most common comments of the nine students responding “Yes, but” expressed a

desire for additional time at the beginning of class to review video material and ask questions. Only 24% of male students responded with an unqualified yes versus 50% of female students who self-reported that they felt the flipped classroom helped their learning. There was also a difference between how students in the top of the sample, based on total average, reported versus those in the lower half. 42% of students in the top reported a clear benefit from the flipped classroom while only 30% of students in the bottom half of the class expressed a certain benefit from the flipped process.

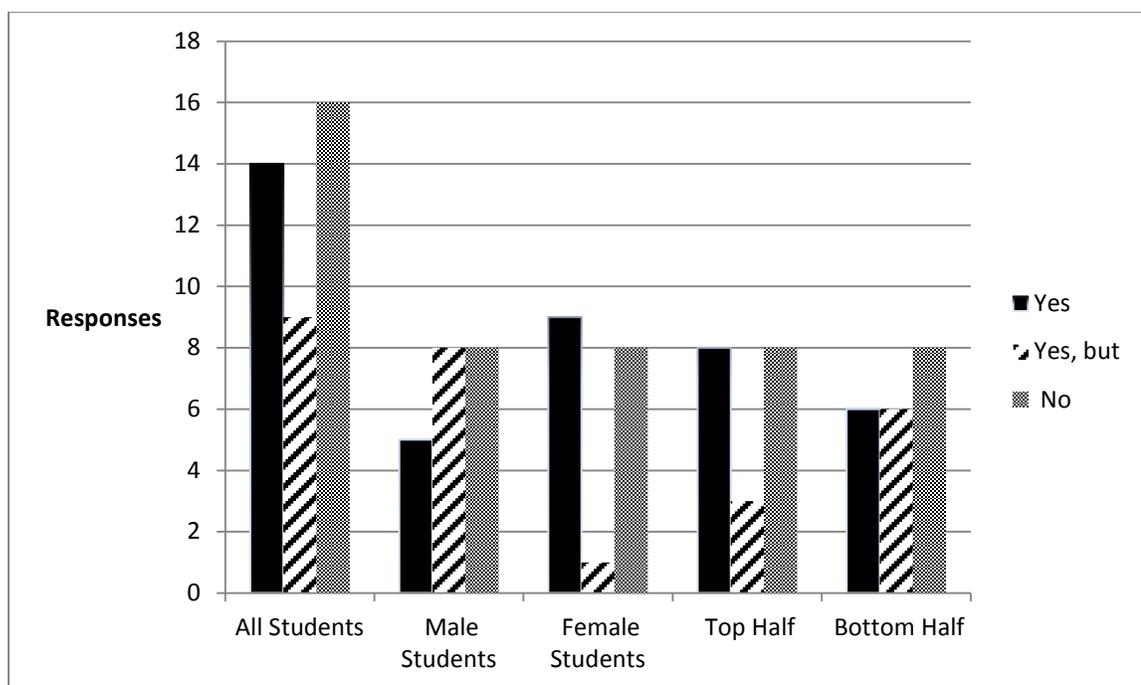


Figure 3. Survey question: Do you think the flipped classroom technique helped you learn chemistry more efficiently than what was done last semester?, ($N=39$).

In order to determine if the flipped classroom increased the amount of time spent on guided and independent practice and lab activities & demonstrations, a student kept a time log each day marking during each ten minute interval what type of activity the class was engaged in. Of the 38 instruction days during the traditionally taught second quarter, only 12 contained lecture or direct instruction. Total lecture time during those 12 class

periods was 24% but only 8% of the total time of the quarter. The average amount of lecture time per lecture day during the second quarter was 12 minutes per 50 minute period. There were 38 days of instruction during the flipped implementation. Within the included two units there were 12 “days” of lecture, all of which were flipped. I would approximate that we spent at least 5 to 10 minutes at the start of each class after a flipped assignment, answering questions and discussing the video. Based on the 12 lecture days during the flipped intervention, I calculated that we gained an additional 60 minutes of time, that would have been spent in lecture over the course of a quarter. My time usage calculations are based on a comparison to the 2011-2012 school year. I do not have time logs for that school year and this time analysis is based on my best estimate of the time it took to deliver those particular lecture lessons in the classroom in a traditional format. While I am not overly confident in the time calculation number, I did not generate enough additional time, at any point in the intervention, to add any completely new activity, lab, or demo, therefore I am confident in saying that there was no significant net gain in classroom time based on flipping lecture content, during this time period and based on my implementation method.

The last pieces of data deal with students attitude toward chemistry class overall. The survey questions reported with a numerical value are based on a Likert scale of 1 to 5, with 1 being disagreed with most and 5 being agreed with most. Based on the same survey question asked before, half way through, and after implementation of the flipped classroom, there is a marked decrease in positive attitudes toward chemistry amongst students, dropping from 3.89 before the intervention to 3.44 by the end, in *Figure 4*. This is a statistically significant effect over time, $t(82) = 2.0602$, $p = 0.04$. The drop amongst

males, to 3.38, is more pronounced but not statistically significant, $t(43) = 1.31$, $p = 0.20$, whereas that of female students which levels off after the midpoint to a value of 3.5 is not quite statistically significant, $t(37) = 1.69$, $p = 0.10$. It is not possible to determine if this drop is solely the function of the flipped implementation; other factors may have contributed to the change such as the unit content, time of year, or other factors.

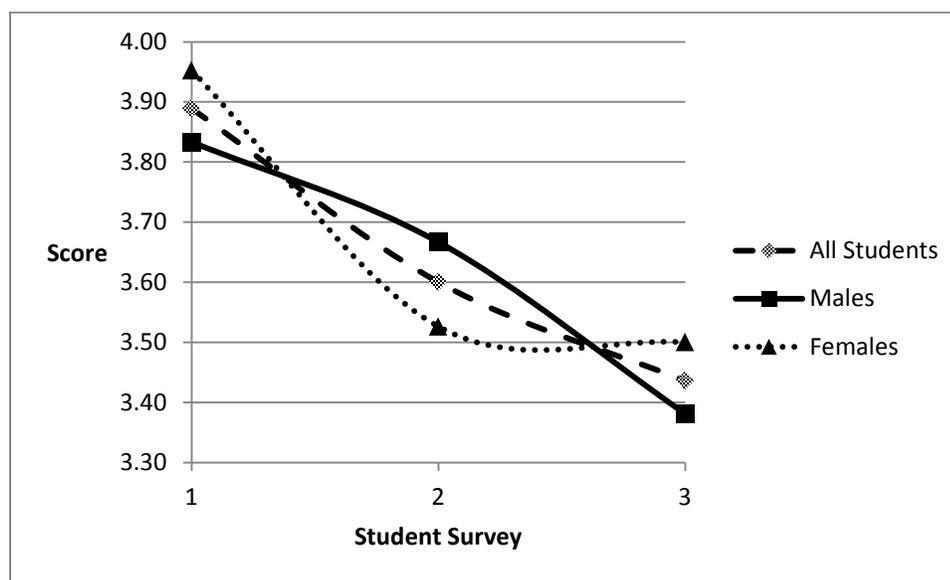


Figure 4. Survey question: Overall, my attitude toward chemistry class is positive. males & females, ($N=39$).

When looking at the same question based on students in the top and bottom of the class, *Figure 5*, there is, again, noticeable change. Students in the top half of the class start the implementation process with a positive attitude of 4.05 and complete the implementation at 3.47, a statistically significant effect, $t(37) = 2.27$, $p = 0.03$. The drop among students in the bottom half of the sample is not statistically significant as their start value is 3.76, $t(43) = 1.06$, $p = 0.30$.

