

THE EFFECT OF THE FLIPPED CLASSROOM ON
STUDENTS' LEARNING OF CHEMISTRY

by

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DEDICATION

I would like to dedicate my work to my Lord Jesus Christ, who makes everything possible, and my beloved Denisse and Santiago. You inspire me to become a better person.

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ABSTRACT

In this investigation the flipped classroom approach to instruction was used to help students improve their understanding of the content and to make science a more enjoyable and engaging subject for my students. This was done in Yew Chung International School in Chongqing, China. This research project found that the flipped classroom method of instruction did not have a significant effect on test scores and therefore on student learning. Results revealed that the flipped classroom does not contribute to making chemistry a more engaging and enjoyable subject for students. Results also showed that the flipped classroom did have a significant effect on instructional pacing for the chemistry class, and doubled the time students spent completing practical hands-on activities in the classroom.

INTRODUCTION AND BACKGROUND

The setting for my classroom research project was the International School of Chongqing Yew Chung (YCIS). This is a private coeducational international school for students of all nationalities that offers the YCIS Diploma and will start offering the International Baccalaureate in 2017-2018 academic year. It is a K3-12 school with an estimated enrollment of 404 students and 22 different nationalities represented in the student body. The school hires 90 full and part time faculty, including North Americans, Australian, Chinese, and third-country nationals. It was established in 2001 and is accredited by The Council of International Schools (CIS), New England Association of Schools and Colleges (NEASC), the National Centre for School Curriculum and Textbook Development (NCCT), and the International Baccalaureate Organization. The main focus of the school is to educate the whole person from infancy through secondary education and prepare students for universities and colleges in the United States, Asia and Europe.

I have been working in this school as a full time high school science teacher for one year. I currently teach IGCSE (International General Certificate of Secondary Education) Science for years 10 and 11, and A-Level Chemistry for year 12. Class sizes range from just 10 students to a maximum of 25.

The subjects of this research study were students in the year 11 IGCSE Co-ordinated Science course I taught. I sought to answer how the flipped model of instruction helps improve student learning of concepts and skills related to the chemistry unit of instruction. The focus of my study was to improve understanding of the content and to make science a

more enjoyable and engaging subject for my students. The research questions I sought to answer were:

1. To what extent does the implementation of the flipped model of instruction increase student learning of chemistry?
2. What are the effects of the flipped model of instruction on my instructional pacing?
3. Does the flipped model of instruction free up class time to focus more on practical activities?
4. Does the flipped model of instruction make chemistry a more engaging and enjoyable subject for students?

CONCEPTUAL FRAMEWORK

The following conceptual framework starts by defining the flipped classroom approach to instruction and its link with active learning through problem-solving, collaborative work, and inquiry-based learning. The results of different studies about this method's effectiveness are presented. Benefits of the flipped classroom are discussed based on research results from different educational settings and studies that probe student perception. Moreover, this conceptual framework presents some concerns raised by the implementation of the flipped classroom. The framework ends with a description of how this relatively new approach can be implemented in the classroom, presenting the main components of the flipped classroom and offering guidelines and suggestions to follow when implementing this approach to instruction.

The flipped or inverted classroom is a model of instruction in which content is introduced at home and class time is used for application, problem-solving, and critical

thinking activities. By doing this, class time is focused on improving and consolidating student learning of new content. This approach to instruction relies heavily on technology and emphasizes collaborative work and inquiry-based learning with students (Mazur, Brown, & Jacobsen, 2015). It is particularly useful in capturing the attention of millennial students, and using class time for active learning that provides vast opportunities for peer-to-peer collaboration and student-teacher interactions (Roehl, Reddy & Shannon, 2013).

Flipped learning completely transforms the dynamics of any classroom. Passive learning is replaced with laboratory activities and collaborative problem-solving sessions (Brunsell & Horejsi, 2013). Since students are required to learn the material on their own before classes, this opens up class time for more meaningful learning activities that include problem-solving, demonstrations, and laboratory experiences, and inquiry activities (McGraw & Chandler, 2015). This instructional approach has proven to be efficient in fusing active student learning, content mastery and solving real-world problems through case studies, games and simulations (Herreid & Schiller, 2013).

The integration of a flipped classroom model in a course conveys several benefits to both instructors and students. Fautch (2015) reported improvements in overall student performance and comfort level in problem-solving for her organic chemistry class. Her study was performed in York College, a small college in Pennsylvania, and included three non-flipped Organic I classes, and three flipped classes. Lecture slides, exams, quizzes and a comprehensive final exam were used to measure the effectiveness of the flipped approach to instruction. Additionally, she noted that withdrawals from the course drastically reduced with the implementation of the flipped classroom. Ojennus (2016) examined the learning

gains between a flipped and a traditional lecture classroom and found that the flipped format of instruction appears to have higher learning gains for low level cognitive questions. The setting for her study was the upper division biochemistry course at Whitworth University during the fall of 2014. Pre- and post- tests, exams, and a cumulative final were used to assess learning in students. Additionally, a Likert scale was administered to students to assess their own learning perceptions. Ojennus also suggested that the flipped model of instruction was more appropriate for introductory level chemistry courses than for advanced ones. Tawfik and Lilly (2015), in a case study that included 24 undergraduate students from a university located in the Midwestern portion of the United States, found that students felt highly motivated and reported improvements in self-efficacy as a result of the flipped classroom environment. Additional benefits for students in a flipped classroom include positive modifications in student preparation habits before classes and increased student understanding of concepts (Sahin, Cavlazoglu & Zeytuncu, 2015). The participants of this study consisted of 96 college students who took the Math 152 course during the Spring 2013 semester in a Texas college. Two different surveys were used in this study, one to assess how the content was taught, and the second one to determine preparation, understanding, and performance in students.

Additional positive outcomes of the flipped classroom reported by teachers and professors include, increased student-teacher interactions that translate in more opportunities for one-on-one conversations, more student-student interactions, and higher frequency of guided learning activities (Torkelson, 2012). The setting for Tokelson's study was a chemistry class in a school in Northern California. Additionally, Torkelson's study

determined that the flipped approach to instruction does not follow specific guidelines for its implementation, and conceived a handbook for that purpose. Another highlighted benefit, derived from the teaching perspective, is enhanced instructional pacing and lesson flow (Ojennus, 2016).

There are several studies that report an overall positive perception of students about the flipped or inverted classroom. Sahin, Cavlazoglu & Zeytuncu (2015) reported that students would manifest a clear preference for a course taught with the flipped format over a course without it. In a recent study (Brown, 2015), the results show that students prefer the flipped classroom format over traditional lecture and that less tutoring, or support after classes, are required by these students. In a study conducted in a general science course in the Training Teaching School of the University of Extremadura in Spain, students reported having a general positive opinion about the flipped methodology. These students reported that the possibility to work autonomously and in their own pace are strengths of the flipped methodology (Gonzalez et al, 2016). This study randomly divided students in two groups; one group was exposed to traditional instruction, whereas and the second group used the flipped approach to instruction. In both groups performance and perception were measured using questionnaires as quantitative instruments.

