

THE IMPLEMENTATION OF A FLIPPED CLASSROOM TO INCREASE  
STUDENT ACHIEVEMENT AND ENGAGEMENT IN  
HIGH SCHOOL CHEMISTRY STUDENTS

by

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A professional paper submitted in partial fulfillment  
of the requirements for the degree

of

Master of Science

in

Science Education

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## ABSTRACT

Over the past few years, I have noticed a decrease in concentration, engagement, and participation in my classroom. It seemed that students were easily distracted when they were not actively participating in activities. In an effort to find a solution to this problem, a flipped classroom was implemented in three general chemistry classes during the spring semester. For four weeks, during two out of seven chemistry units, the students were asked to watch informational videos outside of class and participate in engaging activities during class, a “flip” from traditional methods. There were no statistical differences in the summative assessment scores between the students in the flipped classroom versus the traditionally taught classroom. However, students gained a sense of responsibility for their learning, and I have become a more reflective teacher as a result of this project.

## INTRODUCTION AND BACKGROUND

Rancocas Valley Regional High School (RV) is located in Mount Holly, NJ, a poor urban town with an average household income of \$55,333 a year. The other sending districts are wealthier, with average household incomes between \$77,000 and 85,000 (citydata.com). It seems ironic that this amazing high school is located in the poorest of all the towns that attend RV. There are about 2,300 students enrolled with many different ethnicities, religions, and backgrounds. The ethnicities reported are 4% Asian, 6% Hispanic, 28% African American, and 59% Caucasian. There are students who come from very wealthy families and 22% of students qualify for free or reduced lunch, creating an economically diverse high school (Public School Review, 2012). While we have some of the toughest advanced placement classes, we also have an abnormally large special education population. These students are integrated into the general education classrooms equipped with a special education co-teacher.

The school administration and leaders have created a unique culture based on pride. Despite vast differences between the students' economic and educational levels, there is an underlying sense of family within RV. Support from students, parents, teachers, and administrators is undeniably strong for a school. This was my third year teaching at this institution, and I hope to continue here for many years. The support as a teacher has been wonderful, but I believe the enabling type of support students received from many teachers was actually inhibiting their education. My idea was educate the students, by giving them tools to support themselves and each other in their own learning and discovery.

I teach lower level chemistry, general chemistry, and general environmental science. A part of my philosophy as a teacher is that the one who is doing the work is the one who is learning. However, I have seen a movement toward students relying on teachers to get them through their daily responsibilities, especially in the lower level classes. Students have been observed doing minimal work, complaining, and being coddled along the way. Traditional classrooms include a teacher who lectures and professes knowledge to the students, i.e. the *sage on the stage*. My research was based on a different model aimed at increasing participation, student engagement, and responsibility for learning in my classroom.

For this research project, I reversed the typical teacher/student roles by implementing the flipped or inverted classroom model. In this model, students watched short instructional videos outside the classroom through some sort of media. This enabled the students to become more active participants; spending class-time problem solving and completing tasks during cooperative work, and working on other student-centered activities. This model requires students do more work outside of class time, something most are trying to avoid. The *sage on the stage* now becomes the *guide on the side* allowing students to become independent learners with more useful guidance from their teacher. While access to technology for some students was a struggle, I helped them to make the flipped classroom feasible. In comparing traditional classroom and flipped classrooms, I wanted to address one essential question, *To what extent does student achievement increase in a flipped classroom compared to a traditional method of teaching?* Determining if student engagement increases during the flipped classroom

model also became important to research. After my students had experienced both models of teaching, I wanted to see which model they preferred. These thoughts lead to two secondary questions.

- *Does student engagement increase in a flipped classroom setting?*
- *Do students prefer a student-centered classroom atmosphere?*

### CONCEPTUAL FRAMEWORK

“Learning, regardless of how it is defined, is ultimately the responsibility of the learner, not the teacher” (Kizlik, 2014, p.1). A flipped classroom model requires students to be more responsible for their learning as they watch instructional videos at home. Back in the classroom, students apply the knowledge they learned through practice under the teacher’s guidance. This model is based on the theory of student-based learning in the classroom. The constructionist theory of learning states that the learner must create connections between new information and memorized information. This allows the learner to understand new material which then becomes knowledge. The original founder of this interactive learning theory refers to it as allowing the teacher’s role to change from the *sage on the stage* to the *guide on the side* (King, 1993). Baker (2000) transformed this theory and created what is now called the flipped classroom. He used early principles to apply this interactive, student-based learning environment,

- 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 than on recall of facts 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.

While this was not a fine-tuned instructional method, it gave the next wave of researchers a basis for their discovery. Jonathan Bergmann and Aaron Sams accidentally discovered the flipped classroom after posting videos of their lessons for students who missed class. They noticed students who had been present in class were watching the videos as well. Students seemed to enjoy learning class material through media, which made this approach gain popularity. This fairly new instructional method has attracted many teachers looking to involve more students in their learning (Tucker, 2012).

While there is no one way to flip a classroom, it basically involves students watching teacher-created lecture videos at home and later, completing assignments or activities during class time alongside their peers. The teacher becomes another resource in the classroom instead of the lecturer. An advantage of this approach is that class time is made available for more hands-on activities, problem-based collaborative learning, and increased student-teacher interaction. This also allows struggling students to get assistance with their work-related problems one-on-one with the teacher during class time instead of becoming frustrated at home (Tucker, 2012). In the flipped approach, students tend to misbehave less because their purpose is to focus on learning and applying the information they gathered from the videos (Bergmann & Sams, 2012).

As the flipped classroom approach is utilized by more teachers, issues are being revealed and addressed. Some students take time to acclimate to this different kind of learning method, and it does not work for every student. The most difficult issue is not all students have resources at home to watch videos via the internet (Tucker, 2012;

Noonoo, 2012). With the ever-booming technology industry and increasing access to the internet, hopefully this will not continue to be an issue (Herried & Schiller, 2013).

Glynn (2013) conducted a study to determine if student achievement and attitude toward science increased using the flipped model versus the traditional teaching method. He found that many summative test scores of students in a flipped classroom were not substantially greater than those of students in a traditional classroom. However, he mentioned a flaw to this experiment was that his teaching style already incorporated many student-based learning activities. The only part that changed was his instruction platform. Instead of lecturing during class, students were required to watch a video at home that covered the content. Marginal improvement in student's attitudes toward science was also recorded.

Another study examined student achievement and stress level during the inverted classroom approach. While unit assessments only showed a marginal increase from traditional classroom students, students' attitudes toward the flipped classroom were positive. Surveys showed students' stress levels were dramatically lower in the flipped classroom than their other classes. They reported less stress because they could ask questions during class after viewing the instructional video at home. While Marlowe and Glynn's work did not prove flipped classrooms were better than traditionally taught classrooms, they did prove the flipped classroom to be an effective teaching method (Marlowe, 2012).

Studies by Bergmann and Sams have shown great success implementing the flipped classroom with their own students. However, they mention that there is more to a

flipped classroom than making videos and having students watch them. Integrating watch-at-home videos into the overall approach of student-based learning is key (Tucker, 2012). However, a successful flipped classroom also includes stimulating and meaningful activities during class time (Bergmann & Sams, 2012).

The future of the flipped classroom continues to be bright. Herreid and Schiller (2013) believe if the model gains enough popularity and teachers practice it correctly, it is a win-win. Nothing could be better than engaging more students and incorporating real-world problem solving in the classroom. If more teachers adopt this approach, the expectations of learning and education could be changed forever.

#### METHODOLOGY

The treatment period included the implementation of the flipped classroom model. This flipped classroom model consisted of students watching informational videos for homework and providing them with student-based, experiential activities during class time. All class lectures were distributed through the internet via YouTube and Screencast-O-Matic. 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 (Appendix A).

Rancocas Valley Regional High School participates in block scheduling. There are two semesters each year, with five, 72-minute blocks (classes) each day. Usually a student has a subject for only one semester during the year. The flipped classroom took place during spring semester during two units in three classes of general chemistry; Block 2 with 28 students, Block 3 with 8 students and Block 5 with 30 students. There were 66

students total in the treatment group; 36 females and 30 males. While the population of these classes is mainly Caucasian, there are some minorities present (Table 1).