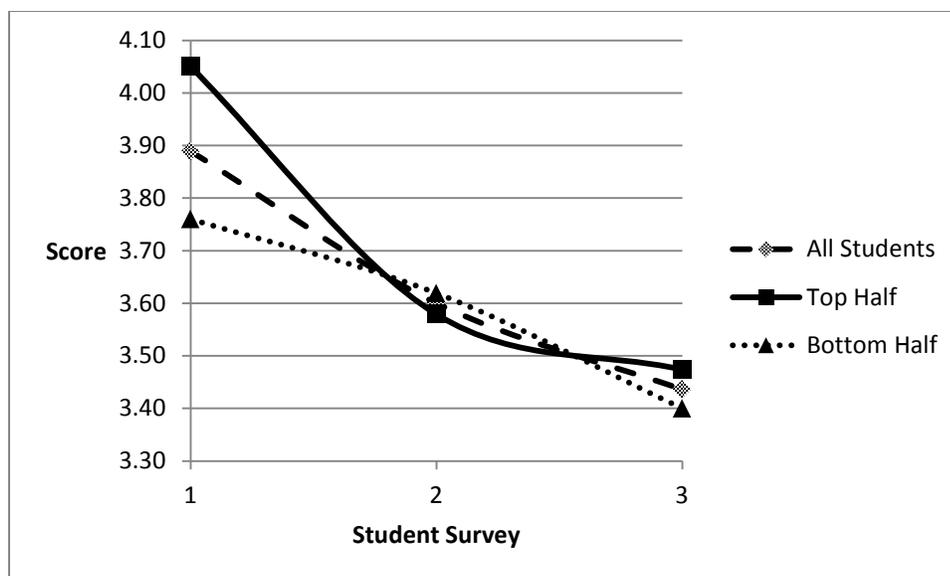


Figure 5. Survey question: Overall, my attitude toward chemistry class is positive. Top and bottom halves of class, ($N=39$).

While students' positive attitudes did decrease throughout the implementation, the data with respect to how lecture material is delivered is mixed, in *Figure 6*. Although the change in students' positive attitudes is not statistically significant, $t(82) = 0.54$, $p = 0.59$, there is a slight drop in the preference of listening to lecture face-to-face. Although the change in response to this survey question is not statistically significant, $t(37) = 0.76$ $p = 0.45$, there is a clear trend among female students with respect to the listening to lecture face-to-face. Over the course of the implementation there appears to be a shift among female students away from face-to-face lecture and presumably toward flipped lecture. The opposite trend occurs among male students. Although again not statistically significant, $t(43) = 0.10$, $p = 0.92$, male students show a marked increase in their preference for face-to-face lecture. Female students consistently watched more of the videos than their male counterparts. During Unit 5, females self-reported watching 4.74 of the assigned videos in comparison to the male rate of only 3.86. The female viewing

rate stayed high at 2.78 of 3 videos while the males' rate remained low in comparison at 2.29.

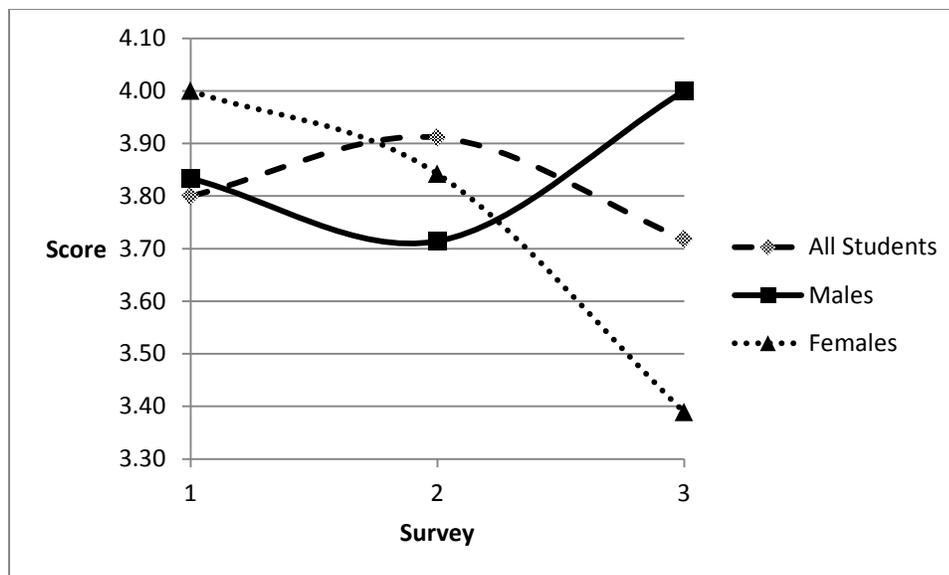


Figure 6. Survey question: I prefer to listen to lecture face to face. males and females, (N=39).

There is also the possibility that a factor in the overall decrease in positive attitudes towards chemistry was a function of the increasing difficulty of the course. The accumulating and spiraling nature of the chemistry content makes the course increasingly difficult as the year progresses. As shown in *Figure 1*, the decreasing summative test scores from the previous, non-flipped year demonstrates that chemistry tends to get “harder” as the year progresses. Although we have intentionally rearranged units to try to increase students’ success during the second semester, students’ averages tend to decrease and stress levels tend to increase. It is likely that the decrease in positive attitudes toward chemistry is both a function of the general nature of second semester chemistry, and the introduction of the flipped model.

When looking at the data for students in the top and bottom halves of the class, based on class average, in *Figure 7*, there is a slight change, although neither final outcome is statistically significant. Students in the top half of the class start with a preference near the whole class mean but with a lower standard deviation. During the first half of the intervention, their preference for face-to-face lecture increases but then drops below their starting value by the end of the course. This pattern might indicate some initial issues with adapting to the new format and an eventual recognition of possible benefits to a flipped classroom. Although the overall change in preference is not statistically significant, $t(37) = 0.53$, $p = 0.60$. The students in the bottom half of the class experience the opposite pattern. They appear initially to respond well to a shift to flipped lecture but over the duration of the intervention move back toward their starting preference. Again, the final outcome is not statistically significant, $t(43) = 0.21$, $p = 0.83$. There was a change in their viewing pattern. During, Unit 5, students in the bottom half of the class self-reported only watching 3.95 of the 5 assigned videos, in comparison to a view rate of 4.63 for the top students. In unit 6, that viewing rate increased to 2.50 of 3, virtually matching the top students 2.53.

