

THE IMPACTS OF BLENDING THE HIGH SCHOOL ADVANCED
PLACEMENT CHEMISTRY CLASSROOM ON STUDENT
ENGAGEMENT AND PERFORMANCE

by

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DEDICATION

This project is dedicated to my fiercest supporters.

To my husband of 25 years. The man that I met by chance at the University of Denver and convinced me to move, sight unseen, to Billings, Montana to finish up an undergraduate degree. Doug, you have been unwavering in your support of this process. You have constantly reminded me that this rocky road has value and that anyone who has the ability to complete this process should. At the start of all of this, you asked me what I wanted to do. My response, “I know what I want to do, but I’ll never do it.” You had confidence in me then, and you’ve been my rock throughout. You allowed me to complete this on my own terms (too aggressively, according to you) and you picked up all the pieces that I left in my wake. Words cannot express how much I appreciate your selfless dedication to the success of our family.

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ABSTRACT

A blended classroom is a new take on traditional education, implemented to support today's learner. It involves the incorporation of technology, personalization, and flexibility. Blended learning is quickly catching on as a best practice in the traditional face-to-face classroom. While individuals have a difficult time settling on one definition for blended learning, it can be summarized by saying that the traditional classroom gains flexibility in pace and adds technology-based resources to supplement and enhance what the teacher is already doing. These additions free up the teacher time so that the instructor can participate in more individual and smaller group remediation and extension.

This project arose when it became apparent that students in my traditional Advanced Placement Chemistry course needed more time for application and practice and less time writing notes through direct instruction. The purpose was to make learning more student-centered through the introduction of varied resources that would be accessible to students when they were ready for them. The implementation of technology-based resources was used to enhance instruction where needed and was never intended to completely replace traditional instruction.

Resources and flexibility were systematically introduced to students. We began as a group by participating in a new warm-up method. I introduced students to Pearson's Mastering Chemistry program for homework that provided them with hints and instant scoring and feedback. I provided students with online flash cards that included important terms and formulas for the unit. I also introduced various videos, graphics, and interactive resources to help promote student engagement and performance on assessment.

During the treatment period students became more engaged in their learning and moved beyond procedural questions to deeper application questions. Students also made deeper connections to the content and gained confidence in their chemistry skills. This study showed that students maintained a high level of achievement on summative assessments even as the content became more challenging. Students survey results also showed that students felt more prepared to perform at a qualified level on the AP chemistry exam.

INTRODUCTION AND BACKGROUND

Technology has become an integral component of daily life. With information at our fingertips, it seems reasonable to embrace technology, rather than view it as a classroom distraction. Assisting students in shifting their mindset towards a new form of education may help students who are accustomed to instant information engage and perform at proficient or advanced levels throughout their high school years. This action research project focuses on the use of technology, flexibility, and alternate resources in an Advanced Placement (AP) classroom at Kiel High School.

Kiel High School is located within the small, rural town of Kiel, Wisconsin, which had a population of 3,948 as of July 1, 2018 (HTL, 2018). Kiel is located approximately one hour north of Milwaukee and one hour south of Green Bay. The city has several growing manufacturing facilities and family dairy farms with a median household income of \$54,327 (HTL, 2018). There are presently 440 students enrolled at Kiel High School. Ethnically, our school is very homogeneous. According to the most recent school report card, 92.5% of the students are Caucasian. We have a very small Asian, African American, Hispanic, and Native American population that cumulatively accounts for 7.5% of students. Nearly 13% of our students have an Individualized Education Plan (IEP) for a disability and 14.5% are considered economically disadvantaged. Eight percent of our students have open enrolled to the district. The school report card further shows that we "Meet Expectations" established for public schools in the state of Wisconsin (WI DPI, 2018). The district is comprised of one elementary school, one middle school, the high school, and the Kiel eSchool.