Table 1  
*Class Demographics: Ethnicity*

Percentage of Students	Race			
	Hispanic	Asian	Caucasian	African American
Block 2	11%	0%	71%	18%
Block 3	25%	0%	63%	13%
Block 5	7%	3%	60%	30%

Note. ( $N=66$ )

In the first week of the class, a Chemistry Pretest was administered to establish a baseline of student knowledge of chemistry content before the treatment period (Appendix B). I compared pretest averages to a traditionally taught chemistry class (control group) to verify there was no difference in prior knowledge of chemistry. Averages were compared using a t-test to determine any statistical differences.

In order to gather data about student internet access at home and their thoughts about the conditions of a flipped classroom, I administered a Student Pre Survey via Google Forms during the first unit (Appendix C). A Likert scale was used for the second portion of the questions. In this scale, a 5 signified *strongly agree*, a 4 *agree*, a 3 *neutral*, a 2 *disagree*, and a 1 *strongly disagree*. I flipped the classroom during the second and third unit of general chemistry, which took place in February and March. Data was analyzed by identifying patterns and determining averages for each scale rating.

Two units were flipped in order to make any adjustments after unit one, so that the difficulty of one unit would not skew overall results. Unit two contained easier content consisting of defining and identifying changes within matter. Unit three's content was more difficult and covered the parts of the atom and developing theories

about atoms. This would allow the students to be more comfortable to this way of instruction after Unit 2 and the data for Unit 3 would be less impacted by the change of instructional methods.

At the end of both units, comprehensive assessments were administered (Appendix D & E). I compared test scores from the treatment group to a general chemistry class I taught the previous semester using the traditional method. An unpaired t-test was used to compare the non-treated and treated assessment scores and to determine statistical significance.

At the conclusion of the treatment period, the Student Post Survey was given to students via Google Forms (Appendix F). Students had ample time to complete the survey. This survey was administered to gather students' thoughts and feelings about their participation in the flipped classroom. It also allowed them to critique the flipped classroom in general. A Likert scale was used for the first portion of the questions, with the same scale as the Student Pre Survey. To analyze the data collected from the students, the average scale ratings were calculated for the class. Responses to questions that appeared on both surveys were compared and non-numeric similarities and differences were noted within the data.

At the beginning of the fourth unit, student interviews were conducted in the back of the room while other students were occupied (Appendix G). Six students were chosen, three male and three female. Within genders, students were randomly chosen using note cards with their names written on them. Data collected from the interviews was used to answer my focus questions and themes within responses were reported in my findings.

The last data collection tool used was teacher observations during class time. At least once a week during a specific activity I counted the number of students who were engaged and actively participating and recorded the percentages. I had also collected this data during a class I taught last semester. I compared the percentage of engaged students in the flipped classroom to those from the traditionally taught class last semester, to answer my secondary questions. The data from all of these instruments was used to answer my focus questions in the Triangulation Matrix (Table 2).

Table 2  
*Triangulation Matrix*

Focus Question	Data Source 1	Data Source 2	Data Source 3	Data Source 4
<i>Primary Question:</i> What is the effect on student’s achievement in a flipped classroom compared to a traditional method of teaching?	Summative unit assessments	Student Pre and Post Surveys	Student Interview Questions	Teacher Observations
<i>Secondary Questions:</i> Does student engagement increase in a flipped classroom setting?	Student Pre and Post Surveys	Student Interview Questions	Teacher Observations	
Do students prefer a student-centered classroom atmosphere?	Student Pre and Post Surveys	Student Interview Questions	Teacher Observations	

## DATA AND ANALYSIS

Average pre-test scores between the flipped and traditional classes were considered not statistically significant,  $p\text{-value } 0.495 \leq \alpha$ . The traditional class average was a 23% while the flipped class was 24%. This indicated no difference in knowledge between treatment and the control group at the beginning of this action research project. Two students reported they did not have any device at home to watch videos on, but were able to use a school computer before or after school, so all students in the treatment groups were able to participate.

Students use the internet often to gain knowledge and skills. Ninety eight percent of students reported using the internet to learn non-academic topics and 88.7% have used it to learn an academic topic ( $N=51$ ). Twenty five percent of students said they never even bothered to watch the video when it was assigned and another 25% responded that they watched the videos eventually, but not when they were assigned.

Average summative assessment scores show little difference for students in the traditionally taught classroom versus the flipped classrooms (Figure 1). Unit 2 and Unit 3 Assessment averages for treatment classes were 82% and 75%, respectively. Treatment class assessment averages decreased five and two percent compared to non-treatment test averages. Block three had the lowest test average overall and that was the smallest class consisting of only nine students.

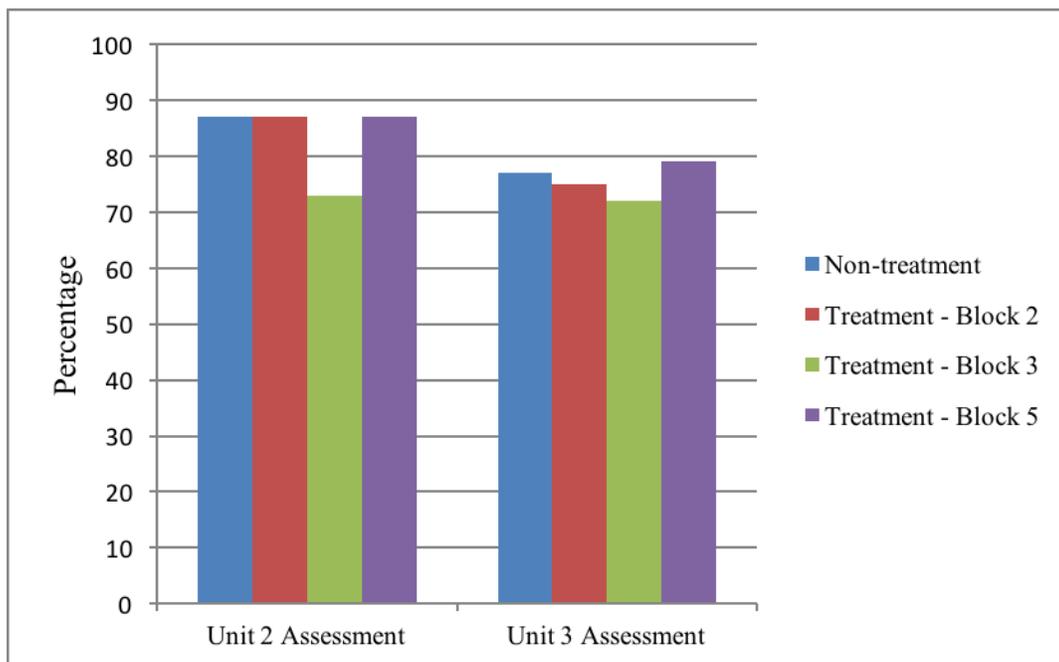


Figure 1. Average score on unit assessments, ( $N=66$ ).

Pre and Post Student Survey data in Figure 2 suggest that after students experienced the flipped classroom, more of them thought it was beneficial to move lecture out of the classroom. In the Student Post Survey, 7% more students strongly agreed that it was beneficial to move lecture out of class time. A combined 52.2% of students *agreed* or *strongly agreed* class time was used to better understand the chemistry concepts.

Flipping the classroom changed the students' attitude toward chemistry. More students formed an opinion about chemistry during the treatment period, and their feelings turned more negative as the majority percentage of students *disagreed* and *strongly disagreed* that they had positive feelings towards chemistry after having experienced the flipped classroom shown in Figure 2. Sixty-eight percent of students

responded ‘no’ when asked if they thought the flipped classroom technique helped them learn chemistry more efficiently.