The format of the flipped classroom allows for more flexibility when it comes to testing; more frequent and less comprehensive tests are common under this format of instruction (Brown, 2015). Students' test grades are significantly higher than the grades students obtain in traditional instruction settings. Course passing rates also increase as a result of the implementation of the flipped format (Gonzalez et al, 2016). Gross et al (2015),

reported that students increase accuracy in answering exams and quizzes with a substantial boost of overall GPA, especially in low-performing students. In short, the flipped classroom approach is likely to be seen by students as a methodology that supports students' academic success (McCallum et al, 2015). McCallum conducted focus groups to gather student feedback and administered surveys to collect information about student perceptions. His study involved 60 undergraduate students from his courses in mathematics and business.

Despite all the benefits of the flipped classroom, this methodology raises some concerns. McIntosh (2011) reported that content exposure at home does not permit students to ask immediate questions and start discussions that may enhance understanding, losing learning momentum. Bergmann and Sams (2012) reported that Internet accessibility in the homes of certain students is a concern; many students may not have internet access or they may experience connectivity issues. Additionally, they also stated that when students fail to watch the videos, they are unprepared for classroom activities and do not take full advantage of class time. For Petrinjack (2012), the biggest drawback of this approach to instruction is the time teachers have to invest in video making, editing, and rendering them to students.

Although there is no single way to flip the classroom or methodology to follow (Bergmann & Sams, 2012), there are some guidelines that might help teachers who want to start implementing this approach to instruction in their classrooms. Lori (2015) provides guidelines for the proper use of Khan Academy as a source of instructional videos. These guidelines might apply to other video platforms or audiovisual material used in the flipped classroom. The article emphasizes that instruction with Khan Academy videos should include four components:

1. Formative assessment data.
2. Goal setting system.
3. Playlists or task lists.
4. Active and collaborative learning activities in the classroom.

In another study that provides guidelines for instructors who want to flipped their classrooms, performed in a large undergraduate architectural engineering course, Zappe et al (2009) recommend keeping students accountable for covering the flipped material at home and using assessments for this purpose, keeping the flipped videos short to ensure that students watch them, briefly reviewing the material in class to ensure that students understand it, and using multi-media to keep students engage. For this study, data about students' preferences and perceptions about the flipped classes were collected several times during the semester. Later in the semester a more comprehensive course survey was administered to collect more data.

To make the flipped classroom approach to instruction a worthy experience for teachers and students, student-centered instruction or activities that lead to active learning must implemented in the classroom. Students should spend far less time receiving knowledge in a passive manner; they should be working individually, or in groups, doing, experimenting, discovering knowledge, and trying to understand the content for themselves (Lunenburg, 1992). According to Bishop and Verlager (2013) the importance of student-centered instruction cannot be understated because without it, the flipped classroom would simply not exist.

The flipped classroom is an approach to instruction that seeks to maximize student learning by using available resources and class time in an effective way. Like any other instructional approach it has pros and cons, but the benefits outweigh the drawbacks considerably.

Although there is not enough research on its overall effectiveness, what is known about the flipped classroom justifies all the effort teachers put in the classroom to implement it. In short, it is safe to say that, the flipped classroom is the where technology meets collaborative learning, problem-based learning, and inquiry based learning to help students grow.

METHODOLOGY

My classroom research project sought to answer whether implementing the flipped model of instruction had a positive impact on students' learning of concepts and skills. The main goal of this project was to improve students' learning of chemistry, and to make science a more enjoyable and engaging subject for students.

Participants

Study participants consisted of all students enrolled in year 11 Coordinated Science course. These students completed two years of science prior to taking in the year 11 IGCSE course; these prior courses cover the introductory content for physics, chemistry and biology. The number of students that took part in this research study was 15. Student demographics for this course consisted of nine males and six females, of which 70 % of students were Korean and 30 % were of other nationalities. Instruction was delivered in English and the study took place at YCIS International School of Chongqing, China. There were no comparison groups used for this research project and pre-treatment data was used as the baseline to compare results after the intervention.

Intervention

My research project was planned for a five week intervention that started the last week of January and extended all the way through the first week of March 2017.

Instructional time this class was seven periods per week of 50 minutes each. These seven periods were arranged in three single and two double period instructions. The double period instructions were designed for carrying out laboratory activities. The intervention for my classroom research project consisted of flipping two units of instruction for my year eleven Coordinated Science course. Prior to this intervention, students were taught using traditional teaching methods. The flipped model of instruction included videos about the content and using practice problems. These videos presented content that was usually delivered to them in lecture format during class. Students had to watch the videos at home and work in the classroom on activities that fostered active learning such as laboratory activities, demonstrations, projects, problem solving, etc.

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 throughout this research (Appendix G).

The list of flipped videos and accompanying practical activities are listed in Table 1.

Table 1
List of Videos and Practical Activities Used in the Intervention

Video Content	Accompanying Practical Activities
1. Chemical reactions Introduction	Types of chemical reactions.
2. Balancing chemical reactions	Balancing chemical reactions <i>Phet</i> simulation.
3. Balancing complex chemical reactions	Using precipitates to work out chemical reactions.
4. Introduction to stoichiometry	Finding the formula of a hydrated copper (II) sulfate crystals.
5. Stoichiometry example problems	Finding the concentration of HCl by titration with standard sodium carbonate.
6. Limiting reactant	Finding the formula of washing soda.
7. Percent yield	Copper chemical reactions and percent yield.

The flipped classroom model of instruction I implemented required students to watch the videos, actively take notes, and answering review questions. Additionally students were asked to write down concepts or ideas that were not clear and needed further discussion. A quick homework check was completed on the day after a video was assigned, and a brief 5 minute question and answer period was held at the beginning of each class. After the question-answer round, students moved to their lab stations and started working on practical activities, or formed groups to complete guided or independent practice activities. Additionally, students were quizzed on content or skills after activities on a regular basis.

The technology I used to make the videos for my flipped classroom included an iPad Mini, Stylus pen and web applications such as, Educreations and Edpuzzle. I used around 20 videos in total, 10 for each units, and the average length was 14 minutes. Students accessed the videos through the application's website using a passcode that would guide them to my chemistry class. Educreations would yield the analytics about how many students watched

the videos and also the last time they were active on the platform. Edpuzzle is a site that allows teachers to select videos and customize them by editing, cropping, recording audio, and adding questions to make them more engaging. This site was used to supplement videos and to make them more interactive and engaging.

Student grades during the intervention included quizzes, tests, and other formative assessments. These grades were compared to pre-intervention ones to determine the efficacy of the intervention in terms of student learning. Students were interviewed to determine if the flipped model of instruction made chemistry a more enjoyable and engaging subject for students.