The Kiel eSchool was established in 2007 with the Appleton eSchool (KASD, 2018). This partnership grew by adding many affiliation and collaborating partners, which included school districts, charter schools, private schools, and educational agencies. With the growth of the eSchool network, students could add more diversified classes to their school day, enhance their academic options, seek out specialized courses that meet their interests and support their future. The most recent Kiel eSchool data compilation showed that there were 113 part-time Kiel High School enrollments for the third term of the 2018-2019 school year. These students typically completed their eSchool course during their school day in the high school library or tech center, though some students chose to work in other classrooms or outside of the school day. There were also 13 full-time enrolled students. The Kiel eSchool had 53 network, part-time, open-enrolled students; many of these students scheduled an off-block at their home school and utilized the state's open enrollment system to pick up the credit that they wished to complete outside of their own district. Finally, Kiel eSchool reported 105 statewide network students who were enrolled into a Kiel course as a part of their school day, through their local school (K. Pionek, personal communication, March 14, 2019). Network students differ from open-enrollment students in that the network students are monitored by a local mentor in their district and have been approved by their home district to participate in the course. Open-enrolled students may have been denied network status because the course is taught locally, yet students did not wish to exercise that option.

The culture at Kiel High School is very representative of small towns in northeast Wisconsin. Weekend sports are important to many area families and almost a quarter of the school participates in the marching band. According to our counseling office, approximately 25% of students will complete an Advanced Placement (AP) class during their high school career (B. Schetter, personal communication, September 18, 2017). Parent/teacher/student conferences are held four times a year and parents are encouraged to play an active role in student learning. We have interventions established in each of our core areas and offer an intervention/enrichment period each day. Our school focuses on both college and career readiness and partners with many local businesses to place students in jobs right out of high school.

I have been a full-time science teacher at Kiel High School since August 2014 and I have taught with the eSchool since August 2009. Teaching was not a first career, rather it was something that I grew into as my own children became school-age. I became interested in teaching when I worked with a local family resource center, charged with creating and maintaining a structured children's program that provided care to young children with disabilities while their parents and guardians attended a support group. Upon completion of my education program, I was first hired as an online science teacher for the Kiel eSchool. Since my first years at the eSchool, I have added classes and now facilitate nine online classes, including biology, chemistry, physics, anatomy and physiology, marine science, Great Minds in Science, physical science, forensic science, and AP biology. I am a two-time Wisconsin Digital Learning Collaborative Teacher of the Year Finalist. Prior to teaching full-time at the high school, I also worked as an

instructional aide at an elementary school and have experience with a separate online charter school. Each experience has provided me with various insights into the development of children throughout the course of their education.

Technology has played a key role in my education since I returned to school to earn my teaching credentials. As I mentored my own elementary children in their school, I noticed the rich technological experiences they were having at a very young age. When I was hired by the eSchool, I hadn't realized that online learning was an option at the high school level. As I began my career as a face-to-face instructor, I was asked by my local eSchool mentor if I would like to explore blended options for my chemistry class. This process has been an ongoing trial and error experience for the last several years. Our students have been issued Chromebooks, yet technology implementation was an expectation that was placed on the educators. The first blending attempt, in general chemistry, was based on a review of other teachers' end results and followed no real recipe for implementation. As a result, the release was not as smooth as I envisioned, and, five years later, the course is still a work in progress. Since this initial attempt at blending, I had often considered making a more systematic, research-based, attempt at another course.

As I began my second year of face-to-face teaching, I was also pleased to have an opportunity to re-establish the AP chemistry program at our school. I did not incorporate technology and instead, proceeded in a very traditional manner based on my interpretation of the College Board guidelines. Furthermore, upon the request of several parents, I designed the class to mimic a college classroom in both procedure and rigor.

Students were exposed to content through lecture, practiced concepts with homework and laboratory exercises, and confirmed their learning through summative assessments.

