

THE EFFECT OF A SUPPORTED FLIPPED LEARNING APPROACH ON
STUDENT LEARNING, ENGAGEMENT, AND PARTICIPATION
IN A HIGH SCHOOL CHEMISTRY CLASSROOM

by

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DEDICATION

This paper is dedicated to my husband, Kevin, who took on the responsibility of being a single parent many days while I worked on this project. Without his support and persistence, this project would not have been realized. I also dedicate this paper to my parents who have always encouraged me to follow my dreams and my children, Brendan, Ryan, Kellen, and Ciara, most of whom were not born when I started this endeavor. This is a reminder that the accomplishments of which they will be most proud in this life demand that they work hard and reach for the stars.

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This project would not have succeeded in practice without the support and guidance of my mentor, Maria Sumereau. Our continuous collaboration about how to best incorporate the flipped learning model into the chemistry classroom and honest reflection about how it was working was instrumental in making this classroom project a reality.

Finally, I would like to thank John Graves who, without once getting frustrated, spent eight years guiding me to the end of the road. Through three different projects and numerous life detours, he saw me through this experience with patience and professionalism. I am very grateful to John as well as to Peggy Taylor, Diana Paterson, Nick Childs, and all of the members of the MSSE team.

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ABSTRACT

The flipped learning approach takes direct content instruction out of the classroom in order to incorporate more student-centered, inquiry-based activities that facilitate learning. In-class lectures are replaced by video lessons that students watch outside of class meeting time. Class time is reserved for practice, activities, and laboratory experiences in the presence and with the support of the teacher. Advantages of the flipped learning approach for students are control over the pace of their learning, increased one-to-one time with the teacher, seamless access to available resources, and more dynamic in-class activities to support learning.

The purpose of this study was to determine if the incorporation of the flipped learning approach to instruction coupled with technology-based formative assessments affected academic achievement, student engagement, and participation in a high school chemistry classroom. A pretreatment phase of traditional instruction was followed by two separate treatment phases. The first treatment incorporated technology-based formative assessments into traditional instruction. In the second treatment phase, the flipped learning approach was used for direct content instruction in addition to the technology-based formative assessments.

Students were administered pre- and post-tests as well as summative tests for each unit to assess and compare learning and achievement. Students participated in surveys and interviews to determine the impact on engagement and participation. A daily journal was kept by the teacher as part of the study as well.

The results of the study revealed that there was no substantial difference in student academic achievement overall. However, students with an IEP and historically low-performing students did show an increase in test scores. Students showed increased interest in chemistry and engagement over the treatment period due to the increased time available for student-centered, inquiry activities in class. While participation rates for class activities remained unchanged, participation rates in class discussion increased. I will continue to utilize the flipped learning approach as a result of this study.

INTRODUCTION AND BACKGROUND

West Morris Central High School (WMC) is a public high school serving students in grades 9 – 12 from Washington Township in Morris County, New Jersey. WMC is part of the West Morris Regional High School District and has a sister school with common curriculum, Mendham High School, which serves the residents of Mendham and Chester, New Jersey. WMC had 1285 students enrolled for the 2015-2016 school year and graduated 327 students in 2015 (West Morris Central, 2015). The WMC student population and community have little ethnic diversity with approximately 88.5% Caucasian students, 5.5% Hispanic, 3.4% Asian, 1.2% African-American, and 1.3% of two or more races (National Center for Educational Statistics, 2015). The school is positively supported by the people of the community who value and invest in strong public education. WMC prides itself on its academic excellence offering Advanced Placement courses in all of its core subjects and is endorsed as a World School by the International Baccalaureate Organization. There is also strong commitment from the administration and staff to create and support a digital learning environment for students across the curricula (West Morris Central, 2015).

I began teaching chemistry at WMC in September 2015 after working several years outside of the classroom raising my children. Just prior to my hiatus from teaching, I had begun the process of transitioning from primarily a traditional lecture-practice-lab teacher to one who incorporated student-centered projects and inquiry activities into my repertoire. Upon returning to the classroom, my greatest concern was not the content of the curriculum or my ability to manage a classroom, it was whether I would be able to

continue to move toward a student-centered approach or if I would rely on the teacher-centered approach that was so often in my comfort zone. In addition, New Jersey was on the precipice of implementing the *Next Generation Science Standards* (NGSS) for the 2016-2017 school year which required teachers to not only incorporate scientific inquiry into classroom practices but also engineering design. This presented itself as another challenge to be faced upon my return.

Technology had also advanced in my time away from the classroom. Grading programs, learning management systems, web-based assessment tools, screencasts, podcasts, and interactive software either did not exist or had not yet emerged in most schools upon my exit. I worried that I would not be able to engage students who, unlike me, were digital natives. In an effort to prepare for this aspect of today's classroom, I enrolled in a web tools course for educators over the summer. Through this course, I was introduced to the idea of flipped learning.

Although I was originally skeptical of the idea of moving direct instruction out of the classroom, I began to realize the benefits that such a move could provide. For my situation and in light of my concerns, the greatest benefit that the flipped classroom approach promised was time, which was always the limiting factor in my attempts to create a more student-centered environment in my classroom. I was also hoping that utilizing the flipped model would afford me the time to implement inquiry-based lessons. Looking forward, the flipped model could also provide time for the scientific inquiry and engineering design practices that NGSS demands.

Upon meeting my chemistry students in September, I found that most students enjoyed science and felt that they learned science best using a “hands-on” approach. All students had Internet connectivity at home and brought some type of device to school. Therefore, incorporating a flipped learning approach would not create a hardship for any student. During the first marking period, I utilized video lectures produced by other science teachers to supplement my lessons. Informal discussion with my students revealed that some students watched the videos several times for understanding while others didn’t bother to watch them at all. I realized that my strategy for implementing a flipped learning approach needed to incorporate some type of formative assessment in order to provide feedback as well as accountability for the content of video lectures. The question remained, however, of whether this strategy would support student learning and keep students engaged during both in-class and out-of-class activities. Therefore, the focus questions that guided my action research were:

1. How did the use of the flipped learning approach and technology-based formative assessments affect students’ academic achievement in chemistry?
2. How did the use of the flipped learning approach and technology-based formative assessments affect student engagement?
3. How did the use of the flipped learning approach and technology-based formative assessments affect class participation?

CONCEPTUAL FRAMEWORK

The release and subsequent adoption of the Next Generation Science Standards (NGSS) marks a major shift in how science education is approached and will require

many science educators to teach in a new way. In *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*, the National Research Council (2012) explained that its vision for science education is that students “actively engage in scientific and engineering practices and apply crosscutting concepts to deepen their understanding of the core ideas in these fields” (p. 8-9). In order to realize this vision, educators must create an atmosphere of learning that incorporates not only the acquisition of content knowledge but the application of knowledge through scientific inquiry and engineering design. The vision challenges educators to deviate from the traditional method of teaching facts recognizing that science “is not just a body of knowledge that reflects current understanding of the world; it is also a set of practices used to establish, extend, and refine that knowledge. Both elements – knowledge and practice – are essential” (National Research Council, 2012, p. 26). The implementation of the NGSS requires that educators balance the need for content instruction with the need to practice science through inquiry and engineering design. At the same time, educators must also address the requirements of diverse learners and limited class time. One solution to these challenges is the flipped learning approach.

The flipped learning, or flipped classroom, approach is one in which “direct instruction moves from the group learning space to the individual learning space, and the resulting group space is transformed into a dynamic, interactive learning environment where the educator guides students as they apply concepts and engage creatively in the subject matter” (Flipped Learning Network, 2014, n.p.). In a flipped classroom, this is achieved by delivering direct instruction to students via video lecture which they watch

outside of class. This reserves in-class time for students to practice what they have learned in the presence of their teacher who can provide direct, targeted instruction (Sams & Bergmann, 2013).

There are several suggested benefits to the flipped learning approach. Utilization of the flipped learning approach provides the teacher with the gift of time to engage students through more meaningful activities that support learning (Bergmann & Sams, 2014; Sams & Bergmann, 2013). Flipping the science classroom maximizes the time in class that can be spent on student-centered activities, project-based learning, and inquiry instruction. Consequently, it eases the transition to the implementation of the NGSS practices of scientific inquiry and engineering design. Furthermore, project-based learning is no longer restricted to an activity that occurs after content instruction takes place. Students have the content resources available on video, and, therefore, can meet learning objectives as they participate in the problem, actively involving them in knowledge acquisition (Sams & Bergman, 2013; FLN, 2014; Johnson, Adams Becker, Estrada, & Freeman, 2015).

Another advantage to employing a flipped learning approach is that it permits teachers the freedom to work one-on-one with students allowing for differentiated instruction. Whether a student is in need of reinforcement or a challenge, the teacher has time to work with students individually or in small groups providing timely instruction at an appropriate level rather than a one size fits all level. In addition, the use of video lectures allows for self-paced learning. Students have the ability to stop, rewind, and re-watch video content that they do not completely understand. They can watch the videos

over and over again for greater content understanding. Once a teacher makes the transition to the flipped learning approach, it affords her students a library of content video lectures. This allows them to move from topic to topic at their own pace developing a mastery of each topic before advancing (Sams & Bergmann, 2013; Johnson et al., 2015; Finkel, 2012).

Until recently, there was no scientific research to support the use of the flipped learning approach as a viable method to improve student achievement (Goodwin & Miller, 2013). However, as the flipped model gains popularity, more concrete scientific research is emerging. One study compared test scores of students in a traditional advanced placement chemistry course to those of students in an identical flipped course. In all assessments, the flipped learning students scored significantly higher (Schultz, Duffield, Rasmussen, and Wageman, 2014). At Marquette University, test scores of students enrolled in a flipped general chemistry course were compared to test scores of students who were enrolled in the traditionally taught version of the course during the prior semester. Results revealed that scores were higher for the bottom third of students on all exams in the flipped classroom. A decrease in “D” and “F” grades and withdrawals was also reported (Ryan & Reid, 2015). In another study, low performing students showed the greatest increase in semester grades in a flipped International Baccalaureate Environmental Systems and Societies course (Marlowe, 2012). Schultz et al. (2014) attributes the increase in student academic performance to three characteristics of the flipped learning approach: self-paced learning, the application of knowledge

through in-class activities, and the additional teacher support available during face-to-face class time.

Other case studies support improvement in the area of academic performance as a result of the flipped learning approach. At Clintondale High School in Michigan, the implementation of the flipped learning approach is credited with reducing the failure rate of ninth grade math students from 44 to 13 percent (Finkel, 2012). Similarly, math mastery at Byron High School in Minnesota as measured by the Minnesota Comprehensive Assessments increased from 29.9% in 2006 to 73.8% in 2011 (Fulton, 2012).

The aforementioned studies also analyzed the effect of the flipped learning approach on student engagement and preference. Students who experienced flipped learning indicated a preference for the flipped method (Schultz et al., 2014; Lage, Platt, & Treglia, 2000), showed positive feelings toward the flipped model (Marlowe, 2012), and more effective engagement with lecture content (Ryan & Reid, 2015). Another study found that students preferred and experienced more innovation and cooperation during the classroom learning experience as a result of the flipped learning approach (Strayer, 2009). The flipped approach also engaged a diverse spectrum of learners resulting from increased student-instructor interaction, more active engagement, and group collaboration during face-to-face instruction time. Survey results revealed that increased student motivation was a result of students taking ownership of their learning (Lage et al., 2000). Others support the idea of increased student engagement and accountability due to the

independent work required of students in a flipped classroom (Sparks, 2011; Bergman and Waddell, 2012).

If you try flipping your classroom, I think you will find that your students start taking more responsibility for their own learning as well. They will be more engaged and active in your classroom, where they will learn how to work collaboratively. They will see you more as a mentor and a coach instead of a disseminator of knowledge. (Bergman and Waddell, 2012, p. 7)

Limitations to the flipped learning approach have also been identified. One study revealed that students were not comfortable with how the flipped classroom structure oriented them to accomplishing learning tasks in the classroom. Students indicated difficulty connecting the online portion of the course with the in-class portion which may actually lower student engagement (Strayer, 2009). Other limitations that have been cited include student distraction while viewing videos at home or students not viewing videos which would leave them unprepared for in-class activities. Furthermore, the videos are viewed by students asynchronously which prohibits students from asking questions of teachers and/or peers while receiving content instruction (Milman, 2012). Teachers must also consider the connectivity of students before deciding to flip their classroom (Bergmann & Wadell, 2012; Milman, 2012).