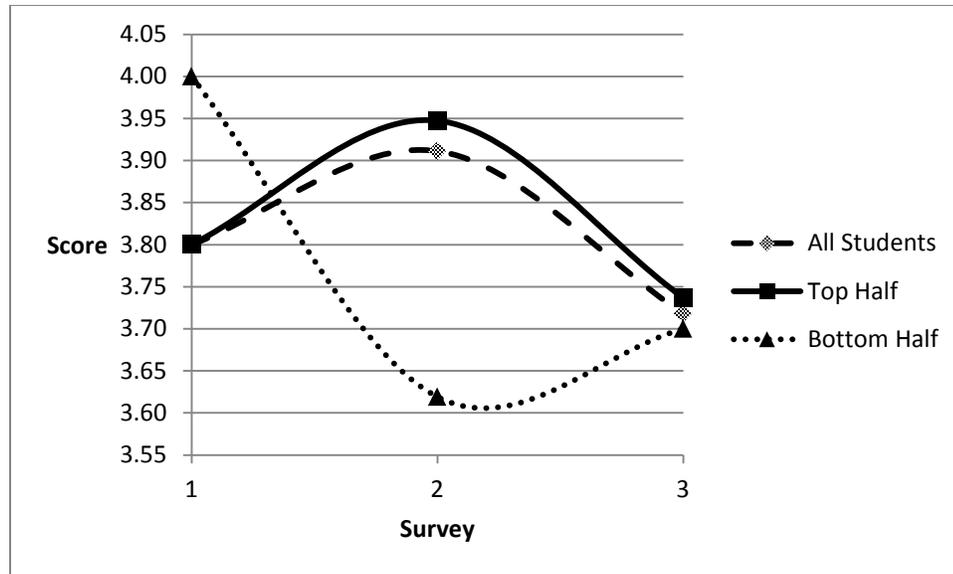


Figure 7. Survey question: I prefer to listen to lecture face to face. Top and bottom halves of class, ($N=39$).

Given a final vote on an absolute preference between the two classroom types, 59% of the students prefer a traditional classroom model, *Figure 8*. Fully 67% of male students preferred a traditional type of classroom whereas there was an even split between female preference. There was also significant discrepancy based on performance in the class with 72% of students in the top half preferring a traditional classroom with another even split between the two types for students in the lower half of the class.

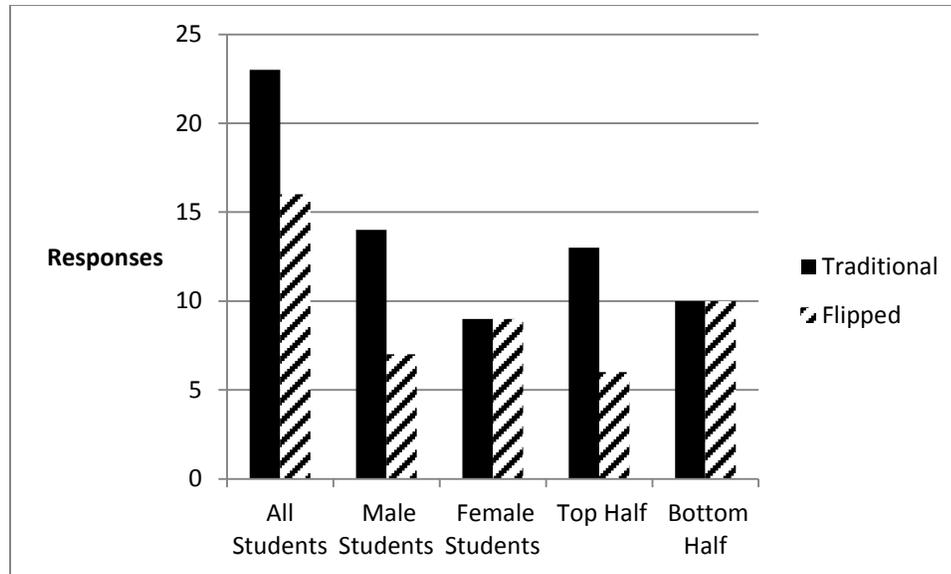


Figure 8. Preferred classroom type, ($N=39$).

When essentially the same question was phrased in a slightly different manner the outcome changed. The response that would demonstrate a preference for a traditional classroom would be, “None, I tried flipping, but it didn’t work for me.” Only 33% of students chose that option or the choice that they had never watched any of the videos. The other two thirds of students all choose an option that involved some degree of flipped lecture. Although most students expressed an absolute preference for a traditional model, this question would seem to indicate some desire to have flipped videos available, *Figure 9*.

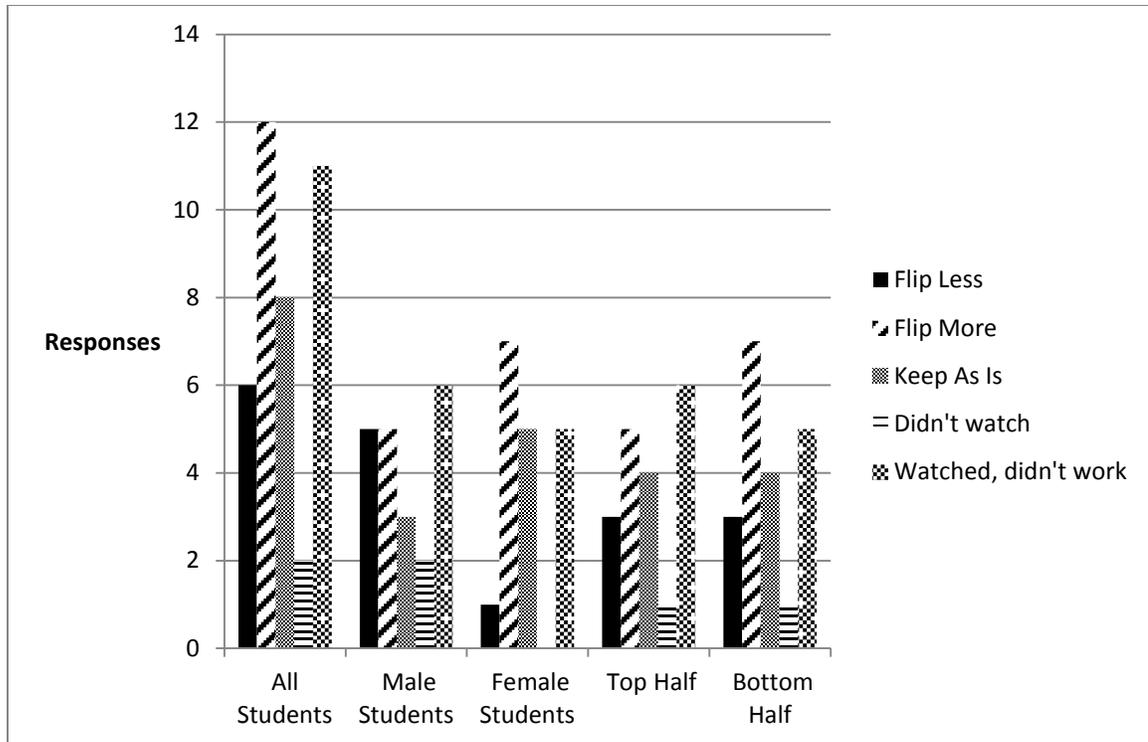


Figure 9. Survey question: In terms of the amount of content that was flipped, would you prefer more or less?, ($N=39$).

Responses of students interviewed matched and supported data gathered from the surveys. Many of my students wanted me to re-lecture the video contents at the beginning of class. One male student said, “I don’t like the new flipped way. Change it! Or, you can go over the contents of the video in the beginning of the class.” There were very different gender responses to flipping. A female student said, “The flipped classroom helps speed the lesson up because of no naïve behavior and I can understand more things. The video helps because you can go back and rewind, you can’t rewind a teacher and sometimes I’m too shy to ask questions.” It was unanimously agreed upon by all the female students interviewed that flipping provided less opportunity for the males to ask tangential, silly, or inappropriate questions during a lecture, interrupting learning. All the female students’ interviewed also found that it was easier to concentrate on the material without the

distractions of the classroom. The general male response, succinctly stated by one male student was, “I hate videos.” Ironically, this particular male student responded in the surveys that he had not, in fact, watched a single video, which I confirmed through the fact that he has not logged into Moodle for weeks to access the video links. In the two class discussions we had after the last two surveys, it was clear that, where female students liked having the videos available, the males universally rejected the entire process. It was very clearly expressed that flipping required them “to do something” in contrast to the traditional method where they could learn by “just sitting in class getting by, you know how cells did it in bio, get stuff.” “Osmosis,” I suggested, “Yeah, why can’t we just learn by osmosis?” as spoken by one a male student.