While this course was praised by parents, it became apparent that my AP students required less direct instruction for background content and more time for application and practice. Students obtained mastery of this advanced level material in a variety of manners and at unique paces. It is for these reasons that I elected to blend my AP chemistry class for this action research project. This blending was supported by research, methodical, based on best practices, and student driven. My goal was to provide students with a variety of primary resources so that they were able to access the content in a timely manner and in a format that was the most compatible with their learning style. The objective was to have students use these primary resources in place of lengthy content lectures to free up my time for individual and small group instruction and remediation. Students also had access to online interactive activities, virtual labs, updated models, and formative practice exercises. Student feedback helped drive the addition of new resources to the course. These resources also helped me collect data and meet with individual students to proactively plan for intervention. Additionally, I had time to build a stronger rapport with students early in the course and gained the opportunity to better understand their individual learning needs.

Through blending the AP chemistry course, I anticipated having additional time during each block to meet the educational needs of individual students through direct instruction, remediation, lab work, and enrichment. Having prepared a variety of blended resources in advance, I was able to more appropriately act as a mentor to my students,

rather than the sole provider of knowledge. My goal was to provide students with tools that gave them the confidence to own their learning and pursue a deeper understanding of the content. As students gained confidence, it was my hope that they moved beyond superficial, procedural, questions and began to ponder deeper connections and applications of the chemistry content. Additionally, as students became more comfortable with the beginning stages of personalizing their learning, they also had a greater tendency to take risks in their problem solving and peer conversations, again resulting in deeper learning and additional confidence. These beliefs resulted in the development of the following questions which guided my action research:

1. Does the blended format increase student engagement in a combined junior and senior level AP chemistry classroom?
2. Does the blended format increase student performance in a combined junior and senior level AP chemistry classroom?

This blended research project is an ongoing work and only the first year of the project is reported on in this writing. I began slowly by introducing students to some of the creative ways that we, as a class, could synchronously use technology to promote learning. The next step was to introduce students to an online homework tool that provided them with hints, instant feedback, and adaptive follow-up problems. And finally, as the blending process continued, I released timely resources to students to help them engage in the content prior to the in-class lesson. This slow release of technological support allowed students to become comfortable with the shift in their education and helped them to not feel overwhelmed with a sudden change to their comfortable routine.

CONCEPTUAL FRAMEWORK

The traditional brick and mortar classroom served students for generations. Those who were motivated to succeed received a solid content background knowledge in the core areas and were able to use their high school diploma as a means for entering college or the work force. Unfortunately, there have been few changes to the education system over the last one hundred years, but there have been dramatic changes in the workplace. It has been said many times, in many ways, that we are training today's students to do jobs and solve problems that we don't yet know will exist. And yet, it's estimated that 60% of all first-year college students require some form of remediation to improve their basic core skills (Patrick, 2018). Patrick continued to explain that if we want students to be ready for their future, we need to ignite a fire in them that motivates them to build skills, learn how to learn, and moves them to attain problem solving skills applicable to future problems. Today's students have a greater need to have the ability to make choices and act on them. We witness inequality in the classroom when we continue to educate each student in the exact same manner and the only way to stop contributing to this is to change it (Patrick, 2018). Blended education has the potential to give agency to all students and prepare them for an unknown future.

Albert Einstein stated, "No problem can be solved from the same level of consciousness that created it." If we recognize that a traditional educational approach is no longer the best practice, we must ask ourselves, "Why?" Our answer should focus on how we can make a move towards personalization for the benefit of each student. We should ask ourselves how we, as educators, can stretch our own thinking and our practice

to help all learners succeed. Personalization should neither have an expectation of narrow outcomes, nor should the outcome expectations be set so low that the outcomes don't support statistical measures (Moreno, 2018). Moreno, in his 2018 iNACOL keynote, encouraged instructors to demonstrate the flexibility to personalize their curriculum without diminishing academic rigor.