Although the challenge of ensuring connectivity for all students can be overcome through the use of DVD copies of lectures, borrowed devices, or dedicated in-school time to engage with videos, the other limitations mentioned are less easily resolved. For the flipped learning approach to be effective and meet the goal outlined in its accepted

definition of creating a meaningful face-to-face learning environment, the educator must have a strategy for student accountability and feedback for the out-of-class knowledge acquisition (Milman2012; Kim, Kim, Khera, & Getman, 2014). One strategy is providing incentives for students to watch video lectures by utilizing formative online quizzes and discussion groups in which students can ask questions (Kim et al., 2014). In addition, incorporating technology-enhanced formative assessment techniques during class can serve to evaluate student understanding of video lecture content in real time for the student and teacher. These practices also drive instruction so that teachers can focus some in-class time on comprehension of the material (Millard, 2012; Kim et al., 2014). Pairing the flipped learning model with technology that has student-response capabilities is a supported flipped approach that can increase student engagement, strengthen team-based skills, offer personalized guidance, and focus classroom discussion and activities (Millard, 2014, p. 29).

METHODOLOGY

The focus of this study was to examine the effects of replacing traditional classroom lecture with video lectures coupled with technology-based formative assessments that provide instant feedback on student achievement, engagement, and participation. This study was conducted over a period of five content units in two sections of Advanced Chemistry with a total of 49 students. Twenty-five students were female, 24 students were male, and all students were sophomores at West Morris Central High School, Chester, New Jersey. The high school was part of a *Bring Your Own Technology* district, and all students participating in this study brought a device to school

and had access to Internet resources. The research methodology for this project received an exemption from Montana State University's Institutional Review Board and compliance for working with human subjects was maintained (Appendix A).

The implementation of this study began with a pretreatment phase which covered the chemistry topic of chemical reactions. During this pretreatment phase, new content was introduced to students in a teacher-centered, lecture format. Occasionally, video lectures were utilized to support the lesson content. These video lectures were available on the teacher's Learning Management System (LMS), Haiku. Formative assessments including exit tickets and minute papers were typically administered to students at the end of class once or twice per week. These assessments were collected and evaluated by the teacher and returned during the subsequent class period. The Assess feature of Haiku was used to create online formative quizzes for students to practice math skills related to chemistry. The online format for formative quizzes was not employed to support content on current topics. Summative assessments such as unit tests, quizzes, labs, and activities were used to measure student achievement to determine their marking period grade.

There were two different treatment phases of this study with each phase encompassing two units of study. The content of the first treatment phase covered the topics of stoichiometry and reaction kinetics. During this phase, the teacher-centered, lecture format for content instruction was maintained. However, technology-based formative assessments accompanied each lecture using the online assessment feature in Haiku or other real-time, online presentation and formative assessment tools like Pear Deck and Kahoot. These formative assessments allowed immediate feedback to be

delivered to both the students and teacher. Other classroom activities such as practice, projects, and labs as well as summative assessment techniques remained the same as during the pretreatment phase.

The second treatment phase was implemented during the thermochemistry and solutions units of the chemistry course of study. This treatment phase coupled the use of technology-based formative assessment tools with the use of video lectures in a flipped learning approach. Four videos were assigned for the thermochemistry unit that provided content instruction and problem solving strategies for heat of reaction, heat of solution, calorimetry, and Hess's Law. Four videos were also assigned for the solutions unit which provided content instruction about mixtures, solutions, and solubility and problem solving strategies to calculate solution concentration. Six of the eight videos were self-created using annotated presentations such as PowerPoint and Prezi, virtual chalkboards, simulations, and video clips. In general, each video was six to ten minutes in length.

Students watched the video lectures for homework prior to class meetings and participated in formative assessments that provided immediate feedback using online tools in Haiku. Each class meeting began with a short discussion of content that sometimes utilized online tools such as Pear Deck and Kahoot to formatively assess students before they embarked on classroom activities of practice, projects, and labs. Participation points were given to those students who watched the videos and completed the online formative assessments in Haiku prior to class. These participation points, in addition to summative assessments such as tests, quizzes, labs and activities, were used to

measure student achievement for their marking period grade but not utilized as data to inform this study.

Student academic achievement was evaluated by the administration of the Chemical Reactions Content Test (Appendix B), Stoichiometry Content Test (Appendix C), Reaction Kinetics Content Test (Appendix D), Thermochemistry Content Test (Appendix E), and Solutions Content Test (Appendix F) both prior to and at the conclusion of each unit. These teacher-generated tests consisted of 12 multiple choice questions specific to each unit of study. A Wilcoxon Signed Rank test was applied to each of these tests to determine a statistical difference in score from pre- to post-test. Each set of pre- and post-test scores was also analyzed for normalized gains for which 0 to 0.3 was considered low gain, 0.3 to 0.7 were medium gain, and above 0.7 was high gain. The normalized gains for the Stoichiometry and Reaction Kinetics Content Tests from the traditional with technology-based formative assessment (TBFA) treatment phase and the Thermochemistry and Solutions Content Tests from the flipped learning treatment phase were compared to the normalized gains of the Chemical Reactions Content Test from the traditional pretreatment phase to determine trends in student achievement with each treatment. Summative unit test scores from the treatment phases were also compared to that of the pretreatment phase. The effect of the treatment on student achievement was also measured by a qualitative analysis of the percentage of students who demonstrated understanding of current content through formative assessments.

The level of student engagement and participation during the traditional pretreatment phase was determined utilizing the Student Pre-Treatment Survey (Appendix G). The Student Post-Treatment Survey was administered after the conclusion of the flipped learning treatment phase (Appendix H). Both surveys included Likert-type statements about content delivery, participation, preparedness, and formative assessments with the choice to respond *strongly agree*, *agree*, *disagree*, or *strongly disagree*. The results of the two surveys were qualitatively compared to determine trends in engagement and participation as a result of the treatments.

Further qualitative evidence of the effect of the treatment on engagement and participation was gathered from Post-Treatment Student Interviews of eight students at the conclusion of the flipped learning treatment (Appendix I). Nine questions about the video lectures and formative assessments were administered to two male students and two female students from each of the two chemistry classes.

A record of participation in the online activities was kept using data amassed from Haiku. The Haiku LMS provided daily reports about student activity that included which students watched the assigned videos, how long they watched, and how many times they watched. A student was considered to have participated if they watched the video for a time equivalent to the length of the video at least once and completed the associated Haiku formative assessment.

A Daily Teacher Journal (Appendix J) was kept during pre-treatment and treatment phases of the classroom research project. The journal entries documented participation, levels of engagement and other observations to qualitatively inform this

study. Observations recorded in the Daily Teacher Journal were made by the classroom teacher. Colleagues also contributed information concerning engagement and interest levels of students to establish a more unbiased view (Table 1).

Table 1
Data Triangulation Matrix

Focus Questions	Data Source 1	Data Source 2	Data Source 3
1. How does the use of the flipped learning approach and technology-based formative assessments affect students' academic achievement in chemistry?	Summative Assessment Scores	Pre- and Post-Content Test Scores	Formative Assessments
2. How does the use of the flipped learning approach and technology-based formative assessments affect student engagement?	Student Pre- and Post-Treatment Survey	Post-Treatment Student Interview	Daily Teacher Journal
3. How does the use of the flipped learning approach and technology-based formative assessments affect class participation?	Daily Teacher Journal	Participation Data for Technology-Based Formative Assessments	Post-Treatment Student Interview

DATA AND ANALYSIS

A difference in the median pre-test and post-test scores for all content tests was revealed by Wilcoxon Signed Rank tests that each produced p-values less than 0.01 ($N=49$). The median score for the Chemical Reactions Content Test administered during the traditional pretreatment phase increased from 58% in the pre-test to 92% in the post-test. The Stoichiometry Content Test and Reaction Kinetics Content Test administered

during the traditional with technology-based formative assessments (TBFA) treatment phase showed increases in median scores from 42% to 67% and 50% to 83% from pre-test to post-test, respectively. Similarly, median scores for the flipped learning treatment phase rose from 33% to 75% for the Thermochemistry Content Test and from 42% to 75% for the Solutions Content Test (Figure 1).

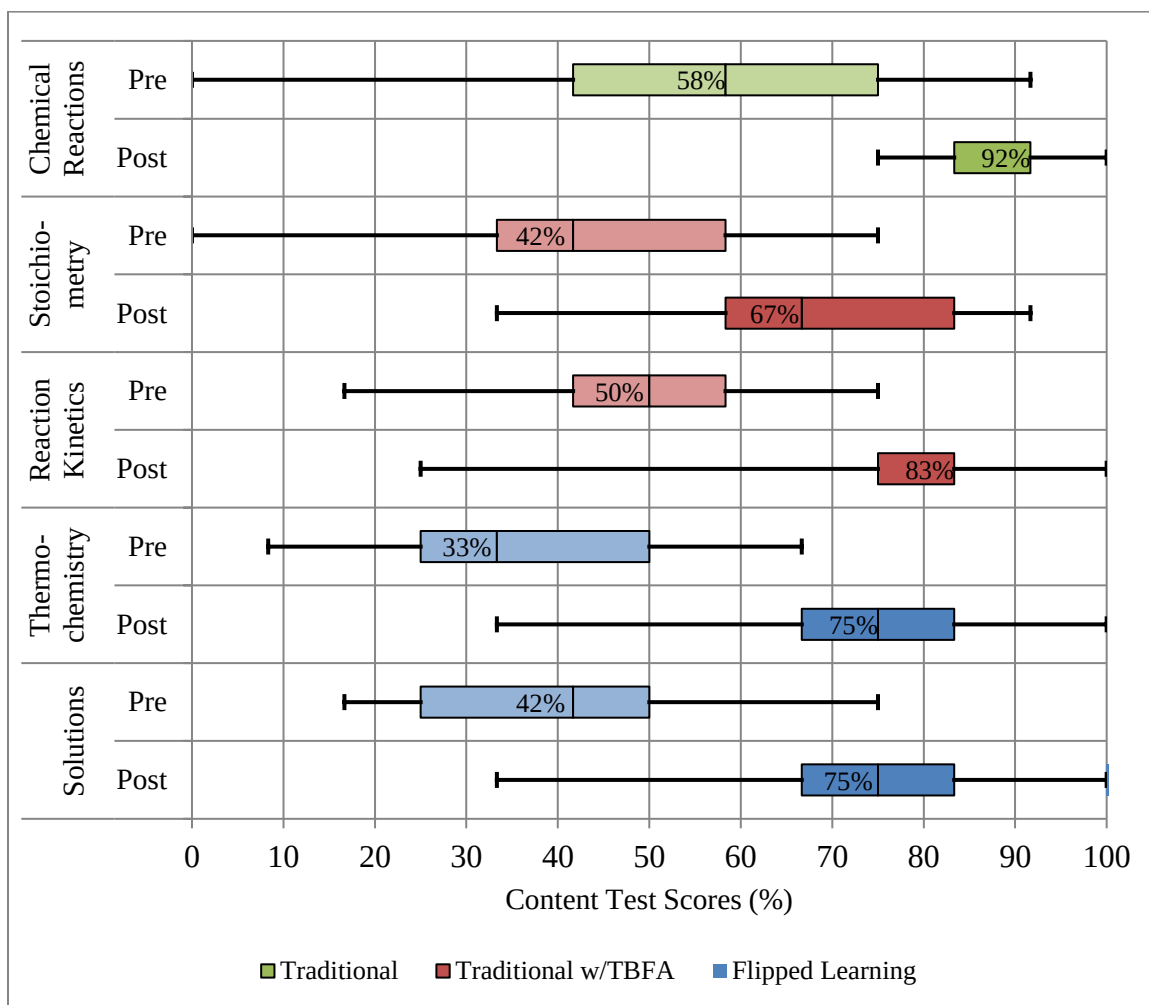


Figure 1. Pre- and post-content test scores, ($N=49$).