Data collection

I gathered data using summative unit tests, quizzes and other formative assessments. These were compared with that of previous units taught without the flipped model. Brown (2015) used a very similar methodology in his Introductory-Level Biology course at the University of Massachusetts. He examined students' perceptions of the flipped classroom and evaluated performance through exams. After, he compared exam scores between his previous traditionally taught and the flipped classroom.

I also analyzed the time it took me to complete flipped and non-flipped units of instruction and the number of practical activities that result from the implementation of the model. Additionally, a student opinion survey was administered before and after the intervention to evaluate the student perception of the flipped model of instruction. The surveys were anonymous and data was collected online. The student survey utilized the Likert scale of *strongly agree*, *agree*, *neutral*, *disagree*, and *strongly disagree*. The survey

results were analyzed to identify trends. These surveys sought to determine if my students found the science experience more enjoyable and engaging. Ojennus (2016) used a very similar methodology in her biochemistry course, administering a pre- and post-test to assess learning gains and a Likert scale survey to assess students' perceptions about the flipped classroom.

To answer my primary question and sub-questions, I used several types of assessments, for both the pre-treatment and post-treatment. These assessments included unit tests, quizzes, class time logs, observation forms, weekly journals, and attitude surveys.

Table 2
Data Triangulation Matrix

Focus Question	Data Source 1	Data Source 2	Data Source 3
Primary Question: 1. To what extent does the implementation of the flipped model of instruction increase student learning of chemistry?	Pre-treatment Assessments (Unit tests)	Post-treatment Assessments (Unit tests)	Pre-treatment and post-treatment student interview questions
Sub-Questions: 2. What are the effects of the flipped model of instruction on my instructional pacing?	Pre-treatment Chemistry unit log	Post-treatment Chemistry unit log	Teacher's record on previously taught units
3. Does the flipped model of instruction free up class time to focus more on practical activities?	Pre-treatment weekly reflection journal	During treatment weekly reflection journal	Class time log before and during treatment
4. Does the flipped model of instruction make chemistry a more engaging and enjoyable subject for students?	Pre-treatment surveys measuring students' level of engagement and attitude about chemistry	Post-treatment surveys measuring students' level of engagement and attitude about chemistry	Pre-treatment and post-treatment student interview questions

The results from the data analyses were used to reflect upon the teaching and learning process in my classroom and streamline the delivery of instruction in my future practice.

DATA AND ANALYSIS

Student learning was measured using pre- and post-treatment grades. Summative unit tests were the primary source of data analyzed to determine if the implementation of the flipped model of instruction increased student learning of chemistry. Pre-treatment test averages were collected during the first semester of the 2016-2017 school year and post-treatment tests during the implementation of the flipped classroom (January-March 2017). While different units are covered in the pre-treatment compared to the post-treatment, they have the same level of difficulty and require the same number of instructional periods. Pre-treatment test scores are slightly, but not significantly higher than post-treatment scores. The mean for the pre-treatment grades ($M=84.8$, $SD=10.0$) was slightly higher than the mean obtained for the post-treatment ($M=83.2$, $SD=9.1$). The range of grades for the pre-treatment is greater than the post-treatment by 6.7 points (Figure 1). The highest grade is obtained in the pre-assessment stage of research, but is not considerably higher than the highest obtained after the implementation of the flipped classroom. The pre- and post treatment assessments were equivalent in level of difficulty, number of questions and timing of administration.

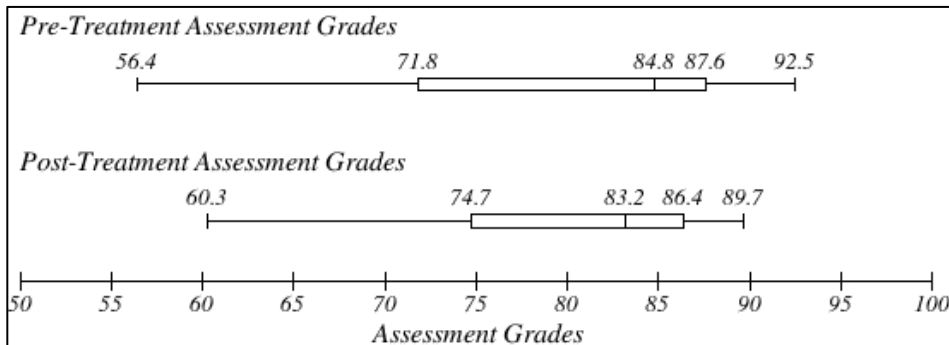


Figure 1. Comparison of pre-treatment and post-treatment assessment grades, ($N = 15$).

An unpaired t -test was run to compare pre-treatment ($M=81.0$, $SD=10.0$) and post treatment grades ($M=79.7$, $SD=9.1$). There was no statistically significant difference between the two means $t(28)=0.3724$ and $p=0.7124$. These results suggest that the flipped classroom method of instruction did not really have an effect on test scores and therefore it is possible that does not increase learning of chemistry because there was no significant change in scores.

Instructional pacing was analyzed by keeping track of the number of instructional periods needed to complete a unit of instruction using a unit log. The longest time spent on a unit of instruction was 25 instructional periods, which corresponds to a non-flipped unit. The flipped units of instruction, Chemical Reactions and Stoichiometry have a completion time of 18 instructional periods, the shortest completion time (Figure 2).

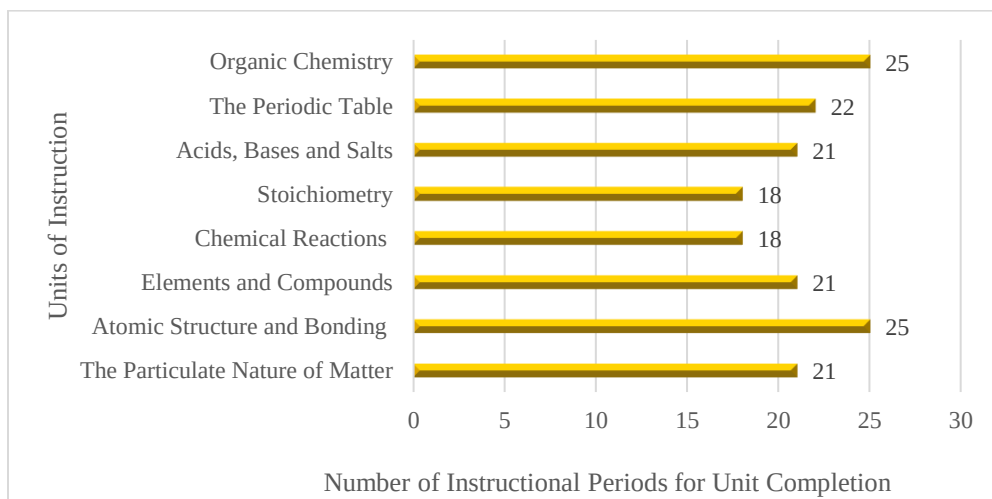


Figure 2. Number of instructional periods for completion of different instructional units.