Many school districts, including the Kiel Area School District, have adopted a personalized learning initiative. Personalization provides flexibility to individual students to tailor their learning based on their strengths, interests, and learning styles. The students have choice in what they will learn, how they will learn it, when they will learn, and where they will do their studying. All the above help students obtain mastery in education (Powell, 2014). Not only is the student allowed flexibility in their learning, they are the ones who lead the way by designing their own path. At the most advanced level, this includes a setting in which learners may determine when and how they show proficiency while still being accountable to the essential standards. And, through this planning and problem-solving venture, students can deepen their learning and connect it to real-world problem-solving skills (Lockett, 2018). There are two expectations in personalized learning. The first is that the teachers still facilitate and offer support. In fact, educator time is more available as students move towards a truly personalized learning environment. The second is that this will not happen overnight. Transition takes time and a systematic change will help students appreciate their newfound freedom to advocate appropriately for themselves. One path to personalized learning is blended learning.

What is Blended Learning?

Personalized learning initiatives are supported by a blended learning model. If you collaborate with a room full of educators familiar with blended learning, and ask them to define blended learning, you will end up with a diverse array of responses. Everyone is doing it differently (Cline, 2018). Most will agree that blended learning involves technology, personalization, and flexibility, but no one cites a specific recipe for blending or how to get there. A blended classroom brings together traditional education and online resources, resulting in a personalized learning environment for each student. A blended learning environment has been described as one in which the educator thoughtfully and methodically assesses the current delivery methods and then incorporates digital resources where they will be more effective or efficient than the present means (Edutopia, 2014). Blending also includes releasing materials early enough so that the most advanced student has access to them when they reach each new learning level. These resources should be varied, appropriate, and enjoyable to the students (Anderson, 2011). The blending process will become unique to the educator as they move in the direction of incorporating the technology and time-based resources that best serve the students before them. Each blended class may look differently.

Research has shown that most instructors blend a traditional class to facilitate positive changes in student learning (Powell, 2014). These changes include increased student engagement, increased learner motivation to be successful, and increased performance on assessment. Students also gain a sense of ownership in their education,

rather than feeling as if their education is predetermined before they even set foot in the classroom.

To attain these positive classroom changes, the instruction becomes student-centered through appropriate technology-based resources. The transition to a blended classroom requires an instructor who exhibits perseverance and is open to constructive feedback. Powell also notes that the instructor must be exemplary at setting priorities, establishing a natural progress to learning in various scenarios, and be able to encourage and motivate students. The instructor needs to have a continuous improvement mindset based on feedback, reviews, and self-reflection. The use of technology in education should build on and enhance traditional instruction (Powell, 2014). If current instruction is working well, there is no need to change every aspect of it.

Rarely do we find a practical example where an individual is not offered choices. Yet, in education, students are often subjected to the same method of instruction, the same practice exercises, and the same summative assessment. Blending can provide students with the options that they need to be satisfied and flourish in a personalized learning setting. Students can choose their learning path based on their strengths, weaknesses, preferences, and desire to meet or exceed personal goals (Johnson, 2016). Blending supports student-centered activities and high-level learning opportunities. Additionally, by blending the class and freeing up instructor time, studies have shown that a proactive approach to student struggles yielded improved work submission and material retention. Blended classes, in general, ran with better time management and students learned to build and refine their own time management skills (Caner, 2014).

Blending not only builds a student's academic awareness, but also enhances essential prioritization and time-management skills, helping students learn how to navigate their own path to success.

Influence of Blended Learning on Student Engagement and Motivation

There is much evidence that blending a classroom leads to a much more satisfied and engaged student. Recent studies at the college level have indicated that 89% of students found the blended treatment to be enjoyable and the same percent recommended that the blended format should continue in their current course. Overall, learner satisfaction was measured at 81% in the blended environment (Kintu, 2017). This suggests that students prefer the responsibility of owning their learning path, while being supported by their instructor.