INTERPRETATION AND CONCLUSION

My primary research question was focused on achievement. I wanted to see if implementing a flipped classroom would increase my students’ summative achievement in chemistry. I believe this intervention did not have any impact on summative achievement for several reasons. First, I did not fundamentally alter the learning style of my classroom. The curriculum we put together for this level of chemistry is heavily student centered and provides students with many phenomenological opportunities to build an understanding of chemistry concepts on their own. Rarely, are any concepts introduced to the students without them having worked with, and through the concepts, in some student centered activity. The flipped classroom did not fundamentally alter the manner in which my students learn chemistry, nor did it provide any significant amount of additional time in which to implement additional and varied learning opportunities. I

do believe that our transition to a block schedule, with a one-to-one device, where each student has an internet capable device in class, will provide an opportunity in which to more fully integrate aspects of a flipped classroom. I believe that flipped videos are a valuable resource and can be used as a component of learning. Flipping benefits a proactive student willing to be responsible for their own learning.

After much thought, I decided that in order to collect comparative data, I would teach the fall semester in the traditional manner and then switch to a flipped classroom for the spring semester. While I do not regret that decision, I do believe things might have gone differently had I started with a flipped classroom from day one. People generally do not like change, and I have come to learn the importance of routine among high school students. Looking at my data and student interviews, it did shown a clear pattern of opposition to, and difficulty adapting to, the flipped process during unit 5 and then by the end of unit 6 some acceptance of the process, if not some appreciation for its benefits. A female student said, "I really like being able to go over stuff at my own pace and I can stop the videos whenever I want." It was also hard for students to reconcile the fact that if there was not an assigned video, then they would have some "regular" written homework.

Then there were issues associated with the watching the videos and the manner in which they were watched. "Mr. Glynn, I couldn't watch the video, it was too long, and I can't concentrate that long," spoke a male student. I pointed out that the video was only nine minutes, to which he simply which he responded, "too long, can't concentrate that long." I also got, "You just said to watch the video, so I watched it, you didn't say anything about taking notes," from a male student, when in fact I put a notes sheet in

Moodle. In hindsight, I think the students' response to the flipped classroom would have been more positive if that was the only chemistry classroom they had experienced.

There was also the issue that this “flipped stuff” might be something they only had to endure with for a single quarter. I also learned a great deal about making the actual videos and using them as the intervention went on. I had initially start with a “you need to watch this video because it is your assigned homework” approach and was forced to move towards a more “there are several examples in the video that you need to complete and will checked at the beginning of class for points.” Many students, particularly males, as they often pointed out, had learned to get by without watching the videos and were simply trying to pick up the content on the fly without overly damaging their grade. I also learned how to better integrate the videos into the overall course structure and make them a more integrated and holistic component of the class.

Towards the end of the intervention, my school made a decision to switch to a 90 minute AB block schedule starting in the fall of 2014. Since most of my chemistry students are sophomores, their senior year will be on a block schedule. The school will have also implemented a one-to-one policy with every student required to have a Chrome book. When I include those two changes into a question of which type of classroom was preferred, the results changed, *Figure 10*. As a group, and within each of the subgroups I looked at over the course of this intervention, all opted for a flipped model. Two-thirds of students expressed a belief that a flipped classroom would work best on a block schedule. Just as with the flipped classroom, the description of a block schedule is different than the actual implementation and practice, and that preference might switch once the schedule change is made. It is telling, however, that given their recent experience with a flipped

classroom, and their generally negative response to it, that so many would think that a flipped model would be a better choice given a block schedule.

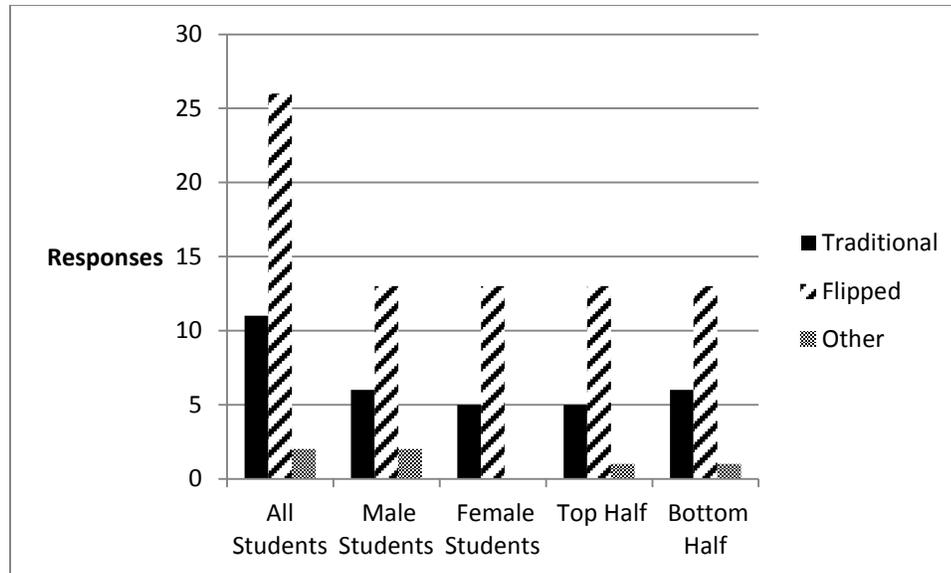


Figure 10. Preferred classroom type on block with one to one, (N=39).

VALUE

One of the impacts of working through the implementation of this action research project has been to remind myself, and reinforce the notion, that to be an effective teacher is to be a reflective teacher. While I feel that I have been a reflective teacher throughout my career, I will acknowledge that in the last few years I have not been as innovative and exploratory in my teaching as I was at the start of my career. I started teaching at another school and I started as a history teacher. I had always had a strong interest in both history and science. When a chemistry position, for which I was endorsed, became available I took the opportunity. Since I had no “official” training in the methods of science teaching, I taught myself to teach chemistry. I developed and implemented methods that I felt were most effective for my students. At the time, I was in a large urban high school

district, at a school with relatively limited resources, and not the best track record of quality teaching. To a certain extent, these factors contributed to a personal teaching style that was as innovative and creative as I could make it, while being effective, to move my students as far forward as possible. While I worked through the National Board process in chemistry, I continued to develop a dynamic teaching style. Some years ago, I took a job at a large, affluent suburban school, a school at which the “system” generally worked. While I would not say that my teaching practice has regressed, I would say that it has not progressed at the tempo at which it once did. The action research process has reminded me that my teaching is most effective when I am innovative and creative in my practice.

An innovative and creative style of teaching will be needed more as we in education teach the 21st century student who has grown up with digital internet based technology. New means of transmitting and gathering information, will change the landscape of the 21st century classroom, the student who uses and has grown up in and around this technology will be different than a student who used to take encyclopedias off a library shelf. I look forward to developing the most innovative and effective teaching practices I can in this new landscape. Of course, sometimes, I would just like a decent piece of chalk.