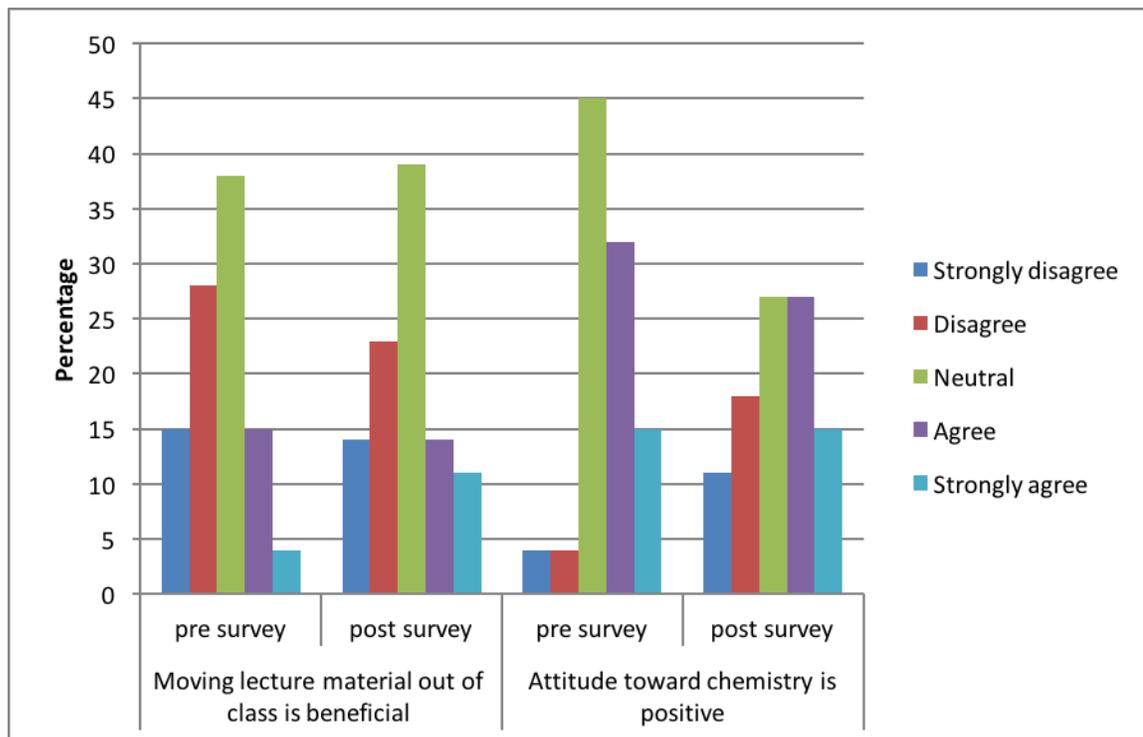


Figure 2. Student pre and post survey questions: benefit and attitude, ( $N=66$ ).

While using the flipped classroom model, students were more engaged during class time. Students were observed and recorded if they were engaged in the lecture. On average, 69% of the students in the non-treated group were engaged during lecture. Ninety-four percent of the time, the students in the flipped classroom environment were on task and engaged in the activities during class. When a student was asked what their classroom experience was like during the flipped classroom, one responded, “There were more hands on activities in the classroom, and it was more engaging.” On the Student Pre Survey, 83% of the students *strongly agreed* or *agreed* that they would be more engaged doing activities during class time. However when asked if they actually were

more engaged during class time, students responded differently on the Student Post Survey. Forty one percent of students responded *neutral* and only 18% of students answered *agreed* and 7% of students answered *strongly agreed*.

Table 3

*Average Percentage of Students Engaged During Class*

Date	Feb 25 <sup>th</sup>	Feb 29 <sup>th</sup>	March 9 <sup>th</sup>	March 16 <sup>th</sup>	Average
Non-treated (%)	70	83	53	70	69
Treated (%)	90	89	100	95	94

On the Student Pre and Post Survey, students were asked the same two questions about preferring to listen to lecture in class or to participate in problem solving activities. After treatment, 29% more students said they preferred to listen to a lecture face to face than before the treatment period. When students were asked if they preferred problem solving in class rather than listening to a lecture, varying results were recorded. Before treatment, 64% of students either *agreed* or *strongly agreed* that they would prefer problem solving during class. After treatment, 43% of students were *neutral* and only 35% of students either *agreed* or *strongly agreed* with the statement (Figure 2). A student responded to the question about the flipped classroom atmosphere during an interview, “I felt that the videos were very educational but I would much rather have my teacher teach me the lessons instead of learning it on my own. I felt the content did not stick in my head as well as it would have if my teacher taught it.” The Student Pre and Post Survey results are reported in Figure 2.

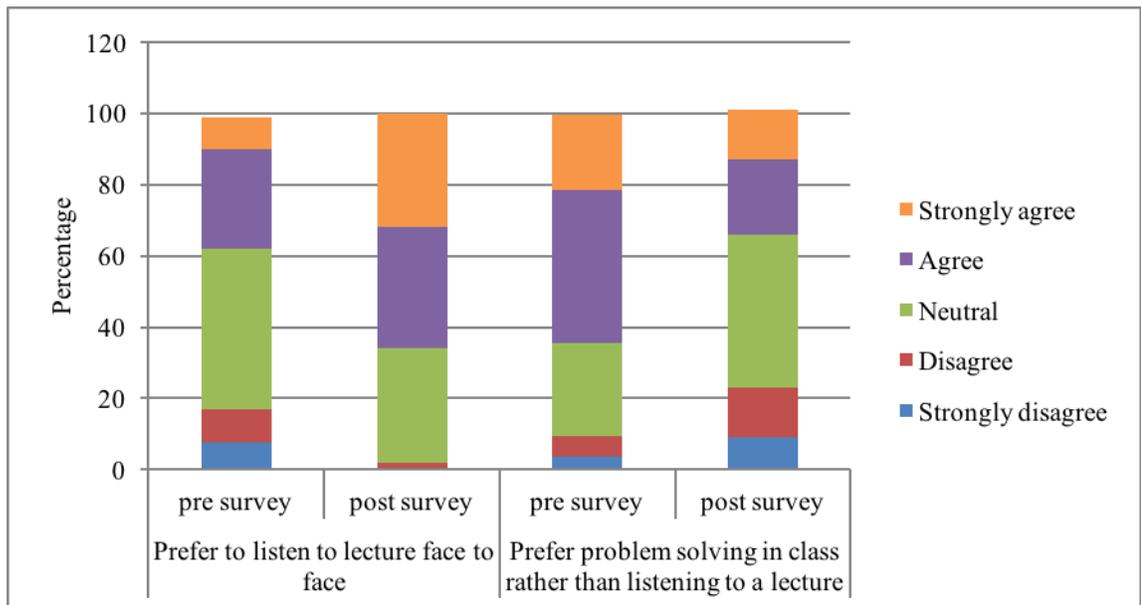


Figure 3. Student pre and post survey question: lecture face to face, (N=66).

Data collected in the Student Post Survey indicate the majority of students did not prefer the flipped classroom experience. Ninety-one percent of students preferred the traditionally taught classroom while only 9% chose the flipped classroom. When asked to describe their experience in the flipped classroom, one student remarked, “We definitely got more class time to do activities and experiments but I would still rather the traditional classroom setting than the flipped.” Several students mentioned that they do not ever want to participate in a flipped classroom again. However, some students mentioned they really enjoyed the flipped classroom experience and would enjoy doing it again, “I would actually love to do this method again.”

#### INTERPRETATION AND CONCLUSION

The results were surprising to me. I expected my students to show a greater understanding of the material because they were actually engaged in more meaningful hands-on activities and lab experiments. However, there was not a significant difference

in unit summative assessment scores versus a traditionally taught classroom. I wonder if this is because some students did not watch the videos when they were assigned, and were not really engaged in activities, but were trying to figure out what the lesson covered.

From my observations, the majority of students did not prefer the flipped classroom. They complained about having to watch the videos, and when I would check their notes, not many students had taken them. Students immediately formed an opinion about the flipped method and that determined their success during those units; Students with a negative opinion did not seem as motivated, while students who enjoyed the flipped method were frustrated by their classmates' negative reactions. I was very surprised how hostile some of my students were in regards to learning in a different manner, but I attribute this to the change in teaching methods in the middle of the semester. Once they experienced the traditional classroom in Unit 1 and then experienced the flipped Units 2 and 3, they much rather preferred the traditional classroom. I wonder if students would have different feelings about the method if the entire semester was flipped, and they did not experience a traditionally taught chemistry classroom at all. I truly think this was because the flipped method forced students to be responsible for their learning, but the many students would rather just absent mindedly take notes in class.

Students were definitely more engaged during class time, which was one of my secondary questions and a primary goal. Students would come in the door and ask "What are we doing today?" in an excited voice, rather than the normal, "Are we taking notes

again today?” Data collected about engagement during class was contrary to what my students thought. In the Student Pre Survey, a majority of students said they would be engaged during class if activities and labs were on the agenda, but post survey answers about engagement in the flipped classroom were neutral. From the observations I collected while students were working, they were more engaged doing activities rather than taking notes during a traditionally taught class.

Because of the resistance against the flipped classroom learning style, students developed negative feelings towards chemistry as a subject. This was obviously not the intent, but data showed students going from a *neutral* feeling towards chemistry to negative attitude. This could be because of the flipped classroom, or it could be because the material was becoming more difficult and students were falling behind which led them to form negative feelings toward the subject. Either way, my intent was to generate positive feelings about the subject so that students stay interested and engaged during class time and, in a perfect world, develop a love for chemistry.