Implementing a variety of methods to engage all learners is important to the success of a blended learning setting. One such strategy is the use of a personal response method, in which students respond to a question using a clicker, or technology-based response option, and class results are instantly tallied. This was found to support peer-to-peer discussion and content analysis (Norman, 2014). Norman also stated in his research that, when using the personal response method, students were able to collaboratively navigate through the answers and share their understanding of the subject. He observed students collectively determine the correct response. All answers added to the robust nature of the activity and students were able to see the value that their engagement brought to the discussion. Students in the Norman study then went on to explore online collaboration tools, online problem-solving programs, and varied assessments. The study

scaffolded the release of resources. The data showed that as intensity of the technology was increased, there was a moderate to strong correlation to student engagement (Norman, 2014). He concluded that as students began to increasingly value their own engagement in their learning; the motivation to stay engaged also increased. The engagement component of learning formed a positive feedback loop with this group of learners.

The study on blended learning which was conducted by Norman yielded exceptional results. Ninety-seven percent of students agreed that the use of digital technology was both appropriate and beneficial to their learning (Norman, 2018). And, while students involved in this study stated that they would have preferred clearer instructions, less outside of class work, and more frequent feedback, 92% of the students agreed that a blended classroom was a setting that other learners should be exposed to (Norman, 2018). This study begins to lay the foundation for how an instructor can encourage engagement in their learners.

The previous two studies represent work done at the college level. A third study, conducted at the middle school level, showed no statistically significant increase in engagement when compared to their peers in traditional classrooms (Saritepeci, 2015). This study went on to further analyze the data and concluded that there was a practical significance to the increased engagement among the blended group.

While the measure of engagement may be age-based, it can be concluded that the blended classroom had a positive impact on student engagement. As students were more engaged, they became increasingly motivated to maintain their engagement. With

improved learner engagement and satisfaction, one would expect that student performance in a blended program would also increase.

Influence of Blended Learning on Student Performance

Unlike the studies on student engagement, the results of blended learning on performance have yet to show any statistical significance over a traditional classroom setting (iNACOL, 2018). Kintu, Et al. suggested that students are more satisfied in the blended setting since it allows them flexibility to better manage other components of their life, such as family commitments, extra-curricular activities, or work. They further considered that blended learning promotes the construction of personal analytical skills which may manifest beyond the content that is under immediate scrutiny (Kintu, 2017). Earlier studies by Caner also showed that no statistical increase in performance came out of the blended classroom, though dropout rates decreased and there were gains in test scores (Caner, 2013). Again, increases in student satisfaction in the blended environment were reported.

Despite a lack of statistical proof of increased performance, educators seem to be flocking towards a broad variety of blended learning scenarios (iNACOL, 2018). With blending learning still being relatively new, perhaps we are still acclimating our students to the new practice and the performance gains are simply not appearing yet. One aspect of the research that we can be certain of is that it takes time to change a mindset and that some individuals take more time to appreciate the potential benefits that may result from a change. The research does show that blending enhances student ability to access their own content understanding, which promotes further student engagement (Kintu, 2017).

Student feedback lead to conclusions that learners are more likely to pursue initial and remedial learning when educational institutions provide quality technology, structured learning systems, prompt feedback, and strong internet (Kintu, 2017). Time, and research studies, will help educators determine the statistical validity of the blended approach on academic performance. Students will truly drive the success of the blended movement.

Studies on blended education have shown that students retained the information that they learned for a longer period (iNACOL, 2018). This gain in retention time will serve students well with regards to spring AP testing and future analytical work. The studies by Kintu and Norman provided optimistic results related to student engagement and motivation in the blended setting. Caner reported on increased student ownership of their learning and the efficiency of the blended classroom. Finally, Kintu suggested that a blended learning environment helps learners develop problem-solving skills that will benefit them beyond the immediate course of study. Thus, my action research question is, "How does a blended classroom impact academic engagement and student performance in a combined junior and senior level AP chemistry classroom?"

METHODOLOGY

AP chemistry students are asked to learn and retain a tremendous amount of content material to earn a score of three or greater on the AP exam. Without personalized access to resources, students are instructed in a traditional manner that may, or may not, suit their learning styles or learning needs. This further limits their ability to apply the content across topics and make connections between content and science practices.