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APPENDICES

APPENDIX A

UNIT 5 EXAM

Chemistry 163-Unit 5 Exam

Directions: Yes! You may write on this test. Begin by writing your name on the test and on the Grade Master form. Then answer the first 20 questions on the Grade Master form. 3 points per multiple choice.

The following information will be helpful for many of the problems.

$$R = 0.0821 \frac{1 \cdot \text{atm}}{\text{mol} \cdot \text{K}} = 8.31 \frac{1 \cdot \text{kPa}}{\text{mol} \cdot \text{K}} = 62.4 \frac{1 \cdot \text{mmHg}}{\text{mol} \cdot \text{K}}$$

$$1.00 \text{ atm} = 760 \text{ mmHg} = 101.3 \text{ kPa} = 14.7 \text{ psi}$$

1. Which of the following gases will have the highest average molecular speed at 25°C?
 - a. F₂
 - b. N₂
 - c. NH₃
 - d. SF₆

2. When a sample of oxygen gas in a closed container of constant volume is heated until its absolute temperature is doubled, which of the following is also doubled?
 - a. The density of the gas
 - b. The pressure of the gas
 - c. The average velocity of the gas molecules
 - d. The number of molecules per cm³
 - e. The potential energy of the molecules

3. A sample of an ideal gas is cooled from 50.0°C to 25.0°C in a sealed container of constant volume. Which of the following values for the gas will decrease?
 - I. The average molecular mass of the gas
 - II. The average distance between the molecules
 - III. The average speed of the molecules
 - a. I only
 - b. II only
 - c. III only
 - d. I and III
 - e. II and III

4. The average rate at which gas molecules move increases with:
 - a. a decrease in pressure

- b. an increase in volume
 - c. an increase in temperature
 - d. an increase in density
5. If the pressure on one mole of gas molecules remains constant while the temperature increases, then the volume occupied:
- a. increases
 - b. decreases
 - c. first decreases, then increases
 - d. remains constant
6. The theoretical point where all molecular motion stops is:
- a. absolute temperature
 - b. absolute zero
 - c. absolute pressure
 - d. absolute volume
7. A sample of butane is collected in a eudiometer over water at 22 °C. The barometric pressure that day was 765 mmHg. The vapor pressure of water at 22 °C is 19.8 mmHg. What is the vapor pressure of the butane in the eudiometer?
- a. 784.8 mmHg
 - b. 765 mmHg
 - c. 760 mmHg
 - d. 745.2 mmHg
8. A spray can of air freshener contains this warning label: "Caution: Do not store at temperature above 120°F (50°C)." What is the scientific explanation for this warning?
- a. The gas will liquefy; spraying could become impossible.
 - b. A chemical reaction will occur; the can could explode.
 - c. The gas pressure will increase; the can could explode.
 - d. The walls of the can will expand; the gas pressure could decrease.
9. At the same temperature and pressure, 5.0 L of sulfur dioxide (SO₂) and 5.0 L of ammonia (NH₃) have the same
- a. mass
 - b. density
 - c. number of molecules
 - d. average molecular speed
10. As the temperature of a fixed volume of gas increases, the pressure will
- a. vary inversely
 - b. decrease
 - c. stay the same
 - d. increase
11. Which of these changes would not cause an increase in the pressure of a gaseous?

system?

- The container is made larger
- the temperature is increased
- another gas is added to the container
- additional amounts of the same gas are added to the container

12. Gases can be compressed much more easily than liquids because
- equal volumes of any two gases contain the same number of molecules.
 - the distance between molecules in gases is much greater than in liquids
 - the average kinetic energy of molecules in a gas is proportional to their temperature.
 - the molecules of a gas are similar than in liquids.
13. Place the following units of pressure in order from lowest to highest pressure.
- 1 atm < 1 mm Hg < 1 psi
 - 1 mm Hg < 1 psi < 1 atm
 - 1 mm Hg < 1 psi < 1 atm
 - 1 mm Hg < 1 atm < 1 psi
 - 1 psi < 1 mm Hg < 1 atm
14. In which reaction will an increase in pressure cause a shift to the right?
- $\text{CaCO}_3 (\text{s}) \leftrightarrow \text{CaO} (\text{s}) + \text{CO}_2 (\text{g})$
 - $\text{H}_2 (\text{g}) + \text{Cl}_2 (\text{g}) \leftrightarrow 2 \text{HCl} (\text{g})$
 - $\text{COCl}_2 (\text{g}) \leftrightarrow \text{CO} (\text{g}) + \text{Cl}_2 (\text{g})$
 - $2 \text{NO} (\text{g}) + \text{O}_2 (\text{g}) \leftrightarrow 2 \text{NO}_2 (\text{g})$
15. Which of the following are exactly equal for the forward and reverse reactions at equilibrium?
- masses of the reactant(s) and product(s)
 - volume of the reactant(s) and product(s)
 - pressure of the reactant(s) and product(s)
 - the rates of the forward and reverse reaction
16. In the reaction,
- $$\text{C} (\text{s}) + \text{CO}_2 (\text{g}) \leftrightarrow 2 \text{CO} (\text{g})$$
- if one mole of solid carbon is added to the system at equilibrium, the result when equilibrium is reattained will be
- To increase the quantity of CO by 2 mol.
 - To decrease the quantity of CO by 2 mol.
 - No change.
 - None of these.
17. For the reaction,
- $$4 \text{NH}_3 (\text{g}) + 5 \text{O}_2 (\text{g}) \leftrightarrow 4 \text{NO} (\text{g}) + 6 \text{H}_2\text{O} (\text{g}) + \text{Heat}$$
- The position of this equilibrium would be shifted to the left by

- a. Increasing the pressure by decreasing the volume of the container.
- b. Removing NO (g).
- c. Adding O₂ (g).
- d. Decreasing the temperature.
- e. None of these.

18. For the reaction: $A + B \leftrightarrow C$

When this reaction “shifts to the right”, this means

- a. [A] decreases, [B] decreases, and [C] increases
- b. [A] decreases, [B] increases, and [C] decreases
- c. [A] increases, [B] increases, and [C] decreases
- d. [A] increases, [B] decreases, and [C] increases

19. For the reaction: $2 A + B \leftrightarrow 3 C$

The equilibrium constant expression would be

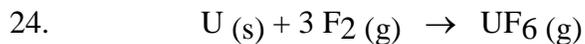
- a. $K = 2[A] + [B] + 3[C]$
- b. $K = [A]^2 [B] / [C]^3$
- c. $K = [C]^3 / [A]^2 [B]$
- d. $K = 3[C] / 2[A] [B]$

20. Given the following equilibrium



At equilibrium

- a. there are more products than reactants
 - b. there are more reactants than products
 - c. the concentrations of the products and reactants are about equal
 - d. there are no products
 - e. there are no reactants
21. A 6.89 g sample of butane gas has a volume of 5.10 liters at 22.0°C and 428 mmHg.
- a. How many moles of the gas are present? (3 pts)
 - b. What is the molecular mass (in g/mol) of the gas? (2 pts)
22. A 50.0 liter balloon which is at 27.0°C and 1.1 atm is sunk to the bottom of the ocean. When it hits bottom the pressure is 95.0 atm and the temperature is -15.0°C. What is the volume of the balloon at this depth? (5 pts)
23. $2 \text{ Al (s)} + 6 \text{ HCl (aq)} \rightarrow 3 \text{ H}_2 \text{ (g)} + 2 \text{ AlCl}_3 \text{ (aq)}$
- If 65 g of aluminum reacts as shown above, to what volume would the H₂ produced by the reaction fill a balloon at 32°C and 1.2 atm? (5 pts)