These positive changes in score from pre-test to post-test corresponded to a 59% increase for the traditional pretreatment unit, 60% and 66% increases for the traditional with TBFA units, and 127% and 79% increases for the flipped learning units.

An evaluation of normalized gains for all content tests revealed mean normalized gains between 0.3 and 0.7, which were considered to be medium gain. The mean normalized gains for the Stoichiometry Content Test from the traditional with TBFA phase was considerably lower at 0.43 than the mean normalized gain for the Chemical Reactions Content Test from the traditional pretreatment phase at 0.65. The differences in gains for the other three content tests compared to the Chemical Reactions Test were not as dramatic with gains of 0.57 for the Reaction Kinetics & Thermochemistry Content Tests and 0.51 for Solutions Content Test (Figure 2).

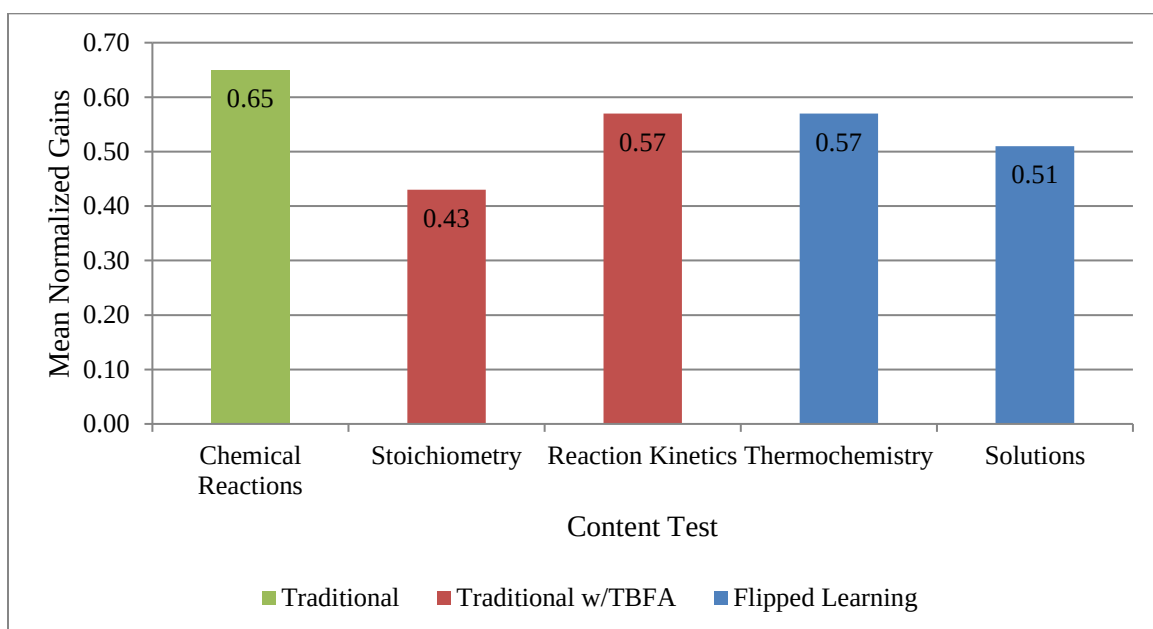


Figure 2. Average normalized gains for pre- and post-content tests, ($N=49$).

A separate analysis of mean normalized gains was conducted for two groups of students, students with Individualized Education Plans (IEP) and students with low academic performance in chemistry. For the group of students with an IEP, mean normalized gains were consistent with the distribution of normalized gains for the whole population ($N=5$). The second group was taken from twelve students who averaged a

75% or below overall in chemistry before this classroom research project began. Of those 12 students, eight actively participated in class and homework activities specific to the treatment. This was evidenced by homework checks, participation in technology-based formative assessments, and watching video lectures prior to class. An analysis of mean normalized gains for this group of eight students revealed an increase from 0.48 in the traditional unit to 0.61 and 0.64 in the flipped learning units (Figure 3).

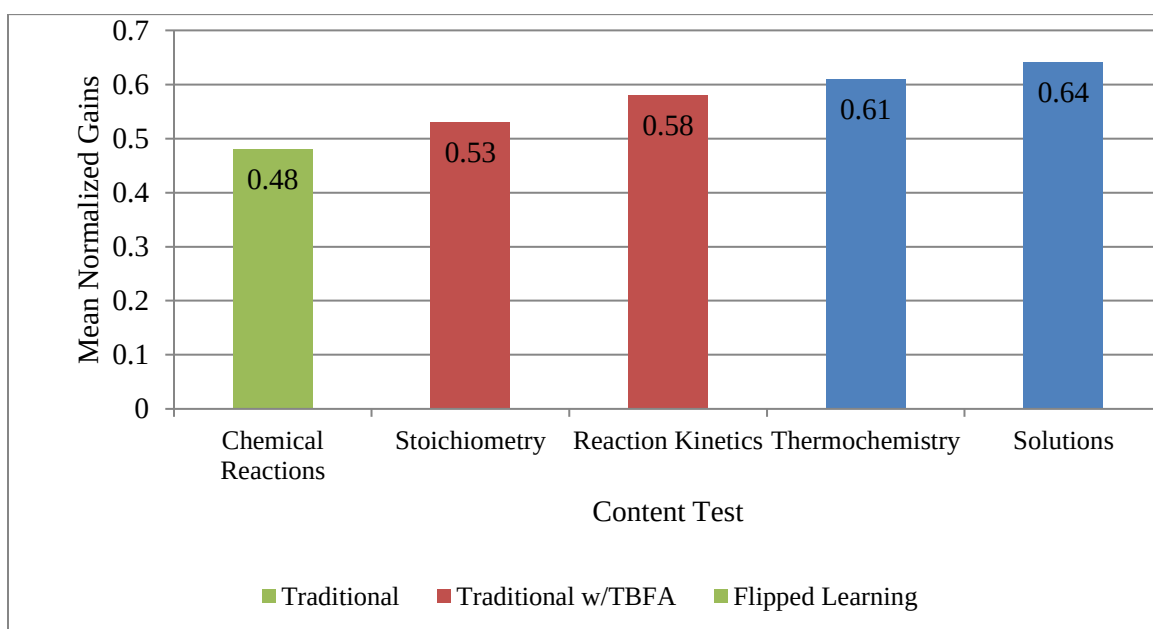


Figure 3. Mean normalized gains for participating low performing students, (N=8).

A synopsis of data from summative assessment scores from tests that were administered at the conclusion of each of the five content units indicated that the median assessment scores were within the 80th percentile range for all tests regardless of treatment. The range of test scores was similar for all treatment units spanning from the 40th percentile to the 100th percentile. The traditional unit had a slightly smaller range from 55% to 99%. Maximum test scores of 100% were earned in the flipped learning units and for the stoichiometry unit during the traditional with TBFA phase. (Figure 4).

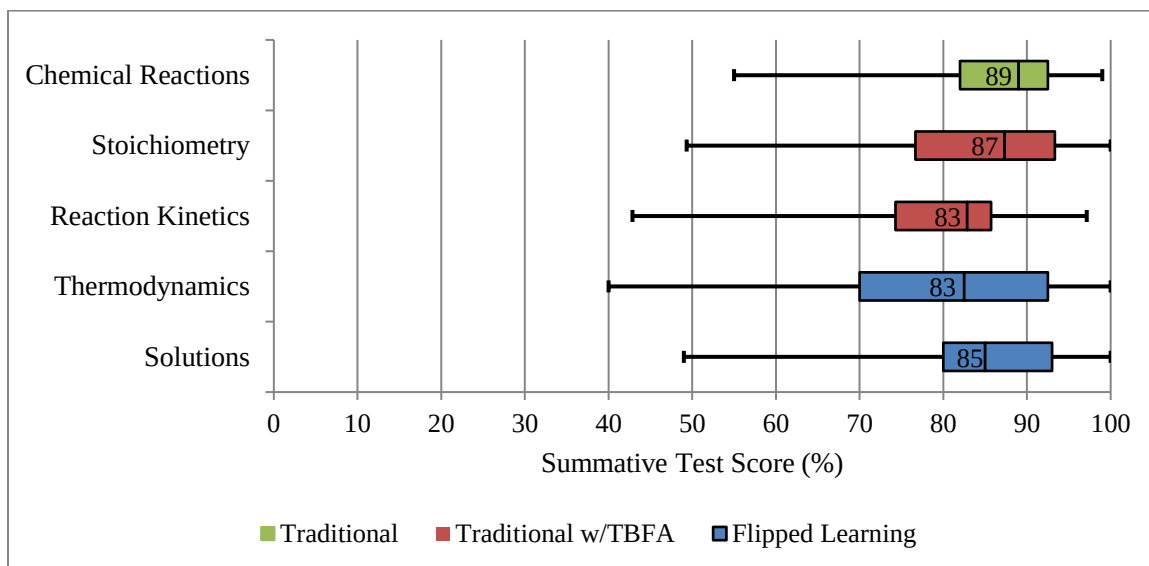


Figure 4. Summative unit test scores, ($N=49$).

A separate analysis of summative test scores for students with an IEP and participating low performing students was conducted. Students with an IEP maintained median scores within six percentage points on the summative assessments over the five content units. There was slight increase from the traditional unit with a median score of 87% compared to the flipped learning units with scores of 90% and 89% (Figure 5).

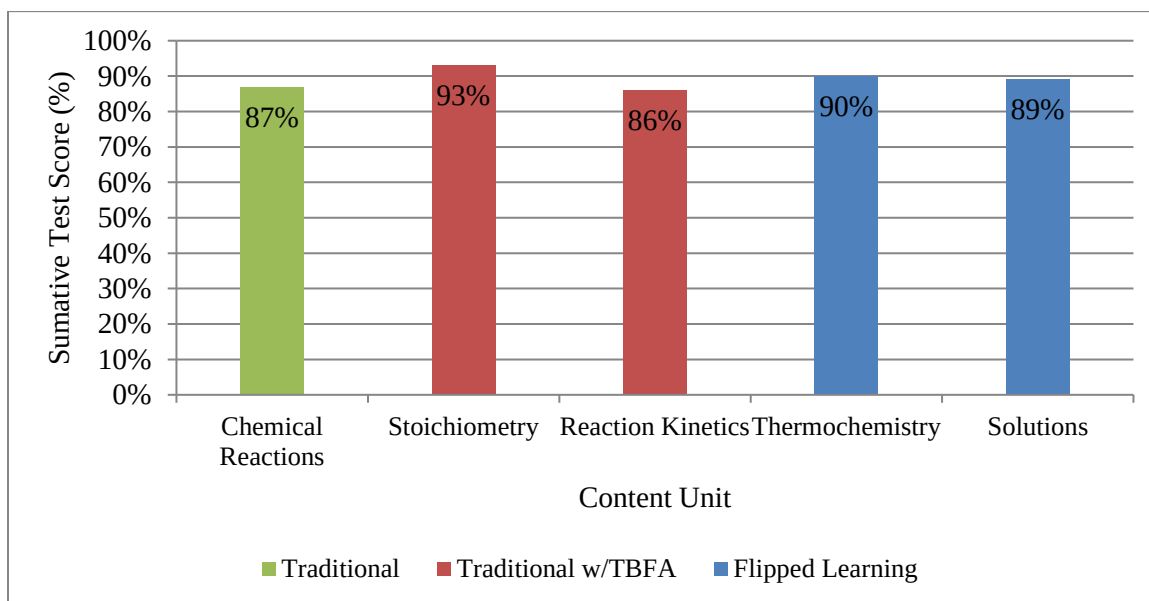


Figure 5. Summative unit test scores for students with an IEP, ($N=5$).