#### VALUE

One of my goals as a teacher is to promote the love of self-learning in my students. This study conjured a feeling of responsibility within my students. Whether they watched the videos right away or not, the responsibility of learning the material was on them, which forced them to become self-learners. I reinforced the idea that college will be like this; a lot of learning on their own. This led to valuable conversations about their future in college or the workforce and the responsibility they would have for their learning and training. I taught them to learn something on their own and from that, ask

questions for clarity and deeper understanding. I think after going through the flipped classroom, my students will continue to use YouTube as a learning resource. My hope is that they will also be more open to different learning styles and techniques.

Personally, this action research-based classroom made me a much more reflective teacher. Every lesson I taught, I reflected on and wrote down what worked and what did not work. As a new teacher, I never even thought about a lesson after I taught it; I was just trying to stay focused day to day. This project has given me a desire to be a reflective teacher and hopefully further prepare my students for college and life beyond school. I have raised my expectations of myself and my students and allowed them to ask questions instead of giving them answers.

As for the actual flipped classroom, I loved this teaching method. When a student was absent, I did not have to spend additional time re-teaching an entire topic over again. The videos presented missed lessons, and afterward, they could come to me for clarity or extra help. I felt that more students who needed extra help could be reached on a daily basis during class. I enjoyed this project and feel I have gained valuable experience and knowledge about my teaching philosophy. One of the lessons I learned is to allow my students to discover on their own so they become more responsible for their own learning.

This project also made me a highly effective teacher in many categories on our state evaluation system. Presenting multiple instructional varieties and sharing the results with fellow colleagues has sparked interest from administrators and other teachers at my school. How I was taught chemistry and how I am teaching chemistry are so very

different. Technology has opened up new ways material can be presented, shared, and produced in any classroom. As teachers we have to expand our teaching styles and stay current. Just as we used to go to libraries to find answers to questions, students now go to the Internet. Reflecting and identifying an issue in my classroom, researching solutions, planning to implement a change, evaluating data, and interpreting results was a process I will continue to think about throughout my career, for that is the nature of a scientist.

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APPENDICES

APPENDIX A  
IRB EXEMPTION LETTER



**INSTITUTIONAL REVIEW BOARD**  
For the Protection of Human Subjects  
FWA 0000165

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**MEMORANDUM**

**TO:** Julie Welde and John Graves  
**FROM:** Mark Quinn, Chair *Mark Quinn*  
**DATE:** November 16, 2015  
**RE:** "The Implementation of a Flipped Classroom to Increase Student Achievement and Engagement in High School Chemistry Students" [JW111515-EX]

The above research, described in your submission of November 10, 2015, is exempt from the requirement of review by the Institutional Review Board in accordance with the Code of Federal regulations, Part 46, section 101. The specific paragraph which applies to your research is:

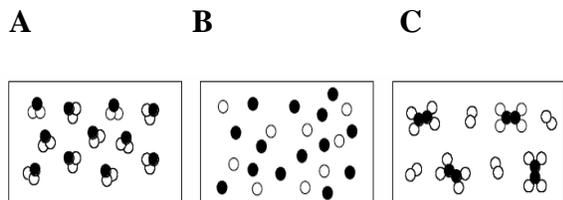
- (b) (1) Research conducted in established or commonly accepted educational settings, involving normal educational practices such as (i) research on regular and special education instructional strategies, or (ii) research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.
- (b) (2) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior, unless: (i) information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects; and (ii) any disclosure of the human subjects' responses outside the research could reasonably place the subjects at risk of criminal or civil liability, or be damaging to the subjects' financial standing, employability, or reputation.
- (b) (3) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior that is not exempt under paragraph (b)(2) of this section, if: (i) the human subjects are elected or appointed public officials or candidates for public office; or (ii) federal statute(s) without exception that the confidentiality of the personally identifiable information will be maintained throughout the research and thereafter.
- (b) (4) Research involving the collection or study of existing data, documents, records, pathological specimens, or diagnostic specimens, if these sources are publicly available, or if the information is recorded by the investigator in such a manner that the subjects cannot be identified, directly or through identifiers linked to the subjects.
- (b) (5) Research and demonstration projects, which are conducted by or subject to the approval of department or agency heads, and which are designed to study, evaluate, or otherwise examine: (i) public benefit or service programs; (ii) procedures for obtaining benefits or services under those programs; (iii) possible changes in or alternatives to those programs or procedures; or (iv) possible changes in methods or levels of payment for benefits or services under those programs.
- (b) (6) Taste and food quality evaluation and consumer acceptance studies, (i) if wholesome foods without additives are consumed, or (ii) if a food is consumed that contains a food ingredient at or below the level and for a use found to be safe, or agricultural chemical or environmental contaminant at or below the level found to be safe, by the FDA, or approved by the EPA, or the Food Safety and Inspection Service of the USDA.

Although review by the Institutional Review Board is not required for the above research, the Committee will be glad to review it. If you wish a review and committee approval, please submit 3 copies of the usual application form and it will be processed by expedited review.

APPENDIX B  
STUDENT PRE TEST

**Directions: Read each question carefully. Select the best possible answer from the choices.**

1. Which of these diagrams illustrate a pure substance?



- A
- B
- C
- B and C
- All of these are pure substances.

2. A student places a piece of zinc in 6 M hydrochloric acid and then makes several observations: (1) a gas evolves and (2) the test tube becomes warm. From this information, what can be concluded by the student?

- An exothermic chemical change took place
- An endothermic chemical change took place
- An exothermic physical change took place
- An endothermic physical change took place
- no reaction took place

3. Which of the following is **NOT** one of the assumptions of kinetic theory?

- Gases consist of hard spherical particles.
- Most of the volume of a gas is empty space.
- All gas particles move in constant random motion.

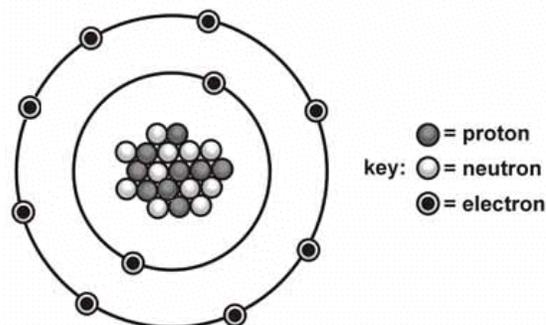
- There are no attractive or repulsive forces between gas particles.
- Collisions between molecules are elastic.

4. Which statement best explains why a confined gas exerts pressure?

- The molecules travel in straight lines.
- The molecules collide with the container walls.
- The molecules are in random motion.
- The molecules attract each other.
- The molecules are in rapid motion.

5. A gas occupies a volume of 0.7 L at 10.1 kPa. What volume will the gas occupy at 101 kPa?

- 7 L
- 4 L
- 0.7 L
- 0.04 L
- 0.07 L



6. What is the mass number of the atom shown above?

- 30
- 20
- 19
- 18
- 11

7. Which is the correct symbol for the atom shown above?

- ${}^9_{20}\text{F}^{1-}$
- ${}^{11}_9\text{F}^{1+}$
- ${}^{20}_{11}\text{F}^{2+}$
- ${}^{30}_{10}\text{F}$
- ${}^{20}_9\text{F}^{1-}$

8. Which statement is true about nitrogen isotopes?

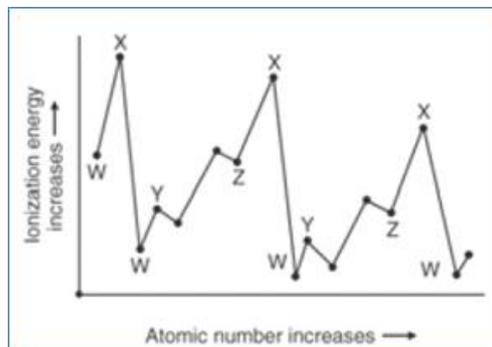
- A majority of the isotopes of this element have a mass of 15 amu.
- A majority of the isotopes of this element have a mass of 17 amu.
- All of the isotopes of this element have a mass of 15 amu.
- All of the isotopes of this element have a mass of 17 amu.
- None of these are true.

9. Which experiment and scientist determined the atom was mostly empty space?

- Plum Pudding Experiment & Rutherford
- Plum Pudding Experiment & Thomson
- Gold Foil Experiment & Rutherford
- Plum Pudding Experiment & Bohr
- Gold Foil Experiment & Bohr

10. Which neutral atom has the electronic configuration of  $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1$ ?

- Na
- K
- Ca
- Ba
- Cu



11. The chart above shows the relationship between the **first ionization energy** and the increase in **atomic number**. Which letter on the chart corresponds to the **alkali** family of elements?