The focus of this study was to explore the effects of replacing traditional classroom techniques with technology-based instructional delivery methods and formative assessments in the Advanced Placement chemistry classroom. My goal was to begin to step back from the role of exclusive information provider and become a mentor to my students, giving them ownership of their learning for the purposes of deepening their engagement and retention. During this time, it was critical to monitor student progress to ensure that it did not negatively impact student growth. This research was determined to involve appropriate instructional strategies and was given an Instructional Review Board for the Protection of Human Subjects exemption on October 17, 2018 (Appendix A).

In this study I looked to determine if a blended classroom setting assisted students in their success throughout the course, which could ultimately allow them to demonstrate knowledge and application of the AP chemistry material on the AP exam, achieving scores of three or higher. In the past, students have struggled to connect concepts, and therefore, struggled to earn a score of three on the exam.

The purpose of this research was to address the big idea question, "How does a blended classroom impact academic engagement and student performance in a combined junior and senior level AP chemistry classroom?" The two specific sub-questions which have guided this research are: Does the blended format increase student engagement in a combined junior and senior level AP chemistry classroom; and, does the blended format increase student performance in a combined junior and senior level AP chemistry classroom? (Table 1).

Table 1
Data Triangulation Matrix

	Data Collection Instruments		
Research SQ. 1: Does the blended format increase student engagement in a combined junior and senior level AP chemistry classroom?	Pre- and Post-treatment student survey	Pre- and Post-treatment homework completion rates, including number of students who engage in adaptive follow-up problems	Student Plus (+) / Delta (Δ) focus group
	Observations on student participation during in-class practice	Student confidence levels as observed through interactions	If possible, user rates on various resources
Research SQ. 2: Does the blended format increase student performance in a combined junior and senior level AP chemistry classroom?	Pre- and Post-treatment chapter quiz scores	Pre- and Post-treatment number of students retaking a summative quiz	Pre- and Post-performance on AP free response practice problems
	Comparison of mid-term exam scores for students as compared to historical data.	AP practice exam to anticipate actual scores.	

It is important to note that I did not have the latitude to advance this class towards a fully blended setting in which student had choice in their learning environment during the school day. Students were required to remain in the high school building and in the AP chemistry classroom. They were allowed to work throughout the space available within the classroom. While unable to allow much choice to students in the way of location, I did systematically release resources to students that they were able to use during the traditional class time, both individually, and as a large group. Other blended resources were available to students outside of the class time so that they were able to begin to make choices regarding content delivery method, homework methods, and additional practice options.

The treatment period occurred over the course of two and a quarter terms of study, or approximately 100 school days. At the time of this study AP chemistry was the only course at Kiel High School that ran a full block period all year long, and as such, is a two credit, laude class. I initiated the treatment period in term two and completed it early in term four. Fifteen students were involved in the treatment. Each student had successfully completed my pre-requisite general chemistry course with a minimum grade of a B- (85%). They have also met all the mathematical prerequisites and have completed, or were concurrently enrolled in, Algebra II. The class was comprised of ten females and five males. There were nine seniors and six juniors participating in the study. Each of these students had demonstrated strong problem-solving skills, a strong desire to be successful, and competency in the core chemistry concepts. I reviewed each enrollment in this class prior to their actual enrollment. The students enrolled in AP chemistry have also completed a minimum of one-half credit through the eSchool. Many students have completed at least an additional exclusively online credit, with some students completing up to five online credits throughout their high school career.

AP chemistry was scheduled during the second block of the day. Each day, except Wednesday, the class met for 82 minutes. Wednesday was our collaborative professional development day and classes were 68 minutes in length. Meeting second block was preferential as students were not pulled out of the class for any after school activities. Following last school year, the request was made that AP chemistry be moved from the fifth block slot to another time of the day so that students would not frequently

miss valuable in-class time due to early dismissal for sports. There was only one AP chemistry class that ran during the school year.

To encourage student engagement in a blended classroom it was important to methodically implement new technology tools and allow students adequate time to become acquainted with how to properly use them. At times, during the transition to a blended classroom, the actual classroom may have appeared to be more of a technology-rich setting rather than a blended setting. It is important to note that many students have had Chromebooks throughout their high school career but have yet to recognize their value as a tool in personalizing learning.