Median summative test scores for the low performing students increased from 72% in the traditional unit to 80% and 74% during the traditional with TBFA units and 79% and 81% during the flipped learning units (Figure 6).

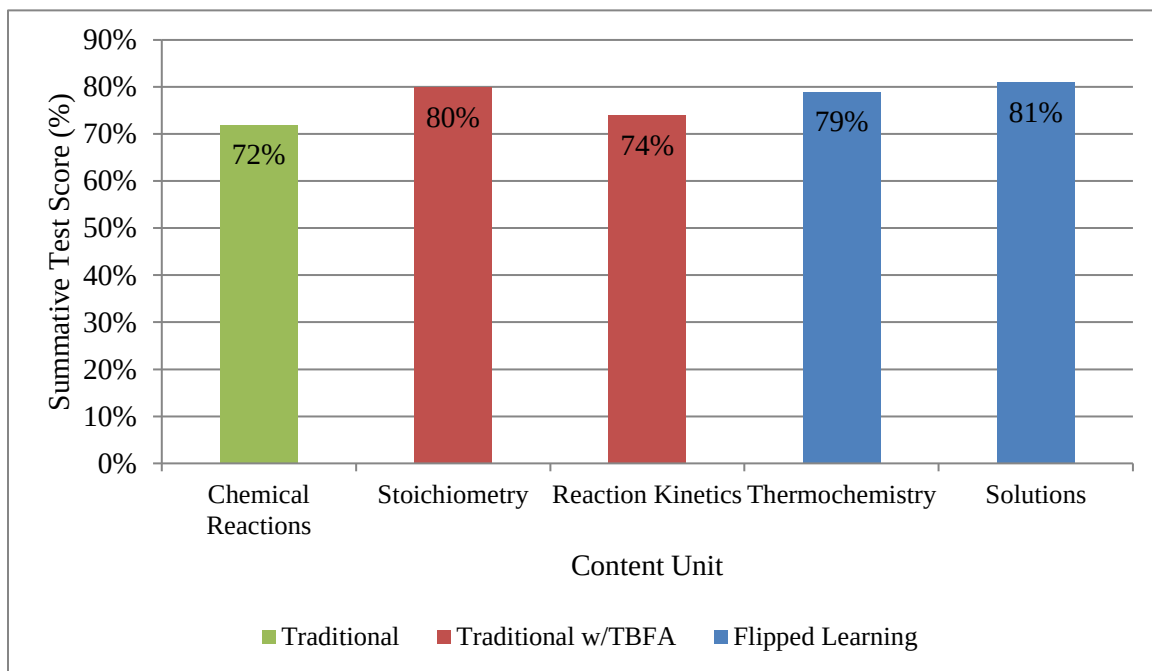


Figure 6. Summative unit test scores for participating low performing students, (N=8).

During the traditional pretreatment phase, students were given paper and pencil formative assessments that were collected and returned with feedback during the next class session. Due to this method of delivery, students were provided only one attempt to demonstrate understanding of content. There were five formal formative assessment opportunities during this phase. Data collected indicated that an average of 78% of the students demonstrated understanding of content using these formative assessments.

Both treatment phases allowed for the use of technology-based formative assessments. These types of assessments provided immediate feedback and students were provided more than one attempt at the assessment. Five formative assessments

were administered for each treatment unit. During the traditional with TBFA phase, 73% of students on average demonstrated an understanding of content during their first attempt at a formative assessment. However, when provided with a second or third opportunity, the percentage of students who could demonstrate understanding increased to 96% on average. Similarly, during the flipped learning phase, the average percentage of students who showed evidence of learning changed from 84% on the first attempt to 98% on subsequent attempts (Figure 7).

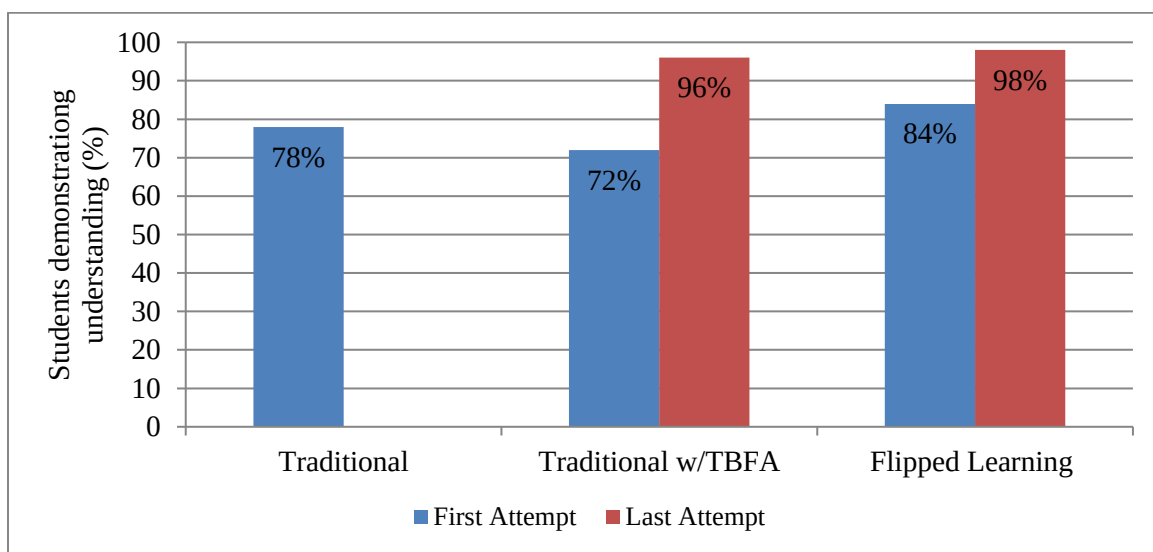


Figure 7. Students demonstrating understanding via formative assessments, (N=49).

Student engagement was identified in this classroom research project by the students' interest in chemistry, comfort with pace of the lecture component, perceived level of preparedness, confidence, interest and involvement during class activities, and completion of assignments. The Pre- and Post-Treatment Surveys revealed that student interest in chemistry was elevated over the treatment period. The percentage of students who *agreed* or *strongly agreed* that they were interested in chemistry increased from 76% to 88%. Additionally, the percentage of students who *strongly agreed* increased from 6%

to 18% after participating in the flipped learning approach with technology-based formative assessments (Figure 8).

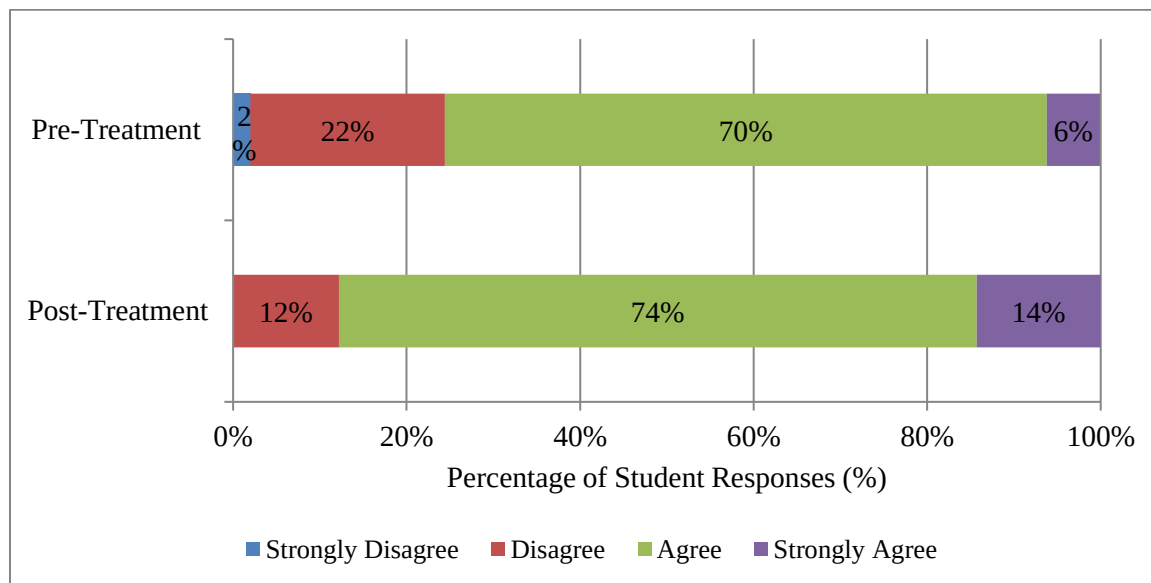


Figure 8. Percentage of students interested in chemistry, ($N=49$).

Student responses to the Pre-Treatment Survey statements concerning the pace of lectures indicated that 22% of students felt that traditional lectures were too fast. Only 6% of students in the Post-Treatment Survey felt that similar lectures accessed by video with the flipped learning approach were too fast. Although the percentage of students who were comfortable with the lecture pace remained consistent, the percentage of students who felt that lectures were too slow rose from 4% for traditional lectures to 25% for the flipped video lectures (Figure 9).

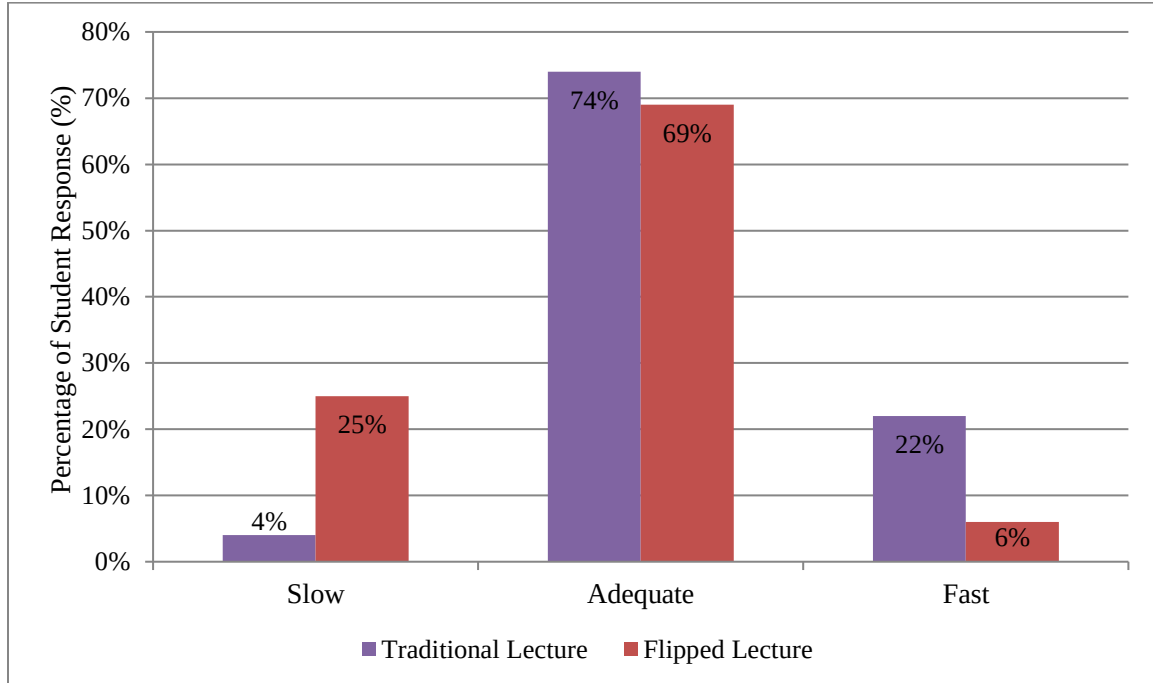


Figure 9. Percentage of student responses on pace of lectures, ($N=49$).

According to the Post-Treatment Survey, 82% of students felt that they were in control of the pace of their own learning by utilizing the video lectures. One student commented, “I miss information when I am trying to listen and take notes in class. I like the video because everything on it is deliberate, and I can control it if I need to go slower or go over it again.” Eighty-eight percent of the students interviewed indicated that the most beneficial aspect of watching the videos at home was the ability to pause, rewind, and watch again ($N=8$). According to Pre- and Post-Treatment Survey results, 75% of students *agreed* or *strongly agreed* that it was easy to listen to the video and take notes compared to 51% for the in-class, traditional lecture. Even a student who thought the pacing of the flipped video lectures was slow said, “I’m better with a fast pace, but I could always fast forward through videos. That’s what I would do if I knew something. I would just focus on the new information.”