- X
- Y
- W
- Z
- X and W

12. Which best explains one reason atomic radius **increases** down a **column** from top to bottom?

- nuclear charge increases for each successive element from top to bottom
- atoms become larger because they have a greater number of electrons
- one additional energy level is added for each successive element from top to bottom
- shielding effect remains constant from top to bottom
- atoms become larger because they have a greater number of neutrons

13. Which gives the correct energy level of **valence shell** and proper number of **valence electrons** for sodium, respectively?

- a. 3,1
- b. 1,3
- c. 3,6
- d. 6,3
- e. 6,8

14. Which particle has the same electronic configuration as argon?

- a.  $\text{Ca}^{2+}$
- b.  $\text{Na}^{1+}$
- c. K
- d.  $\text{Cl}^{1+}$
- e.  $\text{Ne}^{8+}$

15. How does a sodium ion ( $\text{Na}^{1+}$ ) compare to a sodium atom (Na)?

- a. The Na ion is larger than a Na atom.
- b. The Na ion is equal in size to a Na atom.
- c. The Na ion is more reactive a Na atom.
- d. The Na ion is more energetic a Na atom.
- e. The Na ion is smaller than a Na atom.

16. Which describes how an **ionically** bonded compound, such as potassium fluoride (KF), is formed?

- a. A potassium atom loses an electron to form a cation, and a fluorine atom accepts that electron to form an anion.
- b. A fluorine atom loses an electron to form a cation, and a potassium atom accepts that electron to form an anion.
- c. Potassium and fluorine share their valence electrons to obtain a stable octet.
- d. A proton from the potassium atom is transferred to the fluorine atom.

e. A proton from the fluorine atom is transferred to the potassium atom.

17. The tin (IV) ion has a charge of 4+, and the sulfide ion has a charge of 2-. Which is the formula for tin (IV) sulfide?

- a.  $\text{Sn}_4\text{S}_2$
- b.  $\text{Sn}_2\text{S}_4$
- c.  $\text{Sn}_2\text{S}$
- d.  $\text{SnS}_2$
- e. SnS

18. What type of bond is formed when two bonded atoms have the same electronegativity?

- a. non-polar covalent
- b. polar covalent
- c. ionic
- d. metallic
- e. electrovalent

19. What causes a **polar** bond?

- a. Unequal distribution of covalent bonds.
- b. Unequal distribution of ionic bonds.
- c. Unequal distribution of molecules.
- d. Unequal distribution of electrons.
- e. Unequal distribution of protons.

20. Which is the percentage by mass of **oxygen** on  $\text{Ca}(\text{NO}_3)_2$ ?

- a. 16%
- b. 47%
- c. 59%
- d. 65%
- e. 96%

21. Which is the mass of 2.5 moles of calcium atoms?

- a. 10.0 g
- b. 100 g
- c. 42.5 g
- d. 150 g
- e. 250 g

22. Which is the **empirical formula** of a compound that contains 25% hydrogen by mass and 75% carbon by mass? (Hint: Convert to moles)

- CH<sub>4</sub>
- CH<sub>3</sub>
- CH<sub>2</sub>
- CH
- C<sub>2</sub>H

23. If 60.2 g of Hg combines completely with 24.0 g of Br to form a compound, what is the **percent composition** of Hg in the compound?

- 28.5%
- 39.9%
- 71.5%
- 63%
- 60.1%

24. What is the **empirical formula** of a compound that is 53.5% C, 15.5% H, and 31.1% N by weight?

- C<sub>4</sub>H<sub>14</sub>N<sub>2</sub>
- C<sub>2</sub>H<sub>7</sub>N
- CH<sub>2</sub>N<sub>7</sub>
- CH<sub>4</sub>N<sub>7</sub>
- C<sub>3</sub>HN<sub>2</sub>

25. Which of the following quantities is conserved [not lost or gained] in a balanced chemical equation?

- moles
- molecules
- mass
- volume
- all of the above

26. Which would cause the percent yield to **decrease**?

- an impurity in the product
- changing the temperature
- losing product during an experiment
- massing the products

e. massing the reactants

27. What is the **percent yield** for a certain reaction when 42.3 g of a product was obtained in the lab but the theoretical yield was 51.4 g?

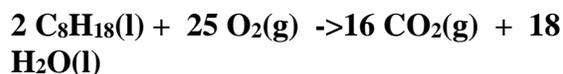
- 17.7%
- 42.3%
- 51.4%
- 93.7%
- 82.3%

28. When the following equation is completely balanced using the **smallest whole number** coefficients, which is the sum of all the coefficients?



- 5
- 7
- 9
- 11
- 3

29. What is the ratio of the molecules of gaseous reactants to gaseous products in the reaction shown below?



- 16:25
- 25:16
- 27:34
- 34:27
- 8:1

30. What is meant by a **perfect mixing ratio** that goes to completion?

- The limiting reactant is left over.
- No reactants are used up at all.
- Both reactants are left over.
- No reactants are left over.
- The ratio is 1 to 1.

APPENDIX C  
STUDENT PRE SURVEY

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

- 1) What kind of internet access do you have at home?
  - a) Laptop
  - b) Desktop
  - c) Ipad/Tablet
  - d) Smart phone
  - e) None
  - f) Other: \_\_\_\_\_
  
- 2) Have you ever used an online video to learn about a non-academic topic? e.g. how to make something, or do something, not related to school
  - a) Yes
  - b) No
  
- 3) Have you ever used an online video to learn about an academic topic?
  - a) Yes
  - b) No

The following questions contain a number of statements with which some people agree and others disagree. Please rate how much you personally agree or disagree with these statements-how much they reflect how you feel or think personally using the scale. Your participation or non-participation will not affect your grade or class standing.

- 4) Overall, my attitude toward chemistry class is positive.
  - (1) Strongly disagree
  - (2) Disagree
  - (3) Neutral
  - (4) Agree
  - (5) Strongly agree
  
- 5) I prefer to listen to a lecture face-to-face.
  - (1) Strongly disagree
  - (2) Disagree
  - (3) Neutral
  - (4) Agree
  - (5) Strongly agree
  
- 6) I prefer using class time for problem solving activities, rather than listening to a lecture.

- (1) Strongly disagree
- (2) Disagree
- (3) Neutral
- (4) Agree
- (5) Strongly agree

7) 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.

- (1) Strongly disagree
- (2) Disagree
- (3) Neutral
- (4) Agree
- (5) Strongly agree

8) I will be more engaged and interested while watching videos at home than I would be listening to lectures in class.

- (1) Strongly disagree
- (2) Disagree
- (3) Neutral
- (4) Agree
- (5) Strongly agree

9) I will be more engaged and interested during class time if I am doing activities, problem solving, and laboratory experiments.

- (1) Strongly disagree
- (2) Disagree
- (3) Neutral
- (4) Agree
- (5) Strongly agree

10) I prefer listening to lectures over doing activities, problem solving, and laboratory experiments.

- (1) Strongly disagree
- (2) Disagree
- (3) Neutral
- (4) Agree
- (5) Strongly agree

APPENDIX D  
UNIT 2 ASSESSMENT

**Part I Multiple Choice**

60 points total (2 points each). Choose the best answer.