An unpaired *t*-test was run to compare average time spent on flipped units ($M=18.0$, $SD=0.0$) with that of non-flipped units ($M=22.5$, $SD=1.97$). The difference between the means is considered to be statistically significant, $t(6)=3.0571$ and $p=0.0223$. This result suggest that the flipped classroom method of instruction did have a significant effect on instructional pacing for my chemistry class.

Time distribution for the non-flipped units included activities such as, introduction to the lesson, homework check, introduction of new content and independent work, practical, or laboratory activity. An estimate of 40% of instructional time was spent completing practical activities in these units. For the flipped units of instruction, the time distribution included a homework check, a question and answer period, and the practical activities. Around 83% of instructional time was spent completing practical activities for the flipped units. The flipped classroom method of instruction doubled the time students spent completing practical hands-on activities in the classroom.

The results from the from the Student Engagement and Attitude survey about chemistry showed for Question 1 (Q1) a decrease from 85.71% (Pre-treatment) to 73.34% (Post-Treatment) in students who agreed they were interested in science ($N=15$). There was an increase of 3.81% agreeing that they enjoyed completing the science homework (Q2), which consisted of watching flipped videos and note taking. A decrease of 4.49% was found for students who agreed they liked the science class (Q3), and a 5.75% decrease agreeing that they were learning chemistry (Q4). Despite a decrease in the number of students who liked the class, question five showed an increase from 71.43% to 73.33% of students with an overall positive attitude towards chemistry (Figure 3).

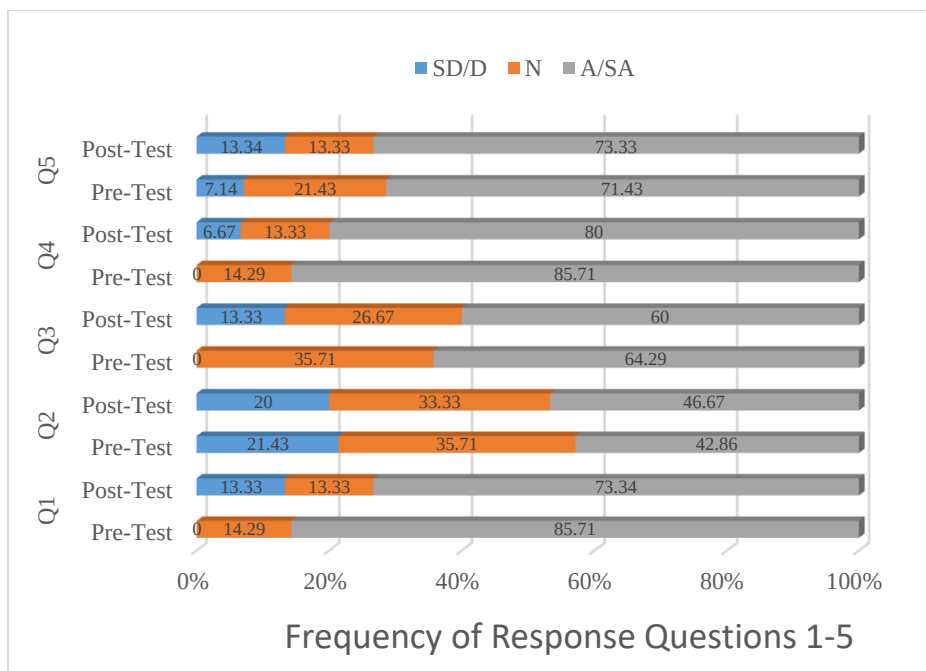


Figure 3. Student engagement and attitude about chemistry, questions 1-5. SD/D = disagree, N = neutral, A/SA = agree.

The survey found a 2.85% decrease in students agreeing that they preferred using class time for problem solving activities, rather than listening to a face-to-face lecture (Q6).

Likewise, a decrease of 24.76% was found in students feeling prepared for class after completing the science homework (Q7). An increase from 28.57% (Pre-treatment) to 57.14% in students who thought that the amount of work in chemistry is manageable. Regarding the willingness to recommend taking chemistry to a friend (Q8), there was an increase of 10.47%. The survey also found that 60% of students agreed that they look forward to coming to chemistry class (Q9), compared to 57.15% prior to the intervention (Figure 4).

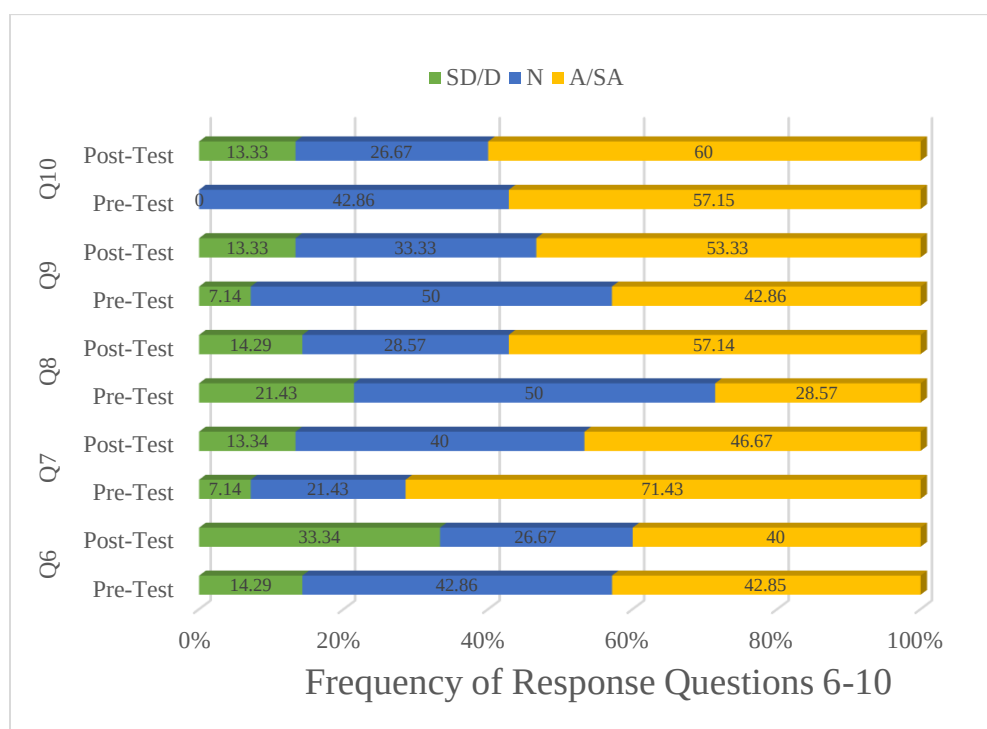


Figure 4. Student engagement and attitude about chemistry, questions 6-10. SD/D = disagree, N = neutral, A/SA = agree.