The level at which students felt prepared for in-class activities and practice was also measured by the Pre- and Post-Treatment Surveys. The results seemed to suggest that the traditional approach left students feeling more prepared for in-class activities and practice than the flipped learning approach (Table 2).

Table 2
Survey Response Concerning Perceived Level of Preparedness

I feel prepared to participate in:	Traditional Lecture	Flipped Video Lecture
Classroom activities	83%	65%
Laboratory activities	86%	69%
Homework/Classwork practice	83%	80%

Note. (N=49)

However, all students who were present in class had the benefit of participating in a traditional, in-class lecture. Moving the lecture out of the classroom introduced the possibility that students did not participate in the flipped video lecture because they chose not to watch it. Post-Treatment Survey results revealed that 16% of students did not watch the videos when they were assigned. In order to realize the effect of students who chose not to watch the videos on the preparedness data, students were grouped according to the Post-Treatment Survey response: *I feel more prepared for class after viewing a video lecture*. Seventy-one percent of students *agreed* or *strongly agreed* that they felt prepared for class as a result of viewing the videos. All of these students watched the videos when they were assigned, and the majority of this group exhibited positive and proactive behaviors when interacting with the video lectures (N=35) (Table 3).

Table 3

Post-Treatment Survey Responses about Video Lecture from Prepared Group

	Agree/Strongly Agree
I watch video lectures when they are assigned.	100%
I take notes on my own while I watch video lectures.	66%
I watch video lectures to prepare for tests and quizzes.	57%

Note. (N=35)

The remaining 29% of students responded that they did not feel prepared for class. From this group, only 43% of the students responded that they watched the video lectures when they were assigned, and few exhibited positive behaviors such as note-taking and watching videos for test and quiz preparation (N=14) (Table 4).

Table 4

Post-Treatment Survey Responses about Video Lecture from Unprepared Group

	Agree/Strongly Agree
I watch video lectures when they are assigned.	43%
I take notes on my own while I watch video lectures.	36%
I watch video lectures to prepare for tests and quizzes.	7%

Note. (N=14)

Analytical data from the learning management system where the video lectures were posted confirmed that the eight students who responded that they did not watch the videos consistently did not participate in the flipped videos lectures. Removing the responses from these eight students from the Pre-and Post-Treatment Survey data revealed a different picture when comparing how prepared students felt with traditional, in-class lectures versus the flipped video lectures. Students felt only slightly less

prepared for classroom and laboratory activities when using flipped video lectures, and more students felt prepared for homework/classwork practice from the videos (Table 5).

Table 5

Survey Response Concerning Perceived Level of Preparedness Revised

I feel prepared to participate in:	Traditional Lecture	Flipped Video Lecture
Classroom activities	85%	78%
Laboratory activities	87%	83%
Homework/Classwork practice	85%	95%

Note. (N=41)

Student interviews supported the idea that students who participated in the flipped video lectures felt prepared for class. One student commented, “I knew what was going on in class a lot better because I had background information. I wasn’t coming in wondering what we were learning and completely overwhelmed with new stuff.” Another student agreed that watching the videos “made it more efficient coming in knowing what we were doing.”

Student interviews and teacher observations indicated that students came to class with more confidence and interest during the traditional with TBFA units and the flipped learning units. Eighty-eight percent of students interviewed indicated that watching videos prior to class increased their confidence. “It does give me more confidence in chemistry because I know what I am doing compared to the beginning of the year when I had to figure it out in class.” Seventy-five percent of students interviewed also agreed that the technology-based formative assessments that supported the lectures boosted confidence. One student commented, “I’m not good at seeing what I’m not good at. So, if I saw that I was bad doing this one thing and good at other stuff, I’d work on that more

before the next day.” Students interviewed also appreciated the chance to have multiple attempts at assessment questions. As one student said, “when you get it wrong, you know to look for your mistake and correct it so you learn that way.”

Daily observations made by the teacher and by colleagues indicated a disparity in the level of interest during lecture and during problem-solving, class activity, or lab time. Traditional class lectures were consistently described as a low engagement and low interest activity. Students were always described as passive with few asking questions or volunteering to answer questions. The Pre-Treatment Survey data supports this observation in that only 18% of students *agreed* or *strongly agreed* that they ask questions during class lecture and 35% *agreed* or *strongly agreed* that they answer questions during discussion. Conversely, observations revealed that students were always on-task and highly engaged in laboratory activities and problem solving tasks regardless of the lecture format that preceded it.

The flipped learning approach allowed more time for problem-solving and laboratory activities in place of lecture time. As a result, more class periods were described by the teacher and her colleagues as high interest during the flipped learning treatment phase than during the traditional pretreatment phase. Student interest and engagement during the traditional with TBFA treatment phase was mixed. When traditional lecture was coupled with the interactive components of Pear Deck and Kahoot, more students actively participated in class according to notes in the Daily Teacher Journal. One student who was interviewed said, “I was more interested in class when we

did Kahoot and Pear Deck because of the enjoyment factor.” Another student attributed her increased interest to the competitive aspect of the technology-based applications.

Teacher records and analytical data from Haiku were used to evaluate homework completion over the pretreatment and treatment periods. Homework completion percentages were similar during the traditional pretreatment phase and traditional with TBFA treatment phase with 70% of students completing homework during the chemical reactions pretreatment unit compared to 65% and 72% during the stoichiometry and reaction kinetics units, respectively. Although there was a decline in homework completion to 63% during the first flipped learning unit of thermochemistry, there was an increase in homework completion for the second flipped learning unit of solutions to 84% (Figure 10).

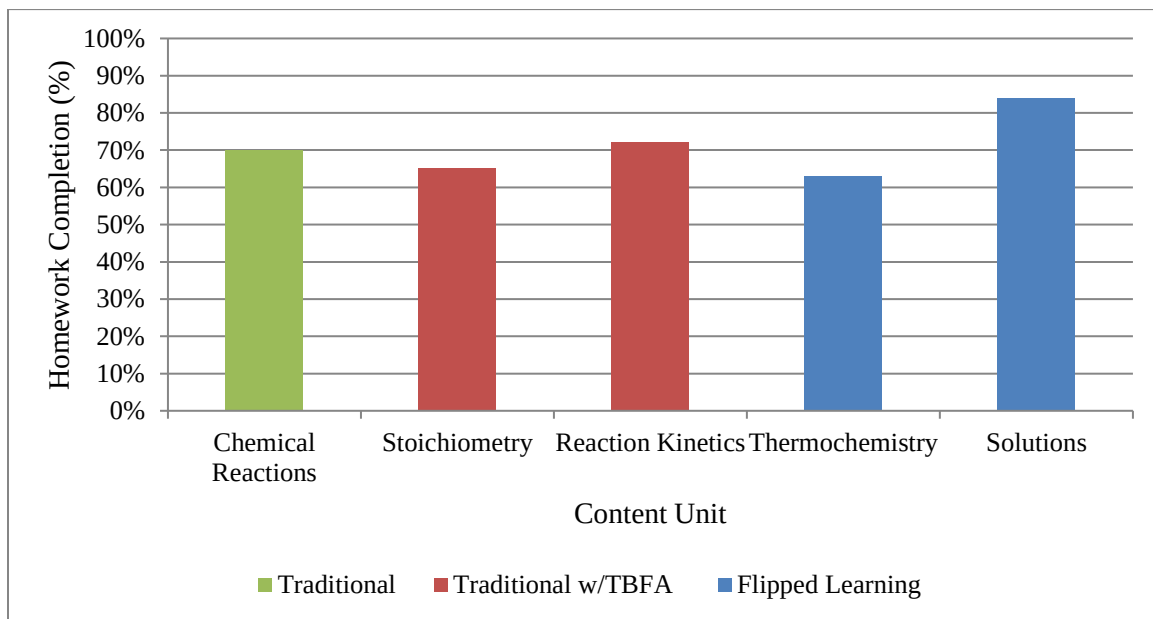


Figure 10. Average percentage of students completing homework, (N=49).

Student participation in classroom activities was tallied using observations recorded in the Daily Teacher Journal. On a daily basis, the teacher asked an average of

six questions during a typical class lecture that lasted from 15 to 30 minutes during the traditional pretreatment phase. On average, 12% of the students would volunteer to verbally answer per question during the pretreatment phase. In addition, two clarification questions were asked during or after each lecture on average, and a probing question was asked on occasion. The average active participation in class and lab activities that followed class lectures was 97%.

During the traditional with TBFA treatment phase, the averages remained consistent with the averages from the pretreatment phase unless Pear Deck or Kahoot was used as the TBFA tool. When these tools were used, the teacher asked an average of 10 questions which 90% of students answered using the interactive applications. The average number of clarification and probing questions asked and the average active participation in class and lab activities remained consistent with the pretreatment phase (Table 6).

Table 6
Comparison of Participation among Treatment Phases

	Traditional Phase	Traditional with TBFA Phase using Interactive Applications	Flipped Learning Phase
Number of questions asked	6	10	10
Percentage of students who volunteer to answer	12%	90%	27%
Number of clarification questions asked by students	2	2	3
Number of probing questions asked by students	>1	>1	>1
Percentage of active participation in class/lab activities	97%	97%	96%

A number of students wrote on the Post-Treatment Survey that they enjoyed participating in both Kahoot and Pear Deck. One student interviewed said, “When we did Pear Deck, it was fun to move the dot or answer questions so I participated where I wouldn’t have raised my hand to answer in class.”

Participation in the online video lectures was determined using the analytical data amassed from Haiku. During the flipped learning units, students watched the videos when they were assigned with 76% participation on average. Eighty-four percent of students watched the videos regularly while sometimes missing one or two video assignments. Sixteen percent of students never watched the videos. Students completed the coupled online formative assessments with 92% participation indicating that students who never watched the videos did participate in the formative assessments. This is supported by Post-Treatment Survey data in which 90% of students *agreed* or *strongly agreed* that they participated in Haiku assessments.

During the flipped learning treatment phase, each class period began with a discussion highlighting the content of the video lectures. Participation data was tallied using the Daily Teacher Journal. The teacher asked an average of 10 questions during the 10 to 15 minute discussion. On average, 27% of students volunteered to verbally answer. The average number of clarification and probing questions asked and the average active participation in class and lab activities remained consistent with the traditional pretreatment phase (Table 6). Of the eight students interviewed, 63% agreed that watching the videos prior to class resulted in their increased participation. One student said, “I definitely participate more after watching the videos because it makes it easier to

answer the questions since I learned it at home and it had time to sink in.” However, for some the flipped approach had no effect on their participation. A student who was interviewed explained, “I liked learning online but it didn’t translate to more participation in class because I just don’t like to talk.”

INTERPRETATION AND CONCLUSION

The data analyzed in this classroom research project suggested that student academic achievement remained consistent throughout the pretreatment and treatment phases for the overall population of students involved. However, a positive effect on student achievement was observed upon isolating achievement data from students with an IEP and historically low-performing students who fully participated in the flipped learning activities. The results of this project also suggested that student engagement and interest in chemistry increased over the treatment period. Furthermore, students actively participated in classroom discussion more as a result of the flipped learning approach.

Considering the academic achievement of the entire population, median content test scores improved for each unit regardless of instructional method, and mean normalized gains were medium for all units as well. The comparison of summative test scores did not demonstrate a substantial difference in scores either. However, the traditional pretreatment unit produced the highest median scores and highest mean normalized gain for both the Pre- and Post-Content Tests and the summative test.

Looking at the content test data, particularly the normalized gains, one could conclude that the traditional lecture approach during the pretreatment phase afforded the students the greatest academic success. Being that this is a classroom research project,

however, it is important to look at the content and the difficulty of the units that were compared. The traditional pretreatment unit was chemical reactions. Evidenced by the high pre-test scores, students had more prior knowledge in this content area than the others. The unit consisted of identifying reaction types and predicting products of chemical reactions. Most importantly, the only mathematical component of this chapter was balancing equations.