- \_\_\_\_\_ 1. A substance made up of two or more substances that are not chemically combined is called:  
 a. an element.  
 b. a compound.  
 c. a mixture.  
 d. an atom.
- \_\_\_\_\_ 2. Which is a mixture?  
 a. air  
 b. gold  
 c. oxygen  
 d. carbon dioxide
- \_\_\_\_\_ 3. Which is an element?  
 a. air  
 b. oxygen  
 c. seawater  
 d. carbon dioxide
- \_\_\_\_\_ 4. Which is a heterogeneous mixture?  
 a. salt and sand  
 b. salt water  
 c. silver  
 d. air
- \_\_\_\_\_ 5. In a \_\_\_\_\_ mixture the separation of substances is visible.  
 a. homogeneous  
 b. heterogeneous  
 c. solidified  
 d. dissolved
- \_\_\_\_\_ 6. Which is an intensive property?  
 a. mass  
 b. volume  
 c. weight  
 d. color
- \_\_\_\_\_ 7. Which is an extensive property?  
 a. odor  
 b. luster  
 c. mass  
 d. color
- \_\_\_\_\_ 8. Which best illustrates a pure substance?  
 See figure-1.  
 a. A  
 b. B  
 c. C  
 d. D
- \_\_\_\_\_ 9. Which is a chemical property?  
 a. conductivity  
 b. freezing point  
 c. melting point  
 d. flammability
- \_\_\_\_\_ 10. Which is a chemical change?  
 a. melting ice  
 b. tearing paper  
 c. chopping wood  
 d. burning paper
- \_\_\_\_\_ 11. Which is a physical change?  
 a. tarnishing silver  
 b. rusting iron  
 c. freezing water  
 d. burning paper
- \_\_\_\_\_ 12. In which state do molecules move the fastest?  
 a. solid  
 b. liquid  
 c. gas
- \_\_\_\_\_ 13. When matter changes temperature or phase, \_\_\_\_\_ is either absorbed or given off.  
 a. salt  
 b. a gas  
 c. light  
 d. energy
- \_\_\_\_\_ 14. When particles at the surface of a liquid change to a gas, \_\_\_\_\_ occurs.  
 a. sublimation  
 b. boiling  
 c. melting  
 d. evaporation

\_\_\_\_\_ 15. Which state of matter has a definite shape and a definite volume?

- a. liquid
- b. solid
- c. gas
- d. plasma

\_\_\_\_\_ 16. Which is the phase change in which a substance changes from a solid to a liquid?

- a. freezing
- b. condensation
- c. melting
- d. sublimation

\_\_\_\_\_ 17. Which phase change is an exothermic change?

- a. boiling
- b. melting
- c. vaporization
- d. freezing

\_\_\_\_\_ 18. Which statement does not describe the motion of molecules in a gas?

- a. The molecules collide with each other.
- b. The molecules collide with the container walls.
- c. The molecules are in random motion.
- d. The molecules travel in a curved path.

\_\_\_\_\_ 19. Which device is used to measure atmospheric pressure?

- a. thermometer
- b. vapometer
- c. barometer
- d. calorimeter

\_\_\_\_\_ 20. As elevation increases, atmospheric pressure:

- a. increases.
- b. decreases.
- c. remains constant.

\_\_\_\_\_ 21. Boyle's Law relates what two variables?

- a. temperature and pressure
- b. volume and temperature

- c. volume and pressure
- d. pressure and moles of gas

\_\_\_\_\_ 22. A gas has a volume of 12.0 L and a pressure of 8.0 atm. Which is the pressure of the gas if its volume is decreased to 3.0 L?

- a. 32 atm
- b. 12 atm
- c. 3 atm
- d. 2 atm

\_\_\_\_\_ 23. If a gas that is confined in a rigid container is heated, the pressure of the gas will:

- a. decrease.
- b. increase.
- c. remain constant.

\_\_\_\_\_ 24. According to Boyle's law, when the pressure of a gas increases at constant temperature, its volume:

- a. decreases.
- b. increases.
- c. remains constant.

\_\_\_\_\_ 25. According to Charles' law, when the temperature of a gas increases at constant pressure, its volume:

- a. decreases.
- b. increases.
- c. remains constant.

\_\_\_\_\_ 26. Which describes what happens when a balloon is exposed to cold air.

- a. The pressure inside the balloon rises.
- b. The volume of the balloon decreases.
- c. The volume of the balloon increases.
- d. The temperature inside the balloon rises.

\_\_\_\_\_ 27. A gas with a volume of 6.0 L is heated from 300 K to 600 K. Which is the final volume of the gas?

- a. 3 L
- b. 6 L
- c. 12 L
- d. 18 L

- \_\_\_\_\_ 28. The greater the speed of gas particles in a container, the:
- fewer collisions there will be.
  - greater the pressure.
  - lower the temperature.
  - lower the pressure.

\_\_\_\_\_ 29. Which graph shows the relationship between volume and pressure for a gas at constant temperature? See figure-2.

- graph A
- graph B
- graph C
- graph D

\_\_\_\_\_ 30. Which graph shows the relationship between temperature and volume for a gas at constant pressure? See figure-3.

- graph 1
- graph 2
- graph 3
- graph 4

Figure 1

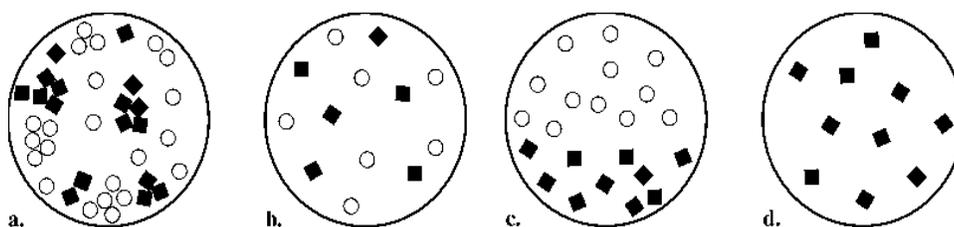


Figure 2

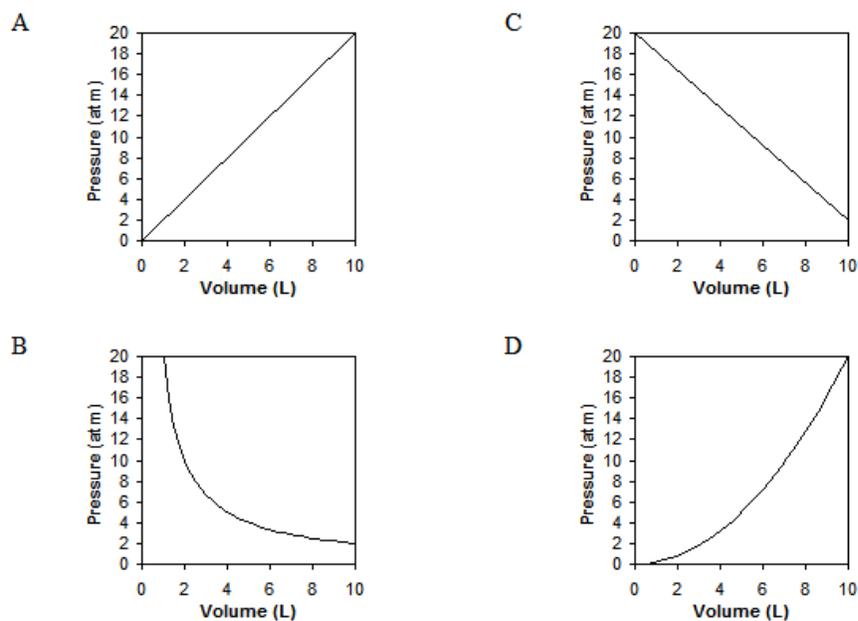
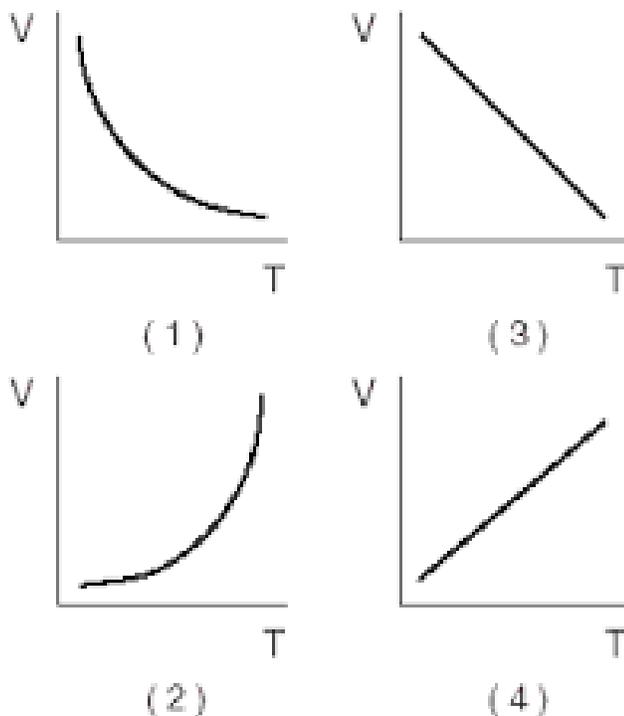


Figure 3

**Part II Matching**

Read each item carefully. Each item is worth 1 point.(Total/15 points)

Match the letter of the change on the right that matches the description on the left. (5 points)

- |       |                              |                    |
|-------|------------------------------|--------------------|
| _____ | 31. cooking an egg           | a. physical change |
| _____ | 32. burning coal             | b. chemical change |
| _____ | 33. dissolving salt in water |                    |
| _____ | 34. melting of wax           |                    |
| _____ | 35. tearing paper            |                    |

Match the letter of the property on the right that matches the description on the left. (5 points)

- |       |                                   |                                |
|-------|-----------------------------------|--------------------------------|
| _____ | 36. Water is clear.               | a. intensive physical property |
| _____ | 37. Iron has the ability to rust. | b. extensive physical property |
| _____ | 38. Salt is white.                | c. chemical property           |
| _____ | 39. The metal is 25 g.            |                                |
| _____ | 40. Copper conducts electricity.  |                                |

Match the letter of the property on the right that matches the description on the left. (5 points)

- |       |                            |                          |
|-------|----------------------------|--------------------------|
| _____ | 41. water                  | a. element               |
| _____ | 42. hydrogen               | b. compound              |
| _____ | 43. italian salad dressing | c. homogeneous mixture   |
| _____ | 44. sugar water            | d. heterogeneous mixture |
| _____ | 45. air                    |                          |

### Part III True/False

Indicate each statement as true or false. If a variable is not mentioned, it is assumed to remain constant. Each item is worth one (1) point.