What volume of F_2 at STP would be needed to react with 150 g of uranium? (5 pts)

25. Write a balanced equation that would lead to the following expression for K . Be sure to include the state (solid, liquid, gas, aqueous) for each substance. (5 pts each)

a.
$$K = \frac{[\text{NO}_2]^2}{[\text{NO}]^2[\text{O}_2]}$$

b.
$$K = \frac{[\text{CH}_4]}{[\text{H}_2]^2}$$



A 5.0 liter flask contains 3.0 mol of CO , 2.0 mol of CO_2 , and 1.0 mol of C which are at equilibrium. Calculate K . (5 pts)

27. Billy and Shawendy are investigating the following equilibrium system with CO_2 , C , and O_2 in a closed container.



They observed that as the temperature is increased, a black solid forms. When the temperature is then decreased, the solid disappears. Dr. Doody wanted them to determine if the forward or reverse reaction was exothermic. Billy said the forward reaction was exothermic. Shawendy concluded that the reverse reaction was exothermic. Who is correct? Explain how you know. (5 pts)

APPENDIX B

UNIT 6 EXAM

Chemistry 163-Unit 6 Exam

Directions: Yes! You may write on this test. Begin by writing your name on the test and on the Grade Master form. Then answer the first 30 questions on the Grade Master form. 2 points per multiple choice.

The following information may be useful:

Compounds containing these ions are soluble in water...	...unless they also contain these ions, which make them insoluble
Ammonium NH_4^+	
Potassium K^+	
Sodium Na^+	
Acetate $\text{C}_2\text{H}_3\text{O}_2^-$	Fe^{3+} , Al^{3+} , Hg_2^{2+}
Chlorate ClO_3^-	
Chloride Cl^-	Ag^+ , Hg_2^{2+} , Pb^{2+}
Nitrate NO_3^-	
Sulfate SO_4^{2-}	Ca^{2+} , Ba^{2+} , Pb^{2+} , Sr^{2+} , Hg_2^{2+}

Compounds containing these ions are insoluble in water...	...unless they also contain these ions, which make them soluble .
Carbonate CO_3^{2-}	K^+ , Li^+ , Na^+ , NH_4^+
Hydroxide OH^-	K^+ , Li^+ , Na^+ , Ba^{2+}
Oxide O^{2-}	
Phosphate PO_4^{3-}	K^+ , Na^+ , NH_4^+
Silicate SiO_3^{2-}	K^+ , Na^+ ,
Sulfide S^{2-}	K^+ , Na^+ , NH_4^+
Sulfite SO_3^{2-}	K^+ , Na^+ , NH_4^+

$$\text{pH} = -\log[\text{H}^+]$$

$$[\text{H}^+] = 10^{-\text{pH}}$$

$$\text{pOH} = -\log[\text{OH}^-]$$

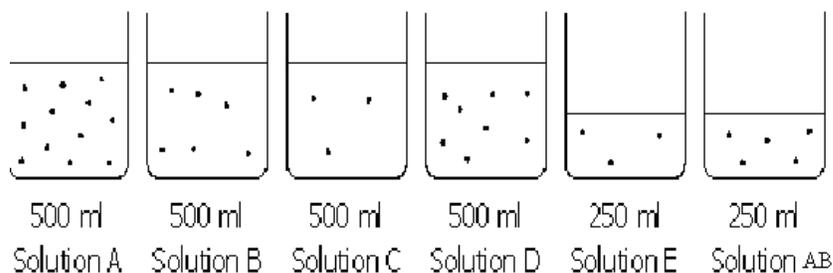
$$[\text{OH}^-] = 10^{-\text{pOH}}$$

$$\text{pH} + \text{pOH} = 14$$

- Based on the solubility table above, all ionic compounds can dissolve in water.
 - TRUE
 - FALSE
- A water solution was thought to contain a high concentration of chloride ions. To confirm the presence of these chloride ions a chemist would probably add a solution of
 - silver nitrate.
 - silver chloride.
 - sodium nitrate.
 - barium chloride.
 - sodium sulfate.

3. Which ion will form a precipitate when added to a 1 M hydroxide ion, $\text{OH}^-(aq)$, solution?
- $\text{Li}^+(aq)$
 - $\text{Fe}^{3+}(aq)$
 - $\text{NH}_4^+(aq)$
 - $\text{SO}_4^{2-}(aq)$
4. Which statement explains that a water solution of hydrogen chloride, HCl , is an excellent conductor, while pure liquid hydrogen chloride does not conduct electricity?
- Water is an electrolyte.
 - Hydrogen chloride ionizes in water.
 - Hydrogen chloride is a non-electrolyte.
 - Hydrogen chloride releases electrons in water.
5. A mixture demonstrates a positive Tyndall effect (light beam is scattered by particles in mixture) but does not settle out therefore you could conclude the mixture is a ...
- solution
 - suspension
 - colloid
 - pure substance
6. When a mixture was filtered, nothing appeared on the filter paper but when the mixture was evaporated, there was a residue left over. Therefore, the mixture is a ...
- solution
 - suspension
 - colloid
 - pure substance

Use the drawings below for questions 7-10 representing beakers of aqueous solutions. Each \cdot represents a dissolved solute particle.



- Which solution is most concentrated?
- Which solution is least concentrated?
- Which two solutions have the same concentration?

10. When Solutions E and AB are combined, the resulting solution has the same concentration as solution_____.
11. Which step is not part of making a 1 L of 1M NaOH solution
- Use a volumetric flask to make your solution
 - Use 40 g of NaOH
 - Use exactly 1 L of water
- I only
 - II only
 - III only
 - all of the above
 - none of the above
12. How many grams of KOH are in 500 mL of a 2 M solution?
- 14 g
 - 28 g
 - 56 g
 - 112 g
 - 560 g
13. Which equation represents the dissolving of Magnesium chloride, MgCl_2 , in water?
- $\text{MgCl}_2(s) \rightarrow \text{Mg}^{2+}(aq) + \text{Cl}_2^-(aq)$
 - $\text{MgCl}_2(s) \rightarrow \text{Mg}^{2+}(aq) + 2\text{Cl}^-(aq)$
 - $\text{MgCl}_2(s) \rightarrow \text{Mg}(aq) + \text{Cl}_2(aq)$
 - $\text{MgCl}_2(s) \rightarrow \text{Mg}(aq) + 2\text{Cl}(aq)$
14. Which of the following is **not** characteristic of acids?
- reacts with some metals to produce hydrogen gas
 - reacts with litmus to form a red color
 - reacts with phenolphthalein to form a pink color
 - reacts with carbonates in rock to make carbon dioxide gas
15. In an acidic solution
- $[\text{H}^+] = [\text{OH}^-]$
 - $[\text{H}^+] < [\text{OH}^-]$
 - $[\text{H}^+] > [\text{OH}^-]$
 - $[\text{H}^+] = 0 \text{ M}$
16. When an acid is added to a solution of a base, what change in pH of the solution could be observed?
- an increase from 7 to 8
 - an increase from 3 to 8