The subsequent units had a significant mathematical component to the content. In addition, students had been introduced to very little of the content in middle school or first-year biology other than a superficial knowledge of solutions. This was evident from the low pre-test scores on the content tests. For these reasons, I was comfortable concluding that utilizing the flipped learning approach in my chemistry classroom had neither a positive or negative impact on student achievement overall despite higher median scores and mean normalized gains for the traditional unit.

An argument can be made that use of the flipped learning method coupled with technology-based formative assessment had a positive effect on student achievement for two groups of students. Students with an IEP and historically low performing students who participated in the flipped learning activities earned better test scores in the treatment units than in the traditional pretreatment unit when qualitatively compared. I singled out these two groups based on student interviews with one student from each group. Both students preferred the flipped learning model and the use of technology-based formative assessments.

Students with an IEP achieved equal or better scores on their summative tests for the treatment units compared to the traditional pretreatment unit. Considering the difficulty factor and the math component of the treatment units, it could be argued that the flipped learning approach and use of TBFA had positive impact on their performance. The student who was interviewed from this group believed she learned best from the flipped learning approach. She stated that watching the videos at home allowed the content to sink in before having to apply it in class. She also preferred it because I was available to help while she was applying the concepts. Additionally, she thought that the interactive component of the technology-based formative assessments agreed with her learning style. Although each student in this group had a different IEP, they each required extra support. The flipped learning approach provided that extra reinforcement with the availability of content lectures on video and the teacher support during problem solving and application.

Low performing students who fully participated in the flipped learning activities also achieved better summative test scores for the treatment units compared to the traditional pretreatment unit. In addition, the mean normalized gains for the pre- and post-content tests were highest for the flipped learning units and lowest for the traditional pretreatment unit. This data implied that the flipped learning approach had a positive impact on student achievement for this group of students. The student who was interviewed from this group also believed that he learned best with the flipped learning approach. He stated that learning from the videos at home worked for him because he was often tired during our class meetings and not retaining anything from the class

lectures. He also said that the TBFA helped him learn because he participated in class without having to speak aloud. Although each student in this group had a different reason for low previous academic achievement, this student's experience illustrated how the flipped learning approach could lead to improved academic achievement for those whom the traditional classroom model does not work.

The impact of the flipped learning approach and technology-based formative assessments on student engagement and participation was measured by students' interest in chemistry, comfort with pace of the lecture component, perceived level of preparedness, confidence, interest and involvement during class activities, and homework completion. Results suggested that my students were more interested and confident in chemistry at the conclusion of the treatment units. This may have been attributed to increased comfort with the pace of the lecture component. Interviewed students cited that the most beneficial part of the video lectures was the ability to pause, rewind and watch the videos over. This enabled students to control the pace of their learning. Students who fully participated in the process also felt equally prepared to engage in class activities like problem solving and lab work. When students were able to understand the content enough to apply it, it followed that they were more interested and confident in the content.

Technology-based formative assessments like Kahoot and Pear Deck were useful and fun additions to both the traditional lecture approach and the flipped learning approach. Students were clearly more engaged in the class lectures that included these technology-based formative assessments. However, their use did not translate into

increased student participation in class discussion. The flipped learning approach, on the other hand, did result in higher participation in class discussion. Again, students were prepared and more confident to answer questions due to their prior exposure to the content.

Although students had greater interest in chemistry after the flipped learning units, it was not watching videos itself that made it more engaging. In fact, several of the students interviewed liked the videos but felt that it was the quantity of labs and classroom activities that we did in place of the lecture that made class more engaging. The data shows that my students were equally interested and involved in classroom activities and labs regardless of the approach used. Therefore, the element that made chemistry more interesting after the flipped learning treatment was the time that flipped learning provided to do more of high interest classroom activities and labs.

Although most of my students preferred the technology-based formative assessments, not all of my students were on board with the flipped learning approach. They struggled at first adjusting to watching videos for homework. The homework completion data showed a decrease in homework completion for the first flipped unit. Informal discussions with my students during that unit revealed that some did not take the homework assignment seriously at first while others did not like being introduced to content without their teacher present to answer their questions. I made some adjustments based on their feedback for the second flipped unit including providing some guided notes sheets for them to complete while watching the videos and making the online

formative assessments on the video content more straightforward. They responded with increased homework completion percentages.

This treatment was a disruption to the routine of the students. The small gains realized during the treatment may have been magnified if the flipped learning approach coupled with technology-based formative assessments had been integrated into the classroom routine at the onset of the school year. Although most of my students eventually accepted the change, there were some who participated fully but still did not prefer flipped learning. It is possible that they may have had a different opinion if it were integrated slowly and methodically from the beginning of the course.

VALUE

After all of the videos were made, the lessons were taught, the data was analyzed, and the conclusions were drawn, the answer to whether the flipped learning approach was worth introducing and pursuing in my chemistry classroom came from one interview with one student who did not prefer it. In her interview, she told me that when she watched the videos she often had questions. She would visit other websites or explore her textbook to clarify some of the video content so that she was prepared for what we were going to do in class the next day. Then, she said that she really didn't like that because she liked it when the teacher told her what she needed to know and gave her steps to solve related problems. It was at that moment that the value of this approach was revealed to me. I was no longer the disseminator of knowledge. Instead, I became the mentor and coach that Bergman and Waddell (2012) described.

Our objective as educators is to teach students not what to learn but how to learn. In a test-driven atmosphere, students often only want to know what they need to know while we want them to appreciate and understand the content of what we teach so that they can apply it. We want to engage with our students during the “understand and apply” part of the learning process. I think that using the flipped learning approach during this classroom project provided me this type of engagement with my students as well as more time to engage with them.

I am looking forward to incorporating the flipped learning model and technology-based formative assessment tools into my chemistry courses next year. Small improvements in academic achievement and confidence for students with an IEP and low performing students validated that this approach is a tool that could make a difference in helping teachers reach students who otherwise may be left behind. I think it would be worthwhile to collect data to determine if and how these students benefit from learning chemistry from the flipped approach for the entire year.

As previously stated, I think that the flipped learning approach should be infused into the classroom routine from the beginning of the course and will be using what I learned through this classroom research project to thoughtfully incorporate it next year. I also think that the video lectures are just a piece to the flipped learning approach. I do believe that they enhance content discovery, but I believe that students should also be asked to read, research, and explore simulations as part of the flipped learning experience. Ultimately, I would like to use the flipped learning approach as a model for

my students of how to become independent learners who are responsible for their own knowledge.

As I reflect on my evolution as a teacher from my first year out of college to today, there has not been a year in which I have grown more than this year. There are several factors that I can attribute for this growth, a new school atmosphere, the supportive, innovative colleagues with whom I work, my different perspective as a parent, and this action research project. In my practice, I have always attempted to relinquish the control that a teacher-centered approach provides. I would strive to create that activity-based atmosphere where students were guided to discover knowledge rather than led. I always fell short though, and I often reverted back to my comfort zone as the disseminator of knowledge. Trying the flipped learning approach was a leap of faith that was unnerving for me. It was a leap that I am glad that I took. Providing my students with videos and other resources to guide their learning so that class time could be spent on activities and labs created a balance of teacher control and student exploration with which I felt comfortable. For the first time, I allowed my students to fail and struggle before pointing them in the direction of success for them to realize on their own.

Implementing this flipped approach wasn't easy for me. One of my strengths as a teacher is that I connect with my students and create trust. When I began the flipped learning approach, my students were wary, and I could feel the connection and trust that I had waiver. Through the observations that I made each day for my action research, I could see the changes though. I could feel the life in my classroom as they were constantly engaged in one activity or another. As the connection and trust was restored,

the classrooms found a rhythm as my students adjusted to my new expectations for them of how they were going to learn. Through this process, I earnestly began my evolution into the teacher that I always wanted to become.

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APPENDICES

APPENDIX A
INSTITUTIONAL REVIEW BOARD EXEMPTION



INSTITUTIONAL REVIEW BOARD
For the Protection of Human Subjects
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MEMORANDUM

TO: Dana Donlon and John Graves

FROM: Mark Quinn, Chair *Mark Quinn cy*

DATE: December 8, 2015

RE: "The Effect of a Supported Flipped Classroom Approach on Student Learning, Engagement, and Participation in a High School Chemistry Classroom" [DD120815-EX]

The above research, described in your submission of December 8, 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:

- X (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.
- X (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
CHEMICAL REACTIONS CONTENT TEST

Chemical Reactions Content Test

- Given the equation: $2\text{Na} + \text{Cl}_2 \rightarrow 2\text{NaCl}$, which of the following is a reactant in the equation?
a. Na b. NaCl c. 2 d. $\rightarrow$
- Given the equation: $2\text{Na} + \text{Cl}_2 \rightarrow 2\text{NaCl}$, which of the following is a product in the equation?
a. Na b. NaCl c. 2 d. $\rightarrow$
- Given the equation: $2\text{Na} + \text{Cl}_2 \rightarrow 2\text{NaCl}$, if 46 grams of Na are reacted with 71 grams of Cl_2 , how many grams of NaCl will be formed?
a. 46 grams d. 234 grams
b. 71 grams e. It will vary
c. 117 grams
- Given the equation: $4\text{Ca}(\text{OH})_2$, which is true?
a. 4 is the coefficient and 2 is the subscript
b. 4 is the subscript and 2 is the coefficient
c. Both numbers are subscripts.
d. Both numbers are coefficients.
- Which balanced equation represents a double replacement reaction?
a. $\text{Mg} + 2\text{AgNO}_3 \rightarrow \text{Mg}(\text{NO}_3)_2 + 2\text{Ag}$
b. $2\text{Mg} + \text{O}_2 \rightarrow 2\text{MgO}$
c. $\text{MgCO}_3 \rightarrow \text{MgO} + \text{CO}_2$
d. $\text{MgCl}_2 + 2\text{AgNO}_3 \rightarrow 2\text{AgCl} + \text{Mg}(\text{NO}_3)_2$
- Which balanced equation represents a single replacement reaction?
a. $\text{Mg} + 2\text{AgNO}_3 \rightarrow \text{Mg}(\text{NO}_3)_2 + 2\text{Ag}$
b. $2\text{Mg} + \text{O}_2 \rightarrow 2\text{MgO}$
c. $\text{MgCO}_3 \rightarrow \text{MgO} + \text{CO}_2$
d. $\text{MgCl}_2 + 2\text{AgNO}_3 \rightarrow 2\text{AgCl} + \text{Mg}(\text{NO}_3)_2$
- Which balanced equation represents a decomposition reaction?
a. $\text{Mg} + 2\text{AgNO}_3 \rightarrow \text{Mg}(\text{NO}_3)_2 + 2\text{Ag}$
b. $2\text{Mg} + \text{O}_2 \rightarrow 2\text{MgO}$
c. $\text{MgCO}_3 \rightarrow \text{MgO} + \text{CO}_2$
d. $\text{MgCl}_2 + 2\text{AgNO}_3 \rightarrow 2\text{AgCl} + \text{Mg}(\text{NO}_3)_2$
- Which balanced equation represents a synthesis reaction?
a. $\text{Mg} + 2\text{AgNO}_3 \rightarrow \text{Mg}(\text{NO}_3)_2 + 2\text{Ag}$
b. $2\text{Mg} + \text{O}_2 \rightarrow 2\text{MgO}$
c. $\text{MgCO}_3 \rightarrow \text{MgO} + \text{CO}_2$
d. $\text{MgCl}_2 + 2\text{AgNO}_3 \rightarrow 2\text{AgCl} + \text{Mg}(\text{NO}_3)_2$

9. Given the activity series below, which element will be able to replace magnesium in the compound, MgCl_2 ?
- a. chromium
 - b. calcium
 - c. iron
 - d. hydrogen