Student interviews provided valuable insight about the flipped classroom intervention. I learned that the three most preferred activities by my students were laboratory activities and experiments, having the teacher presenting a topic (lecture), and student presentations. One student expressed “teacher presentations help me understand difficult topics” and this made me realize how valued lectures were in my current school. Similarly,

students listed the same activities as the ones that help them learned the most. Students also included in the list watching videos as an activity that helped them learn after the intervention. Most students, 13 out of 15, expressed that they felt challenged by the work assigned in class before the implementation of the flipped classroom. The number of students who claimed feeling challenged dropped by one after the flipped classroom experience.

In January, none of my students knew what the flipped classroom was and what to expect, by the end of the implementation, they were all able to describe how a flipped classroom worked and what aspects of it they found beneficial. The aspects of the flipped classroom students enjoyed the most were the increase in number of laboratory activities for the units of instruction and watching instructional videos that they could pause and watch various times to increase understanding of content.

The biggest challenges students faced during the intervention were connectivity issues and accessing some videos that were available on Youtube. Not having a personal VPN (virtual private network) in China did not help students access content and forced them to watch videos at school. One student reported “I took notes, but could not ask the questions right away, by the next day I did not feel like asking the teacher”. The positive outcomes reported included the amount of detailed information videos provided in a relatively short time, improved listening skills in EAL (English as an additional language) students, and more in depth learning of some topics. Other benefits reported were more interest in science and that students were able to cover more detailed content than in previous units.

Nine out of fifteen students reported that the flipped classroom is more enjoyable than the traditional classroom. Students expressed that more emphasis on laboratory activities

allows for more opportunities to demonstrate their knowledge. Students also expressed that even though the flipped classroom approach to instruction is more enjoyable than the traditional method, but as only as a review resource, or for test revision. On this same front, ten students expressed they preferred the traditional method of instruction over the flipped approach because they can learn from the teacher and if questions arise, they could be answered right away. One student stated, “ I like the traditional approach because I like to take notes and study from them, I liked the videos for reviewing purposes; I prefer the traditional classroom.” Three students preferred the flipped classroom and two a combination of the traditional classroom and the flipped approach.

The most recurrent drawbacks of the flipped classroom identified by students were not understanding the content presented in the videos, especially for EAL students, and not being able to ask questions right away. Students also reported that they felt test preparation was more challenging than with the traditional approach. One student claimed, “ I did not do too well on the test, there was too much information for studying”. Another student stated, “the flipped classroom is not for me, I am not the type of student who will learn by himself. I need the teacher in front of the classroom teaching to learn”.

This research project found that the flipped classroom method of instruction did not have a significant effect on test scores and therefore on student learning. Results revealed that the flipped classroom does not contribute to making chemistry a more engaging and enjoyable subject for students. This research also found that the flipped classroom did have a significant effect on instructional pacing for my chemistry class, and doubled the time students spent completing practical hands-on activities in the classroom.

INTERPRETATION AND CONCLUSION

My primary research question was focused on finding the extent to which the implementation of the flipped model of instruction increased student learning of chemistry. This research project revealed that the flipped classroom intervention did not have any significant impact on unit test scores and on student learning of chemistry. Pre-treatment and post-treatment scores did not vary significantly and did not show a clear increase on learning as per analysis of unit test scores. These results contrast the findings of previous research in the field. Fautch (2015) reported improvements in overall student performance in her college students in Pennsylvania. Brown (2015) reported student grades significantly higher with the flipped classroom. Additionally, Ojennus (2016) reported higher learning gains in students answering low-level questions.

The implementation of the flipped classroom had a positive effect on my instructional pacing. The number of instructional periods used to complete the Chemical reactions and Stoichiometry units was significantly lower than the number of periods used for non-flipped units. This relative increase in teaching pace might be useful when teachers fall behind in curriculum coverage.

The flipped model of instruction freed up class time to focus more on practical activities. Instructional time used for completion of laboratory and hands-on activities rose from 40% to 83%. I was able to train my students on investigation design skills, which took a huge chunk of time devoted to practical work. As previously stated by Brunsell & Horejsi (2013), the dynamics of my classroom was completely transformed by the flipped approach to instruction. Time used on completing practical activities was greatly valued by my

students who deemed this as their most preferred classroom activity. As a teacher, I valued the time and opportunity to interact with each and every student. Teacher-student interactions were more personal during the intervention than with traditional teaching. These results are similar to the findings of Torkelson (2012), who also reported increased student-teacher interactions and a higher frequency of guided learning activities.

My intervention did not make science a more engaging and enjoyable subject for students. This finding was confirmed by the student survey results that showed that a smaller number of students agreed they liked the class and that they were learning chemistry in the post-treatment interview and survey. The survey also revealed that interest in science decreased, but contradictorily revealed that students were willing to recommend taking chemistry to a friend. My research results differ from findings from Sahim, Cavlazoglu & Zeytuncu (2015) and Brown (2015), who reported students' preference for the flipped classroom.

There was a slight increase on the number of students who looked forward to coming to chemistry class. Students with a solid grasp of chemistry moved through the material faster than other students and were willing to act as peer-tutors with students who needed assistance, some of them even joined the peer-tutoring program in my school. On this front, I feel that the flipped classroom can be a powerful tool in differentiating instruction for independent and gifted students, but that is beyond the scope of this project.

This research project also revealed how valuable the traditional method of instruction is for my students. It was almost unanimous the preference for the traditional approach to instruction over the flipped classroom. Students who found the flipped classroom enjoyable

also expressed that they would like to use the accompanying platform for flipped videos as review resources for chemistry and other subjects as well. I think that having 70% of Korean students who are also EAL in class favored this marked preference due to the familiarity with the traditional classroom in their home country.

I found my classroom research project and results to be mostly valid. However, I believe that in order to improve validity, more data needs to be collected over multiple semesters, classrooms, and in different international schools.

VALUE

The greatest value gained from this research project is the opportunity to be a reflective practitioner. Reflecting about my teaching practice and how to streamline aspects of it has given me new insight that I can use to make my lessons more engaging. I have had the opportunity to work one-on-one with my year 11 students and get to know them better as persons and learners. Survey results revealed what students want and value in their learning. I have a greater feel of students' needs and they feel that I am truly interested in what they have to say. I have gained valuable insight about their learning preferences and styles that will help me cater to their educational needs appropriately.

Interviewing students was a really useful exercise for obtaining feedback. Asking questions and listening to what students had to say about different aspects of the subject you teach is always valuable, but more valuable than that is to let them be aware that they have a voice that is heard. This experience has helped improve rapport with my students.

Innovation in the classroom is always positive and I am a teacher who is willing to try new things with the best interest of students in mind. On this front, I felt that my

experience with the flipped classroom has been a great opportunity to incorporate technology in the classroom and will lead to future incorporation of new tools.