- c. a decrease from 7 to 6
d. a decrease from 9 to 5
17. Which pH is nearest to neutral?
a. 1.0
b. 0.0
c. 6.5
d. 8.0
18. Which solution has the **lowest** pH?
a. 0.1 M HCl
b. 0.1 M NaOH
c. 0.1 M NH₃
d. 0.1 M HC₂H₃O₂
19. According to the Arrhenius definition, the reaction of an acid with a base always produces
a. water.
b. a precipitate.
c. an acid salt.
d. a soluble salt.
e. a basic salt.
20. Solutions of strong acids and strong bases are alike in that they both
a. taste sour.
b. are electrolytes.
c. taste bitter.
d. turn red litmus blue
21. The combination of hydronium ions with hydroxide ions is known as
a. catalysis.
b. hydrogenation.
c. hydrolysis.
d. neutralization.
e. electrolysis
22. When ammonia, NH₃, is added to water, this reaction occurs.
$$\text{NH}_3(g) + \text{H}_2\text{O}(l) \rightarrow \text{NH}_4^+(aq) + \text{OH}^-(aq)$$

What change occurs in the solution?
a. The concentration of OH⁻(aq) decreases.
b. The concentration of H⁺(aq) decreases.
c. The solution becomes acidic.
d. The pH will drop below 7.
23. The hydrogen sulfate or bisulfate ion HSO₄⁻ can act as either an acid or a base in water solution. In which of the following equations does HSO₄⁻ act as an acid?
a. $\text{HSO}_4^- + \text{H}_2\text{O} \rightarrow \text{H}_2\text{SO}_4 + \text{OH}^-$

- b. $\text{HSO}_4^- + \text{H}_3\text{O}^+ \rightarrow \text{SO}_3 + 2\text{H}_2\text{O}$
- c. $\text{HSO}_4^- + \text{OH}^- \rightarrow \text{H}_2\text{SO}_4 + \text{O}^{2-}$
- d. $\text{HSO}_4^- + \text{H}_2\text{O} \rightarrow \text{SO}_4^{2-} + \text{H}_3\text{O}^+$

24. Which of the following is not true for a solution at 25°C that has a hydroxide concentration of $2.5 \times 10^{-6} \text{ M}$?
- a. The solution has a pH of 8.4
 - b. The solution is acidic.
 - c. The solution is basic.
 - d. The $[\text{H}^+]$ is $4 \times 10^{-9} \text{ M}$.
25. Which of the following indicates the most basic solution?
- a. $[\text{H}^+] = 1 \times 10^{-10} \text{ M}$
 - b. $\text{pOH} = 6.7$
 - c. $[\text{OH}^-] = 7 \times 10^{-5} \text{ M}$
 - d. $\text{pH} = 4.2$
26. What is the equivalence point in an acid-base titration?
- a. It is the point at which the acid and the base have the same number of moles.
 - b. It is the point at which the indicator changes color.
 - c. It is the point at which equal concentrations of acid and base have reacted.
 - d. Both answers a and c are correct.
 - e. Answers a, b, and c are correct.
27. Assuming complete ionization, the pH of a 0.01 M HCl solution would be
- a. 1
 - b. 2
 - c. 3
 - d. 4
 - e. 0.5
28. What is the hydrogen ion concentration, $[\text{H}^+(\text{aq})]$, in a 0.2 M aqueous solution of nitric acid, HNO_3 ?
- a. $1 \times 10^{-2} \text{ mol}\cdot\text{L}^{-1}$
 - b. $2 \times 10^{-2} \text{ mol}\cdot\text{L}^{-1}$
 - c. $2 \times 10^{-1} \text{ mol}\cdot\text{L}^{-1}$
 - d. $2 \times 10^{-12} \text{ mol}\cdot\text{L}^{-1}$
29. The pH of a human blood sample is 7.30. What is concentration of OH^- in blood?
- a. $5.01 \times 10^{-8} \text{ M}$
 - b. $2.0 \times 10^{-7} \text{ M}$
 - c. $7.3 \times 10^{-7} \text{ M}$

- d. $5.01 \times 10^{-5} M$
 e. $2.0 \times 10^7 M$

30. Which list contains only strong acids?

- a. HNO_3 , HF , HClO_4
 b. H_3PO_4 , HClO_4 , NH_3
 c. HCl , HNO_3 , H_3PO_4 ,
 d. HCl , H_2SO_4 , HNO_3
 e. H_2SO_4 , NaOH , H_3PO_4

31. Billy and Shawendy are doing a precipitate lab like the one that you did in this unit. They are going to test the following solutions,

<u>solution</u>	<u>solute</u>
A	K_3AsO_4
B	CaC_2O_4
C	AgNO_3
D	NaNO_3

a. What is the charge on the AsO_4 ion? _____ (2 pts)

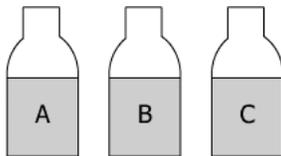
The results of Billy and Shawendy's lab are summarized below.

<u>solutions mixed</u>	<u>results</u>
A + C	a fine white precipitate forms
A + D	no rxn
B + C	a chunky white precipitate forms
B + D	no rxn

b. Write the complete, balanced equation (including states) for the reaction between solutions A and C. (6 pts)

c. Write the complete, balanced equation (including states) for the reaction between solutions B and C. (6 pts)

32. Dr. Doody gave Billy and Shawendy three bottles labeled A, B, and C. One of them contains an acid, one of them contains a base, and the other is pure water.



Billy and Shawendy did the following tests:

Test 1: Billy added a piece of zinc to a sample from each bottle.

Results: Bottle A – fizzing is observed

Bottle B – no change

Bottle C – no change

Test 2: Shawendy added a drop a phenolphthalein (phth) indicator to a sample from each bottle.

Results: Bottle A – no change
 Bottle B – turns bright pink
 Bottle C – no change

Billy concluded Bottle A was an acid, Bottle B was a base and Bottle C was water.

Shawendy concluded Bottle A was a base, Bottle B was water and Bottle C was an acid.

Who is correct? Give evidence for you answer (8 pts)

33. The following data was collected for the titration of 0.200 M H_2SO_4 with a solution of NaOH.

	trial 1	trial 2	trial 3
inital volume of H_2SO_4	0.00 ml	10.55 ml	21.20 ml
final volume of H_2SO_4	10.55 ml	21.20 ml	35.70 ml

initial volume of NaOH	0.00 ml	14.75 ml	29.54 ml
final volume of NaOH	14.75 ml	29.54 ml	39.70 ml

- Write the neutralization reaction that happens when H_2SO_4 reacts with NaOH. (4 pts)
- Use the data above to **best** determine the concentration of NaOH. (14 pts)

APPENDIX C

CLASS TIME LOG 50 MINUTE PERIOD

Time Log

Day _____ Date _____ Period _____

Recorder _____

	Time Interval				
	0-10 min.	11-20 min.	21-30 min.	31-40 min.	41-50 min.
Classroom Activity	Warm-up activity				
	Go over previous night's homework				
	Lecture new content				
	Guided and independent practice and/or lab activity/demo				
	Q & A time on video				
	Other	Other	Other	Other	Other

Time Tally

Warm-up activity _____

Go over previous night's homework _____

Lecture new content _____

Guided and independent practice and/or lab activity/demo _____

Q & A time on video _____

Other _____

APPENDIX D

STUDENT SURVEY 1

Student Survey 1, Student Response to Flipped Classroom
(Administered before implementation of flipped classroom)

Please answer the following questions as accurately as possible. Your participation or non-participation will not affect your grade or class standing.