Two Activity Series	
Metals	Decreasing Activity
lithium	
potassium	
calcium	
sodium	
magnesium	
aluminum	
zinc	
chromium	
iron	
nickel	
tin	
lead	
HYDROGEN*	
copper	
mercury	
silver	
platinum	
gold	

10. Which set of numbers will correctly balance the following reaction:
- $$\text{KBr} + \text{Na}_2\text{S} \rightarrow \text{K}_2\text{S} + \text{NaBr}$$
- a. 1:1:1:1
 - b. 1:2:2:1
 - c. 2:1:1:2
 - d. 1:2:1:2
11. Which set of numbers will correctly balance the following reaction:
- $$\text{FeS}_2 + \text{O}_2 \rightarrow \text{Fe}_2\text{O}_3 + \text{SO}_2$$
- a. 2:8:1:4
 - b. 2:11:1:4
 - c. 4:7:2:8
 - d. 4:11:2:8
12. What is the precipitate in the following reaction?
- $$\text{MgCl}_{2(\text{aq})} + 2\text{AgNO}_{3(\text{aq})} \rightarrow 2\text{AgCl}_{(\text{s})} + \text{Mg}(\text{NO}_3)_{2(\text{aq})}$$
- a. MgCl_2
 - b. AgNO_3
 - c. AgCl
 - d. $\text{Mg}(\text{NO}_3)_2$

APPENDIX C

STOICHIOMETRY CONTENT TEST

Stoichiometry Content Test

- How many copper atoms are there in 1.00 mole?
a. 29 b. 63.5 c. 6.02×10^{23} d. 1.05×10^{23}
- Which of the following is equal to one mole of carbon?
a. 1.00 gram c. 12.0 grams
b. 6.02 grams d. 6.02×10^{23} grams
- What is the percentage of sodium in NaCl?
a. 39.3% b. 50.0% c. 60.7% d. 64.5%
- The molar mass of potassium bromide is
a. 110.0 g/mole c. 158.0 g/mole
b. 119.0 g/mole d. 199.0 g/mole
- Given the equation: $2\text{Na} + \text{Cl}_2 \rightarrow 2\text{NaCl}$, how many moles of sodium chloride are created from 4 moles of chlorine?
a. 1 mole b. 2 moles c. 4 moles d. 8 moles
- For the following reaction: $2\text{KClO}_3(s) \rightarrow 2\text{KCl}(l) + 3\text{O}_2(g)$, what is the molar ratio of potassium chlorate to oxygen?
a. 1:1 b. 2:2 c. 2:3 d. 3:2
- Assume ideal stoichiometry in the reaction $\text{CH}_4 + 2\text{O}_2 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O}$. If you know the mass of CH_4 , what can you calculate?
a. Only the mass of CO_2 produced
b. Only the mass of O_2 reacting
c. Only the mass of CO_2 and H_2O produced
d. The mass of O_2 reacting and the masses of CO_2 and H_2O produced
- For the reaction $\text{C}_3\text{H}_4(g) + 4\text{O}_2(g) \rightarrow 3\text{CO}_2(g) + 2\text{H}_2\text{O}(l)$, how many grams of water are produced if 80.0 grams of C_3H_4 react?
a. 18 grams of H_2O c. 72 grams of H_2O
b. 40 grams of H_2O d. 160 grams of H_2O
- The Haber process for producing ammonia commercially is represented by the equation $\text{N}_2(g) + 3\text{H}_2(g) \rightarrow 2\text{NH}_3(g)$. How many moles of H_2 are required to produce 18 moles of NH_3 ?
a. 12 moles of H_2 c. 27 moles of H_2
b. 18.0 moles of H_2 d. 36 moles of H_2

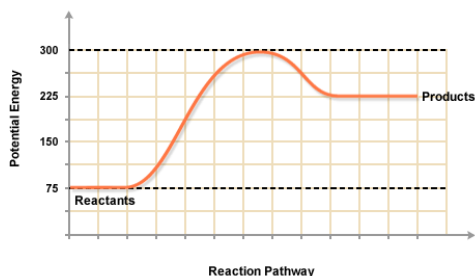
10. If a chemical reaction involving substances A and B stops when B is completely used up, then B is referred to as the ____.
- | | |
|---------------------|----------------------|
| a. excess reactant | c. limiting reactant |
| b. primary reactant | d. primary product |
11. If a chemist calculates the maximum amount of product that could be obtained in a chemical reaction, she is calculating the ____.
- | | |
|---------------------|----------------------|
| a. percentage yield | c. theoretical yield |
| b. mole ratio | d. actual yield |
12. For the equation: $2\text{Al} + 3\text{Cl}_2 \rightarrow 2\text{AlCl}_3$, what is the maximum number of moles of AlCl_3 that can be produced from 5.0 moles of Al and 6.0 moles of Cl_2 ?
- | | |
|---------------------------------|---------------------------------|
| a. 2.0 moles of AlCl_3 | c. 5.0 moles of AlCl_3 |
| b. 4.0 moles of AlCl_3 | d. 6.0 moles of AlCl_3 |

APPENDIX D

REACTION KINETICS CONTENT TEST

Reaction Kinetics Content Test

1. The sequence of steps that occurs in a reaction process is called the
 - a. order of the reaction
 - b. rate law
 - c. overall reaction
 - d. reaction mechanism
2. One factor that cannot be adjusted in order to improve a reaction rate is
 - a. temperature
 - b. surface area
 - c. nature of the reactant
 - d. concentration
3. A species that changes the rate of reaction but is neither consumed nor changed is
 - a. a catalyst
 - b. an activated complex
 - c. an intermediate
 - d. a reactant
4. Two molecules cannot react if there is not enough
 - a. kinetic energy
 - b. pressure
 - c. time
 - d. volume
5. In a graph of how energy changes with reaction progress, the activated complex appears at the
 - a. left end of the curve
 - b. right end of the curve
 - c. bottom of the curve
 - d. peak of the curve
6. To be effective, a collision requires
 - a. enough energy only.
 - b. a favorable orientation.
 - c. enough energy and a favorable orientation.
 - d. a reaction mechanism.
7. Which of the following equations represents an endothermic reaction?
 - a. $\text{N}_2\text{O}_4 + 59\text{kJ} \rightarrow 2\text{NO}_2$
 - b. $2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O} + 572 \text{ kJ}$
 - c. $2\text{BrCl} - 29.3\text{kJ} \rightarrow \text{Br}_2 + \text{Cl}_2$
 - d. $2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O} \quad \Delta\text{H} = -572 \text{ kJ}$
8. Which energy diagram represents an exothermic reaction?
 - a.
 - b.



9. If

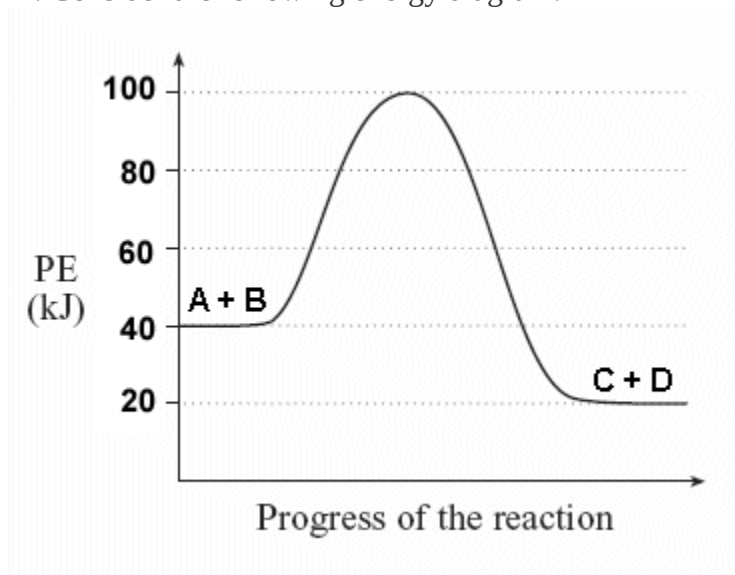
the concentration of reactants is higher,

- the reaction rate of the forward reaction is generally higher.
- the reaction rate of the forward reaction is generally lower.
- the reaction rate is generally not affected.
- the reverse reaction is favored.

10. What impact does an increase in temperature generally have on the rate of reaction?

- It decreases it.
- It has no impact.
- It increases it.
- There is no way to measure it.

11. Consider the following energy diagram:



What is amount of activation energy required for the forward reaction?

- 40 kJ
- 60 kJ
- 80 kJ
- 100 kJ

12. Referring to the energy diagram in the previous question, what is the heat of reaction (ΔH) for this reaction?

- 20 kJ
- 80 kJ
- 20 kJ
- 80 kJ

APPENDIX E
THERMOCHEMISTRY CONTENT TEST

Thermochemistry Content Test

- Energy is measured in
 - joules
 - kelvins
 - pounds
 - grams
- The specific heat of a substance is the amount of energy needed to raise the temperature of
 - 1 gram by 1 K
 - 1 gram by 1°F
 - 1 mole by 1 K
 - 1 mole by 1°F
- What symbol is used to represent enthalpy?
 - K
 - H
 - E
 - None of these
- If the ΔH of a system is measured as -177 kJ, the change is
 - endothermic
 - exothermic
 - either endothermic or exothermic
 - reversible
- According to Hess's Law, the overall enthalpy change in a reaction
 - equals the difference of enthalpy changes for the individual steps in the reaction.
 - equals the sum of enthalpy changes for the individual steps in the reaction.
 - equals the enthalpy change of the first step in the reaction.
 - cannot be determined from the enthalpy changes for the individual steps in the reaction.
- Given the balanced equation: $4\text{Fe(s)} + 3\text{O}_2 \rightarrow 2\text{Fe}_2\text{O}_3\text{(s)} + 1640 \text{ kJ}$
Which phrase best describes this reaction?
 - endothermic with $\Delta H = +1640 \text{ kJ}$
 - endothermic with $\Delta H = -1640 \text{ kJ}$
 - exothermic with $\Delta H = +1640 \text{ kJ}$
 - exothermic with $\Delta H = -1640 \text{ kJ}$
- Using the Heats of Reaction table, which is true for the formation of one mole of NH_3 from its elements?
 - It releases 91.8 kJ of energy.
 - It absorbs 91.8 kJ of energy.
 - It releases 45.9 kJ of energy.
 - It absorbs 45.9 kJ of energy.
- Using the Heats of Reaction table, the formation of one mole of which substance releases the greatest amount of energy?
 - C_2H_2
 - NO
 - C_2H_6
 - NH_3