I would definitely use a streamlined version of my flipped classroom again with other courses I teach. For the flipped classroom to work well, there needs to be clear rules for students and accountability. Early in the introductory stage of this methodology students have to be how it works and what is expected of them; note taking, reviewing notes, writing down questions, classroom discussions and formative quizzes are key components of the flipped classroom. Making sure students will not have internet connectivity issues is also vital; on this front, a youtube video downloader can be used and a DVD (or any other storage device) with the videos could be given to students. Regarding the videos, a combination of either pre-made videos from the web or self made videos works pretty well.

In my educational setting, the flipped classroom would be a great resource for introducing the units that are relatively easy for students and also for test preparation. This initial experience with the flipped classroom has helped me establish a well-managed system for reviewing content, revising and differentiating instruction, not to mention the possibility to access content for students who miss classes due to sports events, illness, or a myriad of other reasons. Further research stemming from this project would explore the connection between the flipped classroom and differentiation strategies in my classroom. I would like to answer the following questions: How can the flipped classroom approach to instruction be used as a differentiation strategy? How effective would it be? What would be the right way to use it? How students would benefit from it? How would they respond to it?

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APPENDICES

APPENDIX A
PRE-TREATMENT TEST

Multiple Choice

Identify the choice that best completes the statement or answers the question.

- _____ 1. In the chemical equation $2\text{Mg}(s) + \text{O}_2(g) \rightarrow 2\text{MgO}(s)$,
a. Mg represents the product magnesium. c. Mg represents the reagent magnesium.
b. the reaction yields magnesium. d. O_2 represents the product oxygen gas.
- _____ 2. In an equation, the symbol for a substance in water solution is followed by
a. (1). c. (aq).
b. (g). d. (s).
- _____ 3. In what kind of reaction does one element replace a similar element in a compound?
a. displacement reaction c. decomposition reaction
b. combustion d. ionic reaction
- _____ 4. The equation $\text{AX} + \text{BY} \rightarrow \text{AY} + \text{BX}$ is the general equation for a
a. synthesis reaction. c. single-displacement reaction.
b. decomposition reaction. d. double-displacement reaction.
- _____ 5. In what kind of reaction does a single compound produce two or more simpler substances?
a. decomposition reaction c. single-displacement reaction
b. synthesis reaction d. ionic reaction
- _____ 6. In what kind of reaction do the ions of two compounds exchange places in aqueous solution to form two new compounds?
a. synthesis reaction c. decomposition reaction
b. double-displacement reaction d. combustion reaction
- _____ 7. Oxides of active metals, such as CaO, react with water to produce
a. metal carbonates. c. acids.
b. metal hydrides. d. metal hydroxides.
- _____ 8. Many metal hydroxides decompose when heated to yield metal oxides and
a. metal hydrides. c. carbon dioxide.
b. water. d. an acid.

- ____ 9. Some acids, such as carbonic acid, decompose to nonmetal oxides and
a. water. c. oxygen.
b. a salt. d. peroxide.
- ____ 10. The replacement of bromine by chlorine in a salt is an example of a single-displacement reaction by
a. halogens. c. water.
b. sodium. d. electrolysis.
- ____ 11. When a slightly soluble solid compound is produced in a double-displacement reaction, a
a. gas bubbles off. c. combustion reaction takes place.
b. precipitate is formed. d. halogen is produced.
- ____ 12. The formulas for the products of the reaction between sodium hydroxide and sulfuric acid are
a. Na_2SO_4 and H_2O . c. SI_4 and Na_2O .
b. NaSO_4 and H_2O . d. $\text{S} + \text{O}_2$ and Na .
- ____ 13. Predict what happens when calcium metal is added to a solution of magnesium chloride.
a. No reaction occurs. c. Magnesium calcite forms.
b. Calcium chloride forms. d. Gaseous calcium is produced.
- ____ 14. What is the study of the mass relationships of elements in compounds?
a. reaction stoichiometry c. percentage yield
b. composition stoichiometry d. Avogadro's principle
- ____ 15. What is the study of the mass relationships among reactants and products in a chemical reaction?
a. reaction stoichiometry c. electron configuration
b. composition stoichiometry d. periodic law
- ____ 16. Each of the four types of reaction stoichiometry problems requires using a
a. table of bond energies. c. Lewis structure.
b. chart of electron configurations. d. mole ratio.
- ____ 17. Which coefficients correctly balance the formula $\text{NH}_4\text{NO}_2 \rightarrow \text{N}_2 + \text{H}_2\text{O}$?

- a. 1,2,2
- b. 1,1,2
- c. 2,1,1
- d. 2,2,2

- ____ 18. When the formula equation $\text{Fe}_3\text{O}_4 + \text{Al} \rightarrow \text{Al}_2\text{O}_3 + \text{Fe}$ is correctly balanced the coefficient of Fe is number
- a. 3.
 - b. 2.
 - c. 7.
 - d. 9.
- ____ 19. In the chemical reaction represented by the equation $w\text{A} + x\text{B} \rightarrow y\text{C} + z\text{D}$, a comparison of the number of moles of A to the number of moles of C would be a(n)
- a. mass ratio.
 - b. mole ratio.
 - c. electron ratio.
 - d. energy proportion.
- ____ 20. In the chemical equation $w\text{A} + x\text{B} \rightarrow y\text{C} + z\text{D}$, if one knows the mass of A and the molar masses of A, B, C, and D, one can determine
- a. the mass of any of the reactants or products.
 - b. the mass of B only.
 - c. the total mass of C and D only.
 - d. the total mass of A and B only.
- ____ 21. In the reaction represented by the equation $\text{N}_2 + 3\text{H}_2 \rightarrow 2\text{NH}_3$, what is the mole ratio of nitrogen to ammonia?
- a. 1:1
 - b. 1:2
 - c. 1:3
 - d. 2:3
- ____ 22. In the reaction represented by the equation $2\text{Al}_2\text{O}_3 \rightarrow 4\text{Al} + 3\text{O}_2$, what is the mole ratio of aluminum to oxygen?
- a. 10:6
 - b. 3:4
 - c. 2:3
 - d. 4:3
- ____ 23. For the reaction represented by the equation $\text{N}_2 + 3\text{H}_2 \rightarrow 2\text{NH}_3$, how many moles of nitrogen are required to produce 18 mol of ammonia?
- a. 9.0 mol
 - b. 18 mol
 - c. 27 mol
 - d. 36 mol
- ____ 24. For the reaction represented by the equation $\text{AgNO}_3 + \text{NaCl} \rightarrow \text{NaNO}_3 + \text{AgCl}$, how many moles of silver chloride, AgCl, are produced from 7.0 mol of silver nitrate AgNO₃?