While I do have experience establishing a blended classroom, that was not a research-based study and the process of refinement has been ongoing. Since my initial blending effort, I have attended multiple professional development seminars, including sessions at SLATE, iNACOL, and Heather Staker's "Ready to Blend" conference. At the onset of this project, I had nine years of online teaching experience and four years of face-to-face experience. It was important for me to meld the best of both learning scenarios into a situation that would benefit the students and support their learning and retention in a highly rigorous course. It was also essential to present the content and practice to students in a manner that would reduce the likelihood of burnout as the third term of the class began.

The first tool that students were exposed to was technology-rich on the teacher end, allowing me to model a creative use of technology in learning. Plickers.com allows the instructor to generate a class specific question bank. I projected the question and

gave students the opportunity to respond using unique answer cards that are tied directly to the student (Appendix B). Then, I used my cell phone to scan the room and pick up each student's answer. After I scanned each card, the student name was highlighted on the screen without identifying the answer that they had selected. After everyone answered, I was then able to show how many students selected each answer. This application encouraged interactions between the students, the teacher, and technology. I could directly measure engagement through the online completion roster, which is not as easy to do when students complete questions in their notebook. I was also able to view individual student results and scaffold future reviews, re-teaching, or remediation. The interactive nature also naturally helped students encourage each other to participate and did not allow anyone to disengage without making an attempt while one person completed the problem on the board. I used this tool to drive student discussion and let them decide why one answer was better than the others. After the discussion had taken place, I showed the correct answer and reinforced their discussion or provided information regarding the correct response. The time required for the use of this tool was supported throughout the research period as the blended aspect afforded more class time for focused AP exam preparation. I initially began using this site for general review questions and eventually moved into released AP exam questions. This tool was used as a warm-up activity at least twice a week.

Another change implemented at the onset of the blending period was a shift to the rigidity of the lab work. While this is limited in technology, outside of where students find handouts and some lab data collection tools, it was important to allow students to

coordinate and structure their lab time to their benefit. This provided them with voice and choice in when they would complete a lab during a unit of study and who they would work with. Students could use class time, intervention time, off-blocks, or time before/after school to complete labs with a partner or independently. After the AP exam, students were offered full choice in which remaining labs they could complete, in which order, and with whom.

At the onset of the treatment period, all students were asked to complete two surveys. Both surveys were completely anonymous and administered by another adult to ensure students that I did not know who completed the specific survey. The first survey gave students an opportunity to reflect on their engagement and performance in AP chemistry (Appendix C). The second survey asked students to determine how much they value the use of a variety of tools and teaching methods in the AP chemistry classroom (Appendix D). Both surveys were created using a five category Likert format. The exact same surveys were given before the treatment period and at the close of the treatment period to help me determine if the students felt more engaged in the blended classroom, if they believed there was a positive change in their performance due to the blended classroom, and if their perceptions on technology-based tools became more favorable during the treatment period. Survey results were tabulated, categorized, and qualitatively analyzed. Specific questions were analyzed using Fisher's exact test for count data.

The main instrument that was incorporated throughout the treatment period was the Pearson Mastering Chemistry program (2018, Pearson). Students accessed this program for homework. The program provided hints to students as they worked through

practice problems. Students were given immediate feedback on both correct and inaccurate answers, either to refine their answer or guide them in the correct direction. Additionally, the program allowed for adaptive follow-up that was tailored to individual student needs. The primary purpose for the introduction of this program was to encourage students to begin working independently, take small risks in their work, and learn from their mistakes. At the onset of this research, many students in this AP level class were hesitant to work through any practice problem without asking questions every step of the way. While I value the interaction with the students, I also recognize that this does not help them when they must navigate the AP exam on their own. If this program helped to change present habits, students would be more confident in their work, increase their independent engagement, and initiate higher levels of thinking that lead to greater success on AP level work. I was able to track completion and the number of students willing to engage in work beyond the initial assignment. Moreover, the immediate constructive feedback offered by the program eliminated the need to go over every homework problem in class, which was a low engagement time for many, and opened time for more in-depth work. Students were assigned regular homework that specifically reinforced the skill or concept addressed during the class period and were given adequate time to complete each set. After every two sections of homework students completed a homework check to confirm their understanding of the content before being allowed to move on to new, or more advanced, topics.