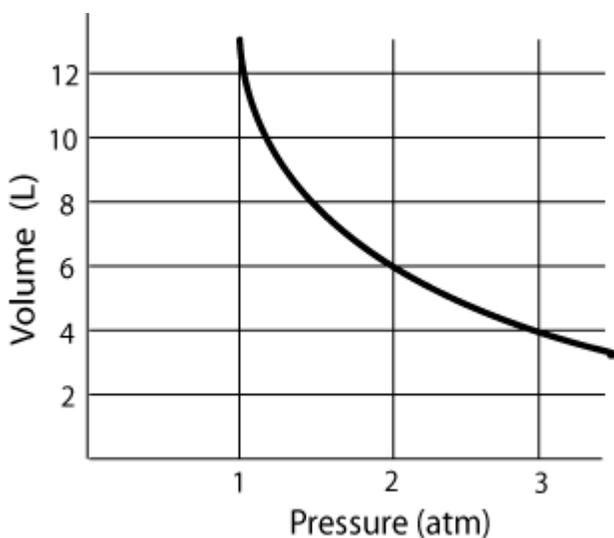
(Total/5 points)

- T F 46. In a mixture, each component retains its own properties.
- T F 47. The properties of a compound are the same as the properties of the elements that \_\_\_\_\_ combined to form it.
- T F 48. The phase change from a liquid to a gas is vaporization.
- T F 49. Boiling and evaporation are exothermic processes.
- T F 50. Molecular motion ceases at absolute zero.

### Part IV Free Response

Clearly show the method used and the steps involved in arriving at your answers. It is to your advantage to do this, since you may obtain partial credit if you do and you will receive little or no credit if you do not. Attention should be paid to significant figures.

(Total/15pts)



51. Using the graph to the right answer the following questions: (3 points)

a. At a pressure of 2 atmospheres, what is the volume of the gas?

\_\_\_\_\_

b. As the pressure of the gas increases from 1 atmosphere to 2 atmospheres, does the volume increase or decrease?

\_\_\_\_\_

c. When the volume of the gas is 8 L, what is the pressure being exerted upon it?

\_\_\_\_\_

52. Describe completely the characteristics of a solid (shape and volume), as well as the motion of molecules in a solid. (4 points)
53. A gas is confined in a rigid container (fixed volume) at 25 °C. Describe what will happen to the motion of the molecules and the pressure exerted by the gas when the gas in the vessel is heated to a higher temperature. (4 points)
54. A sample of sulfur dioxide gas has a volume of 375 ml at 250 kPa. What is the volume of this gas at 450 kPa? (4 points)

APPENDIX E  
UNIT 3 ASSESSMENT

**Part I Multiple Choice**

Select the best answer for each item.

Each item is worth two (2) points.

(Total/44 points)\_\_\_\_\_

1. Which is the atomic number of an element?

- The number of protons in an atom.
- The number of neutrons in an atom.
- The number of protons and neutrons in an atom.
- The number of electrons in an atom.

\_\_\_\_\_ 2. Which subatomic particle does not have a mass of 1 amu?

- proton
- cation
- neutron
- electron

\_\_\_\_\_ 3. Which is the mass number of an atom or ion?

- The number of electrons and protons in an atom.
- The number of protons and neutrons in an atom.
- The number of valence electrons in an atom.
- The number of energy levels in an atom.

\_\_\_\_\_ 4. Which atom in figure-1 has the greatest mass? (at end of test)

- atom A
- atom B
- atom C
- atom D

\_\_\_\_\_ 5. Which pairing does not list two isotopes of the same element?

- boron-10 and beryllium-10
- carbon-12 and carbon-14
- $^{22}\text{Na}$  and  $^{23}\text{Na}^{1+}$
- $^{35}\text{Cl}$  and  $^{36}\text{Cl}^{1-}$

\_\_\_\_\_ 6. Which is the same for the three isotopes of oxygen; oxygen-16, oxygen-17 and oxygen-18?

- atomic mass
- number of protons
- number of neutrons
- mass number

\_\_\_\_\_ 7. A certain element has two naturally occurring isotopes of mass 25 amu and 26 amu. If the average atomic mass for the element is 25.7, which statement is true?

- A majority of the isotopes of this element have a mass of 25 amu.
- A majority of the isotopes of this element have a mass of 26 amu.
- Each isotope makes up 50 % of all of the atoms.
- Neither isotope is accounted for in the average atomic mass.

\_\_\_\_\_ 8. Which is **not** true about the average sulfur atom?

- It is about eight times more massive than the average helium atom.
- It contains eight neutrons in the nucleus.
- It contains six electrons in the valence shell.
- It is about twice as massive the average oxygen atom.

\_\_\_\_\_ 9. Which best describes the fact that the atomic mass of carbon is 12.011 amu?

- All carbon atoms have a mass of 12.011 amu.
- Carbon consist of primarily of two isotopes of carbon, and a majority of them have a mass of 13 amu.
- Carbon-12 is 12.011 times more massive than all hydrogen isotopes.
- Carbon consists primarily of two isotopes of mass 12 amu and 13 amu, whose average mass is 12.011

- amu.
- \_\_\_\_\_ 10. Which does the following electron configuration convey? ( $1s^2 2s^2$ )
- There are four electrons in the atom.
  - The second energy level contains 1 electron.
  - The 1s sublevel contains 3 electrons.
  - There are three energy levels containing electrons.
- \_\_\_\_\_ 11. The electrons in the outermost energy level are referred to as the:
- noble electrons.
  - kernel electrons.
  - orbital electrons.
  - valence electrons.
- \_\_\_\_\_ 12. Which has the ability to accommodate 6 electrons?
- an s orbital
  - a p sublevel
  - a d sublevel
  - an f orbital
- \_\_\_\_\_ 13. Which orbital has a peanut shape?
- s orbital
  - p orbital
  - d orbital
  - f orbital
- \_\_\_\_\_ 14. Which is **not** true about two electrons in the same orbital?
- They have the same spin.
  - They have opposite spins.
  - They are in the same energy level.
  - They possess the same amount of energy.
- \_\_\_\_\_ 15. Which is true of the particle formed when an atom of lithium-7 loses an electron?
- It is a cation.
  - It is an isotope of lithium.
  - It has one valence electron.
  - All of the above.
- \_\_\_\_\_ 16. J.J. Thomson did experiments with a cathode ray tube. Which statement best describes one of the conclusions of his work?
- Atoms contain electrons.
  - All atoms contain protons.
  - All atoms contain neutrons.
  - Atoms are indestructible.
- \_\_\_\_\_ 17. Which type of radiation has the greatest penetrating power?
- alpha particle
  - beta particle
  - gamma ray
  - delta charge
- \_\_\_\_\_ 18. Which statement is **not** accepted as correct?
- Elements are composed of atoms.
  - Atoms are composed of protons, neutrons and electrons.
  - All atoms of the same element have the same mass.
  - Protons are located in the nucleus of the atom.
- \_\_\_\_\_ 19. A certain radioisotope has a half-life of 5 years. If given a 60 g sample of this radioisotope, how many grams will remain after 10 years?
- 60g
  - 30 g
  - 15 g
  - 7.5 g
- \_\_\_\_\_ 20. Rutherford shot alpha particles at a thin sheet of gold foil in an attempt to better understand the structure of the atom. Which statement about the structure of the atom did he derive from his experiment?
- All atoms of the same element have the same mass.