1. To the best of my knowledge, my current grade in chemistry is...
(A, B, C, D, F,)
2. Overall, my attitude toward chemistry class is positive.
(Disagree to Agree, 1 to 5)
3. I prefer to listen to a lecture face-to-face.
(Disagree to Agree, 1 to 5)
4. I prefer using class time for problem solving activities, rather than listening to a lecture.
(Disagree to Agree, 1 to 5)
5. I feel that moving lecture material out of class and having more time to work in groups and/or with the teacher is a beneficial use of course time.
(Disagree to Agree, 1 to 5)

APPENDIX E

STUDENT SURVEY 2

Student Survey 2, Student Response to Flipped Classroom
(Administered at mid-point of implementation of flipped classroom)

Please answer the following questions as accurately as possible. Your participation or non-participation will not affect your grade or class standing.

1. To the best of my knowledge, my current grade in chemistry is...
(A, B, C, D, F,)
2. Overall, my attitude toward chemistry class is positive.
(Disagree to Agree, 1 to 5)
3. I prefer to listen to a lecture face-to-face.
(Disagree to Agree, 1 to 5)
4. I prefer using class time for problem solving activities, rather than listening to a lecture.
(Disagree to Agree, 1 to 5)
5. I feel that moving lecture material out of class and having more time to work in groups and/or with the teacher is a beneficial use of course time.
(Disagree to Agree, 1 to 5)
6. Do you think the flipped classroom technique helped you learn chemistry more efficiently than what was done last semester?
Yes/No/Yes, but...
If you answered “yes, but...” please explain here, otherwise proceed to the next question.
7. I watched this many of the 5 videos?
(0, 1, 2, 3, 4, 5)
8. I watched each video typically this many times?
(0, 1, 2, 3, more than 3)
9. Generally, I watched the video when...
(it was assigned, after it was due but I still watched it, never bothered, it was assigned and then again to review)
10. Did you watch the video straight through, or watch it in pieces and take breaks?
(Straight through without pausing; Watched different sections at different times; Straight though, then reviewed unclear sections; All in one sitting, but I would pause and review certain sections)
11. The time spent in class was helpful to your understanding of the concepts?
(Disagree to Agree, 1 to 5)

12. I had a difficult time following this video content.
(Disagree to Agree, 1 to 5)
13. I felt prepared to complete introductory problems in class after listening to the video content.
(Disagree to Agree, 1 to 5)
14. I feel that more time needs to be spent at the beginning of class reviewing the video content.
(Disagree to Agree, 1 to 5)

Let it rip: Love it, hate it, write whatever you want. You won't hurt my feelings and it won't affect your grade, have at it.

APPENDIX F

STUDENT SURVEY 3

Student Survey 3, Student Response to Flipped Classroom
(Administered at The end of implementation of flipped classroom)

Please answer the following questions as accurately as possible. Your participation or non-participation will not affect your grade or class standing.

1. To the best of my knowledge, my current grade in chemistry is...
(A, B, C, D, F,)
2. Overall, my attitude toward chemistry class is positive.
(Disagree to Agree, 1 to 5)
3. I prefer to listen to a lecture face-to-face.
(Disagree to Agree, 1 to 5)
4. I prefer using class time for problem solving activities, rather than listening to a lecture.
(Disagree to Agree, 1 to 5)
5. I feel that moving lecture material out of class and having more time to work in groups and/or with the teacher is a beneficial use of course time.
(Disagree to Agree, 1 to 5)
6. Do you think the flipped classroom technique helped you learn chemistry more efficiently than what was done last semester?
Yes/No/Yes, but...
If you answered “yes, but...” please explain here, otherwise proceed to the next question.
7. I watched this many of the 3 videos?
(0, 1, 2, 3)
8. I watched each video typically this many times?
(0, 1, 2, 3, more than 3)
9. Generally, I watched the video when...
(it was assigned, after it was due but I still watched it, never bothered, it was assigned and then again to review)
10. Did you watch the video straight through, or watch it in pieces and take breaks?
(Straight through without pausing; Watched different sections at different times; Straight though, then reviewed unclear sections; All in one sitting, but I would pause and review certain sections)
11. The time spent in class was helpful to your understanding of the concepts?

- (Disagree to Agree, 1 to 5)
12. I had a difficult time following this video content.
(Disagree to Agree, 1 to 5)
13. I felt prepared to complete introductory problems in class after listening to the video content.
(Disagree to Agree, 1 to 5)
14. I feel that more time needs to be spent at the beginning of class reviewing the video content.
(Disagree to Agree, 1 to 5)
15. Which of the two types of classrooms do you prefer working in?
(Traditional, Flipped)
16. Was it beneficial having additional time in class to work with the instructor and your classmates?
(Yes, No, Didn't make a difference)
17. In terms of the amount of content that was flipped, would you prefer more or less?
(None, I tried flipping but it didn't work for me; None, I didn't watch the videos; I liked it the way it is; Flipping worked for me but I would like more videos; Flipping worked for me but I would like less videos)
18. As you know, we will be going to block at the start of your senior year with 90 minute periods every other day. By that time, you will also have your own internet capable tablet device with you every day, or one-to-one, one device for every student. Which would likely mean you text would be digital. Given that, what would you think of a flipped classroom given those changes?
(I think a flipped classroom will work best on block with a one-to-one device, I think a traditional classroom we use now would be the best choice, I think some third option will work best)
19. I would like to briefly interview some of you when we return from break. I can only interview students who have been in this class for all of second and third quarters. Given that, would you be interested in being interviewed?
(Yes, No)

APPENDIX G
STUDENT INTERVIEWS

Initial student interview questions:

Some prompts to start the conversation.

Your participation or non-participation will not affect your grade or class standing.

1. What is the first thing that comes to your mind when you think about your experience working in a flipped classroom? Can you explain/elaborate?
2. Did the flipped format make it easier or more difficult to learn the content? Can you give some reasons why?
3. Which of the two types of classrooms do you prefer working in? Can you explain/elaborate why?
4. Was it beneficial having additional time in class to work with the instructor and your classmates? Can you explain/elaborate why?
5. In terms of the amount of content that was flipped, would you prefer more or less? Can you explain/elaborate why?
6. Is there anything else you would like to add about your experience working in the flipped classroom?

APPENDIX H
UNIT SCHEDULES

Unit 5 Gases & Equilibrium	
Day	Topic/Activity
1	Gas demos and concepts
2	Gas ChemThink
3	Gas PhET activity
4	Gas PhET activity
5	Combined Gas Law
6	Dalton's Law
7	Molar Volume Lab
8	Ideal Gas Law
9	Gas Density
10	Gas Stoichiometry
11	Gas Workshop
12	Gas Quest
13	Gas Lab Practical
14	Equilibrium Simulation
15	Equilibrium Concepts
16	Le Chatelier
17	Equilibrium Lab
18	Equilibrium Workshop
19	Review
20	Unit Test

Unit 6 Solutions and Acids & Bases	
Day	Topic/ Activity
1	Solution concepts
2	Molarity
3	Solubility Lab
4	Molarity Workshop
5	Solubility Lab Assessment
6	Acid Base Properties Lab
7	Strong and Weak
8	pH concepts
9	Acid Base Calculations
10	Titration Lab 1
11	Titration Lab 2
12	Titration Lab 2
13	Titration Lab 3
14	Acid Base Workshop
15	Review
16	Acid Base Lab Practical
17	Unit Test