Table I
Heats of Reaction at 101.3 kPa and 298 K

Reaction	$\Delta H \text{ (kJ)}^*$
$\text{CH}_4\text{(g)} + 2\text{O}_2\text{(g)} \rightarrow \text{CO}_2\text{(g)} + 2\text{H}_2\text{O(l)}$	-890.4
$\text{C}_3\text{H}_8\text{(g)} + 5\text{O}_2\text{(g)} \rightarrow 3\text{CO}_2\text{(g)} + 4\text{H}_2\text{O(l)}$	-2219.2
$2\text{C}_8\text{H}_{18}\text{(l)} + 25\text{O}_2\text{(g)} \rightarrow 16\text{CO}_2\text{(g)} + 18\text{H}_2\text{O(l)}$	-10943
$2\text{CH}_3\text{OH(l)} + 3\text{O}_2\text{(g)} \rightarrow 2\text{CO}_2\text{(g)} + 4\text{H}_2\text{O(l)}$	-1452
$\text{C}_2\text{H}_5\text{OH(l)} + 3\text{O}_2\text{(g)} \rightarrow 2\text{CO}_2\text{(g)} + 3\text{H}_2\text{O(l)}$	-1367
$\text{C}_6\text{H}_{12}\text{O}_6\text{(s)} + 6\text{O}_2\text{(g)} \rightarrow 6\text{CO}_2\text{(g)} + 6\text{H}_2\text{O(l)}$	-2804
$2\text{CO(g)} + \text{O}_2\text{(g)} \rightarrow 2\text{CO}_2\text{(g)}$	-566.0
$\text{C(s)} + \text{O}_2\text{(g)} \rightarrow \text{CO}_2\text{(g)}$	-393.5
$4\text{Al(s)} + 3\text{O}_2\text{(g)} \rightarrow 2\text{Al}_2\text{O}_3\text{(s)}$	-3351
$\text{N}_2\text{(g)} + \text{O}_2\text{(g)} \rightarrow 2\text{NO(g)}$	+182.6
$\text{N}_2\text{(g)} + 2\text{O}_2\text{(g)} \rightarrow 2\text{NO}_2\text{(g)}$	+66.4
$2\text{H}_2\text{(g)} + \text{O}_2\text{(g)} \rightarrow 2\text{H}_2\text{O(g)}$	-483.6
$2\text{H}_2\text{(g)} + \text{O}_2\text{(g)} \rightarrow 2\text{H}_2\text{O(l)}$	-571.6
$\text{N}_2\text{(g)} + 3\text{H}_2\text{(g)} \rightarrow 2\text{NH}_3\text{(g)}$	-91.8
$2\text{C(s)} + 3\text{H}_2\text{(g)} \rightarrow \text{C}_2\text{H}_6\text{(g)}$	-84.0
$2\text{C(s)} + 2\text{H}_2\text{(g)} \rightarrow \text{C}_2\text{H}_4\text{(g)}$	+52.4
$2\text{C(s)} + \text{H}_2\text{(g)} \rightarrow \text{C}_2\text{H}_2\text{(g)}$	+227.4
$\text{H}_2\text{(g)} + \text{I}_2\text{(g)} \rightarrow 2\text{HI(g)}$	+53.0
$\text{KNO}_3\text{(s)} \xrightarrow{\text{H}_2\text{O}} \text{K}^+\text{(aq)} + \text{NO}_3^-\text{(aq)}$	+34.89
$\text{NaOH(s)} \xrightarrow{\text{H}_2\text{O}} \text{Na}^+\text{(aq)} + \text{OH}^-\text{(aq)}$	-44.51
$\text{NH}_4\text{Cl(s)} \xrightarrow{\text{H}_2\text{O}} \text{NH}_4^+\text{(aq)} + \text{Cl}^-\text{(aq)}$	+14.78
$\text{NH}_4\text{NO}_3\text{(s)} \xrightarrow{\text{H}_2\text{O}} \text{NH}_4^+\text{(aq)} + \text{NO}_3^-\text{(aq)}$	+25.69
$\text{NaCl(s)} \xrightarrow{\text{H}_2\text{O}} \text{Na}^+\text{(aq)} + \text{Cl}^-\text{(aq)}$	+3.88
$\text{LiBr(s)} \xrightarrow{\text{H}_2\text{O}} \text{Li}^+\text{(aq)} + \text{Br}^-\text{(aq)}$	-48.83
$\text{H}^+\text{(aq)} + \text{OH}^-\text{(aq)} \rightarrow \text{H}_2\text{O(l)}$	-55.8

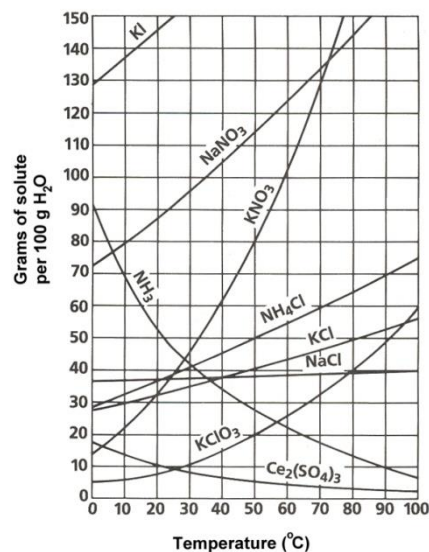
*Minus sign indicates an exothermic reaction.

9. When two moles of $\text{KNO}_3(\text{s})$ is dissolved in water the heat of solution is +34.89. What happens to the temperature of the water?
- It increases as 34.89 kJ of energy is released.
 - It increases as 69.78 kJ of energy is released.
 - It decreases as 34.89 kJ of energy is absorbed.
 - It decreases as 69.78 kJ of energy is absorbed.
10. Which of the following is not needed to calculate the energy required to increase the temperature of a substance?
- the mass of the substance
 - the specific heat of the substance
 - the molar mass of the substance
 - the temperature change
11. Use Hess's Law to calculate the enthalpy of reaction:
- $$\text{XeF}_2(\text{s}) + \text{F}_2(\text{g}) \rightarrow \text{XeF}_4(\text{s}), \Delta H = ?$$
- Given the following enthalpy changes,
- $$\text{Xe}(\text{g}) + \text{F}_2(\text{g}) \rightarrow \text{XeF}_2(\text{s}), \Delta H = -123 \text{ kJ}$$
- $$\text{Xe}(\text{g}) + 2\text{F}_2(\text{g}) \rightarrow \text{XeF}_4(\text{s}), \Delta H = -262 \text{ kJ}$$
- 385 kJ
 - 139 kJ
 - +139 kJ
 - +385 kJ
12. How much energy is absorbed when 100.0 grams of CaO reacts according to the equation below?
- $$\text{CaO} + 3\text{C} \rightarrow \text{CaC}_2 + \text{CO}, \Delta H = +464.8 \text{ kJ}$$
- 260 kJ
 - 464.8 kJ
 - 830 kJ
 - 929.6 kJ

APPENDIX F
SOLUTIONS CONTENT TEST

Solutions Content Test

- All homogeneous solutions have all of the following properties except
 - the dissolved particles are molecular in scale (size).
 - the particles are evenly distributed.
 - the particles do not settle to the bottom.
 - the final physical state is a liquid.
- A solution that contains as much solute as possible under a given set of conditions is called
 - saturated
 - soluble
 - concentrated
 - miscible
- Polar solids best dissolve in solvents that are
 - immiscible
 - transparent
 - nonpolar
 - polar
- The rate at which a solid solute dissolves in a solvent is affected by all of the following except
 - temperature
 - stirring
 - pressure
 - crushing
- Colligative properties of solutions depend on the
 - chemical nature of the solute
 - chemical nature of the solvent
 - number of moles of solvent
 - concentration of solute particles
- Referring to the solubility curve, what happens to a saturated solution of NaNO_3 at 30°C when it is heated to 50°C ?
 - It is unchanged.
 - It becomes unsaturated.
 - It becomes supersaturated.
 - Excess solute precipitates out of solution.
- Referring to the solubility curve, how many grams of KNO_3 would be needed to make a saturated solution in 100 g of water at 40°C ?
 - 42 grams
 - 10.5 grams
 - 68 grams
 - over 100 grams
- Referring to the solubility curve, how many grams of KClO_3 needs to be dissolved in 50 g of water to have a saturated solution at 80°C ?
 - 21 grams
 - 10.5 grams
 - 42 grams
 - 84 grams



9. When the energy released by forming solvent-solute attractions is greater than the energy absorbed by overcoming solute-solute and solvent-solvent attractions, a dissolving process
- has a negative heat of solution
 - has a positive heat of solution
 - decrease the temperature of the solution
 - is endothermic
10. The concentration of a solution can be quantitatively measured by calculating
- molarity
 - molality
 - both of these
 - neither of these
11. Which of the following types of compounds is most likely to be a strong electrolyte?
- a polar compound
 - a nonpolar compound
 - a covalent compound
 - an ionic compound
12. How many moles of NaOH are contained in 2.5 L of a 0.010 M solution?
- 0.010 moles
 - 1.0 moles
 - 0.025 moles
 - 0.40 moles

APPENDIX G
STUDENT PRE-TREATMENT SURVEY

Student Pre-Treatment Survey

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

Directions: Read each statement and check the box that best reflects your feelings about the statement.

	Strongly Agree	Agree	Disagree	Strongly Disagree
I am interested in chemistry.				
During class lectures, the pacing is too slow.				
During class lectures, the pacing is adequate.				
During class lectures, the pacing is too fast.				
During class lectures, it is easy for me to listen and take notes at the same time.				
I often ask questions during a class discussion.				
I often offer to answer questions that my teacher asks during a class discussion.				
I feel prepared to participate in classroom activities as a result of a class lecture.				
I feel prepared to participate in laboratory activities as a result of a class lecture.				
I feel prepared to complete my homework practice as a result of a class lecture.				
I complete all of my chemistry homework assignments.				
I watch video lectures when they are assigned.				
I only watch a video lecture when it is necessary to complete a homework assignment or assessment.				
I take notes on my own while I watch video lectures.				

I watch video lectures to prepare for tests and quizzes.				
I feel more prepared for class after viewing a video lecture.				
I feel that I control the pace of my learning when I utilize the video lectures.				
I participate in Haiku assessments even when they are not graded.				
I feel that completing the Haiku assessments helps me to learn chemistry.				
I often retake the Haiku assessments when I do not answer most of the questions correctly.				
I am responsible for my own learning in chemistry.				
I am responsible for my own success in chemistry.				

APPENDIX H
STUDENT POST-TREATMENT SURVEY

Student Post-Treatment Survey

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

Directions: Read each statement and check the box that best reflects your feelings about the statement.

	Strongly Agree	Agree	Disagree	Strongly Disagree
I am interested in chemistry.				
During video lectures, the pacing is too slow.				
During video lectures, the pacing is adequate.				
During video lectures, the pacing is too fast.				
During video lectures, it is easy for me to listen and take notes at the same time.				
I often ask questions during a class discussion.				
I often offer to answer questions that my teacher asks during a class discussion.				
I feel prepared to participate in classroom activities as a result of a video lecture.				
I feel prepared to participate in laboratory activities as a result of a video lecture.				
I feel prepared to complete my homework practice as a result of a video lecture.				
I complete all of my chemistry homework assignments.				
I watch video lectures when they are assigned.				
I only watch a video lecture when it is necessary to complete a homework assignment or assessment.				

I take notes on my own while I watch video lectures.				
I watch video lectures to prepare for tests and quizzes.				
I feel more prepared for class after viewing a video lecture.				
I feel that I control the pace of my learning when I utilize the video lectures.				
I participate in Haiku assessments even when they are not graded.				
I feel that completing the Haiku assessments helps me to learn chemistry.				
I often retake the Haiku assessments when I do not answer most of the questions correctly.				
I am responsible for my own learning in chemistry.				
I am responsible for my own success in chemistry.				

APPENDIX I

POST-TREATMENT STUDENT INTERVIEW

Post Treatment Student Interview

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

1. How do you think you learn best? Do you think that traditional classroom lecture, traditional lecture with Haiku assessments, or online video lectures and Haiku assessments support your preferred method of learning?
2. What was most and least beneficial to you about the video lectures? Why?
3. What was most and least beneficial to you about the Haiku assessments? Why?
4. Did you only view the video lectures when they were assigned? If not, when and for what purpose did you re-watch them?
5. How do you think watching the videos affected your engagement (participation, interest, confidence) in chemistry class?
6. How do you think completing the Haiku assessments affected your engagement (participation, interest, confidence) in chemistry class?
7. Can you suggest any changes or improvements to the format or content of the Haiku assessments for next time? Please provide reasoning.
8. Can you suggest any changes or improvements to the format or content of the videos for next time? Please provide reasoning.
9. Is there anything else that you would like me to know about in this blended learning (online and classroom) environment?

APPENDIX J
DAILY TEACHER JOURNAL

Daily Teacher Journal

Date _____

Haiku Participation:

- Number of students who viewed video lecture: _____
- Number of students who attempted online assessment: _____
- Number of students who completed online assessment to mastery level: _____

Classroom Participation:

- Number of questions asked by teacher: _____
- Average number of students who volunteer to answer:
Tally here: _____
- Number of students on-task in classroom activity/lab: _____
- Number of clarification questions asked during classroom activity/lab: _____
- Number of probing questions asked during classroom activity/lab: _____

*Approximate time spent on each classroom activity:**Teacher Notes & Reflection:*

- Describe the engagement/interest level of students today.
- Memorable/thoughtful comments and questions by students.
- Did the use of the video lectures and assessments enhance today's class?