- a. 1.0 mol
- b. 2.3 mol
- c. 7.0 mol
- d. 21 mol

- ____ 25. For the reaction represented by the equation $2\text{Na} + \text{Cl}_2 \rightarrow 2\text{NaCl}$, how many grams of chlorine gas are required to react completely with 2.00 mol of sodium?
- a. 35.5 g
 - b. 70.9 g
 - c. 141.8 g
 - d. 212.7 g
- ____ 26. For the reaction represented by the equation $2\text{HNO}_3 + \text{Mg}(\text{OH})_2 \rightarrow \text{Mg}(\text{NO}_3)_2 + 2\text{H}_2\text{O}$, how many grams of magnesium nitrate are produced from 8.00 mol of nitric acid, HNO_3 , and an excess of $\text{Mg}(\text{OH})_2$?
- a. 148 g
 - b. 445 g
 - c. 593 g
 - d. 818 g
- ____ 27. For the reaction represented by the equation $\text{CH}_4 + 2\text{O}_2 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O}$, how many moles of carbon dioxide are produced from the combustion of 100. g of methane?
- a. 6.23 mol
 - b. 10.8 mol
 - c. 12.5 mol
 - d. 25 mol
- ____ 28. For the reaction represented by the equation $2\text{KIO}_3 \rightarrow 2\text{KCl} + 3\text{O}_2$, how many moles of potassium chlorate are required to produce 250. g of oxygen?
- a. 2.00 mol
 - b. 4.32 mol
 - c. 4.97 mol
 - d. 5.21 mol
- ____ 29. What is the maximum possible amount of product obtained in a chemical reaction?
- a. theoretical yield
 - b. percentage yield
 - c. mole ratio
 - d. actual yield
- ____ 30. For the reaction represented by the equation $\text{Cl}_2 + 2\text{KBr} \rightarrow 2\text{KCl} + \text{Br}_2$, calculate the percentage yield if 200. g of chlorine react with excess potassium bromide to produce 410. g of bromine.
- a. 73.4%
 - b. 82.1%
 - c. 91.0%
 - d. 98.9%

APPENDIX B
POST-TREATMENT TEST

Multiple Choice

Identify the choice that best completes the statement or answers the question.

- _____ 1. Which of the following is a formula equation for the formation of carbon dioxide from carbon and oxygen?
- | | |
|--|--|
| a. Carbon plus oxygen yields carbon dioxide. | c. $\text{CO}_2 \rightarrow \text{C} + \text{O}_2$ |
| b. $\text{C} + \text{O}_2 \rightarrow \text{CO}_2$ | d. $2\text{C} + \text{O} \rightarrow \text{CO}_2$ |
- _____ 2. Which equation is *not* balanced?
- | |
|---|
| a. $2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O}$ |
| b. $4\text{H}_2 + 2\text{O}_2 \rightarrow 4\text{H}_2\text{O}$ |
| c. $\text{H}_2 + \text{H}_2 + \text{O}_2 \rightarrow \text{H}_2\text{O} + \text{H}_2\text{O}$ |
| d. $2\text{H}_2 + \text{O}_2 \rightarrow \text{H}_2\text{O}$ |
- _____ 3. In what kind of reaction does a single compound produce two or more simpler substances?
- | | |
|---------------------------|---------------------------------|
| a. decomposition reaction | c. single-displacement reaction |
| b. synthesis reaction | d. ionic reaction |
- _____ 4. The reaction represented by the equation $2\text{HgO}(s) \rightarrow 2\text{Hg}(l) + \text{O}_2(g)$ is a(n)
- | | |
|----------------------------------|----------------------------|
| a. single-displacement reaction. | c. combustion reaction. |
| b. synthesis reaction. | d. decomposition reaction. |
- _____ 5. The reaction represented by the equation $\text{Cl}_2(g) + 2\text{KBr}(aq) \rightarrow 2\text{KCl}(aq) + \text{Br}_2(l)$ is a(n)
- | | |
|----------------------------|----------------------------------|
| a. synthesis reaction. | c. single-displacement reaction. |
| b. decomposition reaction. | d. combustion reaction. |
- _____ 6. In one type of synthesis reaction, an element combines with oxygen to yield a(n)
- | | |
|---------------|-----------|
| a. acid. | c. oxide. |
| b. hydroxide. | d. metal. |
- _____ 7. When heated, a metal carbonate decomposes into a metal oxide and
- | | |
|--------------------|--------------|
| a. carbon. | c. oxygen. |
| b. carbon dioxide. | d. hydrogen. |
- _____ 8. Many metal hydroxides decompose when heated to yield metal oxides and
- | | |
|--------------------|--------------------|
| a. metal hydrides. | c. carbon dioxide. |
| b. water. | d. an acid. |
- _____ 9. Some acids, such as carbonic acid, decompose to nonmetal oxides and
- | | |
|------------|--------------|
| a. water. | c. oxygen. |
| b. a salt. | d. peroxide. |

- ____ 10. When potassium reacts with water, one product formed is
- hydrogen gas.
 - oxygen gas.
 - potassium oxide.
 - salt.
- ____ 11. Predict the product of the reaction represented by the following equation:
 $\text{MgO} + \text{CO}_2 \rightarrow$
- MgCO_3
 - $\text{Mg} + \text{CO}_3$
 - $\text{MgC} + \text{O}_3$
 - $\text{MgCO}_2 + \text{O}$
- ____ 12. What is the study of the mass relationships of elements in compounds?
- reaction stoichiometry
 - composition stoichiometry
 - percentage yield
 - Avogadro's principle
- ____ 13. What is the study of the mass relationships among reactants and products in a chemical reaction?
- reaction stoichiometry
 - composition stoichiometry
 - electron configuration
 - periodic law
- ____ 14. Which equation is *not* balanced?
- $2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O}$
 - $4\text{H}_2 + 2\text{O}_2 \rightarrow 4\text{H}_2\text{O}$
 - $\text{H}_2 + \text{H}_2 + \text{O}_2 \rightarrow \text{H}_2\text{O} + \text{H}_2\text{O}$
 - $2\text{H}_2 + \text{O}_2 + \text{H}_2\text{O}$
- ____ 15. Given the equation $3\text{A} + 2\text{B} \rightarrow 2\text{C}$, the starting mass of A, and its molar mass, and you are asked to determine the moles of C produced, your first step in solving the problem is the multiply the given mass of A by
- $\frac{2 \text{ mol C}}{3 \text{ mol A}}$
 - $\frac{3 \text{ mol A}}{2 \text{ mol C}}$
 - $\frac{1 \text{ mol A}}{\text{molar mass A}}$
 - $\frac{\text{molar mass A}}{1 \text{ mol A}}$
- ____ 16. In the reaction represented by the equation $2\text{Al}_2\text{O}_3 \rightarrow 4\text{Al} + 3\text{O}_2$, what is the mole ratio of aluminum to oxygen?
- 10:6
 - 3:4
 - 2:3
 - 4:3
- ____ 17. For the reaction represented by the equation $\text{C} + 2\text{H}_2 \rightarrow \text{CH}_4$, how many moles of hydrogen are required to produce 10 mol of methane, CH_4 ?
- 2 mol
 - 4 mol
 - 10 mol
 - 20 mol