- b. All atoms contain protons and electrons.  
 c. Protons are in the nucleus of the atom.  
 d. Cathode rays are electrons.
- \_\_\_\_\_ 21. Which is the number of valence electrons in an atom that has the electron configuration:  $(1s^2 2s^2 2p^6 3s^2 3p^4)$   
 a. 2  
 b. 3  
 c. 4  
 d. 6
- \_\_\_\_\_ 22. Which of the electron configurations shows 1 valence electron?  
 a.  $1s^2$   
 b.  $1s^2 2s^2 2p^1$   
 c.  $1s^2 2s^2 2p^6 3s^1$   
 d.  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^1$

### Part II True or false

Indicate whether the following statements are true or false. (Total/5 points)

- T F 23. The neutron to proton ratio determines the stability of nuclei.  
 T F 24. All isotopes of sodium (Na) contain twelve protons.  
 T F 25. A neutral atom contains an equal number of protons and electrons.  
 T F 26. Light is emitted when an electron drops from a higher energy level to a lower energy level.  
 T F 27. An atom of Neon (Ne) is about seven times more massive than an atom of helium (He)

### Part III Fill in/Matching Read each item carefully.

28. Write an **electronic configuration** ( $1s^2 2s^2$  etc...) for the following elements. (1 pt each)

K

V

29. Write an electron configuration for each of the following elements using **orbital box notation**. (1 pt each)

$1s^2$        $2s^2$        $2p^6$        $3s^2$        $3p^6$        $4s^2$

O    \_\_\_\_\_

Al    \_\_\_\_\_

Match the number on the right that matches the description on the left using the above electron configurations. You can use a letter more than once. (9 points)

- \_\_\_\_\_ 30. potassium's valence shell (a). 1  
 \_\_\_\_\_ 31. number of electrons in potassium's valence shell (b). 2  
 \_\_\_\_\_ 32. number of electrons in vanadium's third energy level (c). 3  
 \_\_\_\_\_ 33. number of electrons in vanadium's valence shell (d). 4  
 \_\_\_\_\_ 34. vanadium's valence shell (e). 5  
 \_\_\_\_\_ 35. number of kernel electrons in aluminum (ab). 6  
 \_\_\_\_\_ 36. valence shell of oxygen (de). 8

- \_\_\_\_\_ 37. number of valence electrons in oxygen (ad). 9
- \_\_\_\_\_ 38. number of electrons within spherical orbitals in aluminum (ae). 10
- (bc). 11
- (bd). 12
- (be). 13
- (ce). 14

#### Part IV Free Response

Clearly show the method used and the steps involved in arriving at your answers. It is to your advantage to do this, since you may obtain partial credit if you do and you will receive little or no credit if you do not. Attention should be paid to significant figures. (4 pts each)

39. Write a complete electron configuration for sulfur (S). Identify the energy level of the valence shell, number of valence electrons, and number of kernel electrons.
40. Draw a Bohr Model of an atom of sulfur (S), depicting the number of electrons in each energy level.
41. Illustrate a 2s and 2p orbital in an atom. How many electrons can fit into an s orbital? p orbital? How many electrons can fit into an s sublevel? p sublevel?
42. The half-life of polonium-210 is 138.4 days. How many milligrams of polonium-210 remain after 415.2 days if you start with 4.0 mg of the isotope? **Show work!**
43. Complete the chart below. (12 pts)

symbol	name	atomic number	mass number	protons	neutrons	electrons	charge
		9	20			10	
B			11				0
					9	10	2-
	Beryllium			4	5		2+
			8		5		1+

Figure 1

APPENDIX F  
STUDENT POST SURVEY

The following questions contain a number of statements with which some people agree and others disagree. Please rate how much you personally agree or disagree with these statements-how much they reflect how you feel or think personally using the scale. Your participation or non-participation will not affect your grade or class standing.

1. I enjoyed working with the online videos.
  - (1) Strongly disagree
  - (2) Disagree
  - (3) Neutral
  - (4) Agree
  - (5) Strongly agree
  
2. I learned a lot from watching the chemistry videos.
  - (1) Strongly disagree
  - (2) Disagree
  - (3) Neutral
  - (4) Agree
  - (5) Strongly agree
  
3. It was helpful to have the lectures recorded on video.
  - (1) Strongly disagree
  - (2) Disagree
  - (3) Neutral
  - (4) Agree
  - (5) Strongly agree
  
4. Class time was used efficiently in the absence of lectures.
  - (1) Strongly disagree
  - (2) Disagree
  - (3) Neutral
  - (4) Agree
  - (5) Strongly agree
  
5. I feel that I got more hands-on work during class time.
  - (1) Strongly disagree
  - (2) Disagree
  - (3) Neutral
  - (4) Agree
  - (5) Strongly agree

6. I feel that I got more individualized attention than in a traditional classroom.
- (1) Strongly disagree
  - (2) Disagree
  - (3) Neutral
  - (4) Agree
  - (5) Strongly agree
7. I would like to continue learning via the flipped classroom model.
- (1) Strongly disagree
  - (2) Disagree
  - (3) Neutral
  - (4) Agree
  - (5) Strongly agree
8. Overall, my attitude toward chemistry class is positive.
- (1) Strongly disagree
  - (2) Disagree
  - (3) Neutral
  - (4) Agree
  - (5) Strongly agree
9. I prefer to listen to a lecture face-to-face.
- (1) Strongly disagree
  - (2) Disagree
  - (3) Neutral
  - (4) Agree
  - (5) Strongly agree
10. I prefer using class time for problem solving activities, rather than listening to a lecture.
- (1) Strongly disagree
  - (2) Disagree
  - (3) Neutral
  - (4) Agree
  - (5) Strongly agree
11. 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.

- (1) Strongly disagree
- (2) Disagree
- (3) Neutral
- (4) Agree
- (5) Strongly agree

12. I had a difficult time following the video content.

- (1) Strongly disagree
- (2) Disagree
- (3) Neutral
- (4) Agree
- (5) Strongly agree

13. I feel that more time needs to be spent at the beginning of class reviewing the video content.

- (1) Strongly disagree
- (2) Disagree
- (3) Neutral
- (4) Agree
- (5) Strongly agree

14. I felt prepared to complete introductory problems in class after listening to the video content.

- (1) Strongly disagree
- (2) Disagree
- (3) Neutral
- (4) Agree
- (5) Strongly agree

15. The time spent in class was helpful to your understanding of the concepts.

- (1) Strongly disagree
- (2) Disagree
- (3) Neutral
- (4) Agree
- (5) Strongly agree

16. I was more engaged and interested while watching videos at home than I would be listening to lectures in class.

- (1) Strongly disagree

- (2) Disagree
- (3) Neutral
- (4) Agree
- (5) Strongly agree

17. I was more engaged and interested during class time while experiencing the flipped classroom model.

- (1) Strongly disagree
- (2) Disagree
- (3) Neutral
- (4) Agree
- (5) Strongly agree

18. Generally, I watched the video when...

- A) It was assigned
- B) After it was due but I still watched it
- C) Never bothered
- D) It was assigned and then again to review

19. Do you think the flipped classroom technique helped you learn chemistry more efficiently than a traditional classroom might have?

- A) Yes
- B) No
- C) Yes, but... If you answered "yes, but..." please explain here, otherwise proceed to the next question.

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20. Did you watch the video straight through, or watch it in pieces and take breaks?

- A) Straight through without pausing
- B) Watched different sections at different times
- C) Straight though, then reviewed unclear sections
- D) All in one sitting, but I would pause and review certain sections

21. Was it beneficial having additional time in class to work with the instructor and your classmates?

- A) Yes
- B) No

C) Didn't make a difference

22. I would like to briefly interview some of you. Would you be interested in being interviewed?

A) Yes

B) No

23. Which of the two types of classrooms do you prefer working in?

A) Traditional

B) Flipped

24. In terms of the amount of content that was flipped, would you prefer more or less?

A) None, I tried flipping but it didn't work for me

B) None, I didn't watch the videos

C) I liked it the way it is

D) Flipping worked for me but I would like more videos

E) Flipping worked for me but I would like less videos

25. Please describe your CLASSROOM experience during the flipped chemistry units.

26. Please describe your HOMEWORK experience during the flipped chemistry units.

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

APPENDIX G  
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. Did you feel that the flipped classroom afforded you more time to interact with your instructor and classmates during classroom sessions? 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. Do you think you were more or less engaged watching the videos at home? Do you think you were more or less engaged during class time?
7. Is there anything else you would like to add about your experience working in the flipped classroom?