18. For the reaction represented by the equation $2\text{Na} + 2\text{H}_2\text{O} \rightarrow 2\text{NaOH} + \text{H}_2$, how many grams of sodium hydroxide are produced from 3.0 mol of sodium with an excess of water?
 - a. 40. g
 - b. 80. g
 - c. 120 g
 - d. 240 g
19. For the reaction represented by the equation $\text{SO}_3 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{SO}_4$, how many grams of sulfur trioxide are required to produce 4.00 mol of sulfuric acid in an excess of water?
 - a. 80.0 g
 - b. 160. g
 - c. 240. g
 - d. 320. g
20. For the reaction represented by the equation $2\text{Fe} + \text{O}_2 \rightarrow 2\text{FeO}$, how many grams of iron(II) oxide are produced from 8.00 mol of iron in an excess of oxygen?
 - a. 71.8 g
 - b. 575 g
 - c. 712 g
 - d. 1310 g
21. For the reaction represented by the equation $\text{Pb}(\text{NO}_3)_2 + 2\text{KI} \rightarrow \text{PbI}_2 + 2\text{KNO}_3$, how many moles of lead(II) iodide are produced from 300. g of potassium iodide and an excess of $\text{Pb}(\text{NO}_3)_2$?
 - a. 0.904 mol
 - b. 1.81 mol
 - c. 3.61 mol
 - d. 11.0 mol
22. For the reaction represented by the equation $2\text{KIO}_3 \rightarrow 2\text{KCl} + 3\text{O}_2$, how many moles of potassium chlorate are required to produce 250. g of oxygen?
 - a. 2.00 mol
 - b. 4.32 mol
 - c. 4.97 mol
 - d. 5.21 mol
23. Ozone, O_3 , is produced by the reaction represented by the following equation:
 $\text{NO}_2(\text{g}) + \text{O}_2(\text{g}) \rightarrow \text{NO}(\text{g}) + \text{O}_3(\text{g})$
What mass of ozone will form from the reaction of 2.0 g of NO_2 in a car's exhaust and excess oxygen?
 - a. 1.1 g O_3
 - b. 1.8 g O_3
 - c. 2.1 g O_3
 - d. 4.2 g O_3
24. For the reaction represented by the equation $\text{SO}_3 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{SO}_4$, how many grams of sulfuric acid can be produced from 200. g of sulfur trioxide and 100. g of water?
 - a. 100. g
 - b. 200. g
 - c. 245 g
 - d. 285 g
25. Which reactant controls the amount of product formed in a chemical reaction?
 - a. excess reactant
 - b. mole ratio
 - c. composition reactant
 - d. limiting reactant

- _____ 26. To determine the limiting reactant in a chemical reaction, one must know the
- a. available amount of one of the reactants.
 - b. amount of product formed.
 - c. available amount of each reactant.
 - d. speed of the reaction.
- _____ 27. What is the ratio of the actual yield to the theoretical yield, multiplied by 100%?
- a. mole ratio
 - b. percentage yield
 - c. Avogadro yield
 - d. excess yield
- _____ 28. In most chemical reactions the amount of product obtained is
- a. equal to the theoretical yield.
 - b. less than the theoretical yield.
 - c. more than the theoretical yield.
 - d. more than the percentage yield.
- _____ 29. A chemist interested in the efficiency of a chemical reaction would calculate the
- a. mole ratio.
 - b. energy released.
 - c. percentage yield.
 - d. rate of reaction.
- _____ 30. For the reaction represented by the equation $\text{SO}_3 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{SO}_4$, calculate the percentage yield if 500. g of sulfur trioxide react with excess water to produce 575 g of sulfuric acid.
- a. 82.7%
 - b. 88.3%
 - c. 91.2%
 - d. 93.9%

APPENDIX C

PRE AND POST-TREATMENT STUDENT INTERVIEW

1. Which classroom activities do you prefer?
2. Which classroom activities help you learn more?
3. Do you feel challenged by the work assigned in this class?
4. Do you understand what the flipped classroom is? Please elaborate.
5. What aspects of the flipped classroom do you like?
6. How has the flipped classroom impacted your learning? Would you describe how?
7. Would you say that the flipped Science classroom is more enjoyable than the traditional method of instruction?
8. Please describe your classroom experience with the last two units of instruction.
9. What method of instruction do you prefer, traditional or flipped classroom? Why?
10. What else would you like to add about your flipped Science classroom experience?

APPENDIX D
WEEKLY REFLECTION JOURNAL

Please answer the following questions by providing as much evidence as you can:

Participation in this research is voluntary and participation or non-participation will not affect a student's grades or class standing in any way.

1. Were students engaged during the lessons?
2. Did students pay attention during the lessons?
3. Were students actively involved in all activities?
4. What activities helped most students learn?
5. Were students working collaboratively?

APPENDIX E
CLASS TIME LOG

CLASSROOM ACTIVITY	TIME	COMMENTS
Introduction to lesson		
Homework check		
Introduction of new content		
Independent work, practical or lab activity		
Other		

APPENDIX F

PRE AND POST-TREATMENT STUDENT SURVEY

Please circle the response that best fits how you feel about chemistry. Answer these questions as accurately as possible.

Participation in this research is voluntary and participation or non-participation will not affect a student's grades or class standing in any way.

1. I am interested in learning Science.

Strongly agree agree neutral disagree strongly disagree

2. I enjoy completing the Science homework.

Strongly agree agree neutral disagree strongly disagree

3. I like this class.

Strongly agree agree neutral disagree strongly disagree

4. I am learning in this class.

Strongly agree agree neutral disagree strongly disagree

5. My overall attitude towards Science is positive.

Strongly agree agree neutral disagree strongly disagree

6. I prefer using class time for problem solving activities, rather than listening to a face-to-face lecture.

Strongly agree agree neutral disagree strongly disagree

7. I feel prepared for class after completing the Science homework.

Strongly agree agree neutral disagree strongly disagree

8. The amount of work in Science is manageable.

Strongly agree agree neutral disagree strongly disagree

9. I would recommend taking Science to a friend.

Strongly agree	agree	neutral	disagree	strongly disagree
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10. I look forward to coming to Science class.

Strongly agree	agree	neutral	disagree	strongly disagree
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APPENDIX G
INSTITUTIONAL REVIEW BOARD



INSTITUTIONAL REVIEW BOARD

For the Protection of Human Subjects

FWA 00000165

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MEMORANDUM

TO: Alvaro Door and Eric Brunsell
FROM: Mark Quinn *Mark Quinn CJ*
DATE: November 29, 2016
SUBJECT: "The Effects of the Flipped Classroom on Students' Learning of Chemistry" [AD112916-EX]

The above research, described in your submission of November 28, 2016, 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.