During the treatment period I observed and monitored the types and depth of interactions that I had with students. Prior to the treatment the questions from students

were very frequent and did not dig into any depth of knowledge as related to the subject. I took an objective look at whether students moved beyond the surface level questions as they began to gain confidence through completing problems on their own while utilizing the online feedback. The goal was to get students to reach a point where they made an honest attempt on their own before seeking help or made a blanket statement about being confused. This was a qualitative observation that was noted on a regular basis, particularly with regards to quizzes, homework, and laboratory work. The data was thematically analyzed with respect to the depth of knowledge associated with student questioning.

Throughout the school year I quantitatively analyzed pretest and post-test quiz scores (Appendix E). To maintain consistency with the homework, and provide leveled questions, the questions on these assessments were pulled directly from the Instructor Test Bank in Mastering Chemistry (Pearson, 2018). Each new chapter began with a pretest. Students who earned a 90% or higher on the pretest were not required to complete homework problems, homework checks, or the post chapter quiz unless they wished to improve their score. All other students completed the activities throughout the chapter and took the first version of the post-test. Again, if a student earned a 90% or higher on the first post-test, they could call the chapter work complete. However, any student who was unable to meet the benchmark was required to update their quiz, do additional studying, and complete a second version of the post-test. I compared post-test scores for the pre-treatment period and the treatment period using basic statistical data, Wilcoxon Rank-Sum two-tailed tests, and normalized gains to confirm that students were

able to learn the material at a greater depth of knowledge, with increased problem-solving skills. I also compared the number of students' pre-treatment and post-treatment who were required to take the second summative assessment, keeping in mind that the content became more challenging as the course progressed. My proposal was that as blended learning took over, and there was more class time for application problems, students would gain higher levels of problem-solving mastery and confidence and would be more proficient on the end of chapter quizzes.

To free up class time for more rigorous application problems that mimic the AP exam, I slowly incorporated various technology-based resources to help deliver background content and review material. In the spirit of blending, these resources also included traditional textbook readings. The addition of videos, both found and created, online flash cards for terms and definitions, interactive simulations, and virtual labs rounded out the blended resources that students chose from when personalizing their path to understanding the background concepts for the chapter. Students selected resources based on what they were discovering about their academic needs or learning styles, or with the help of this instructor. Students who needed remediation were directed towards straightforward, easy to navigate content resources or direct instruction, while advanced and more inquisitive students could access my suggestions, or even find and suggest their own resource. This related well to students beginning to advocate for their own needs as they will be expected to do independently at the college and career level. With the background material accomplished before the student arrived in the classroom, we were able to eliminate the long lectures in class and use that time for application and AP

practice. Class time became available for more individual- and smaller group-practice at a greater depth of knowledge. Students were assigned blended resources as applicable for background information throughout each chapter.

AP exam practice occurred in a variety of manners. In addition to the Plickers website, I presented students with individual free response practice problems from past exams. They were given the opportunity to complete these problems and self-score their answers. This again gave students an opportunity to make errors and learn from those mistakes without penalty. I monitored pre- and post- treatment performance and engagement on these passages to see if there was a shift in students' willingness to try them independently. Passages were given at the end of each chapter of study and were directly tied to the concepts that were previously explored. Passages were also administered and reviewed once a week in our advisory period during the six weeks prior to the AP exam.

Students completed a mid-term exam at the end of the first semester. This exam consisted of retired AP exam multiple choice and free response questions. I was able to compare how the blended students performed on the exam to the performance of my past students who were exposed to a very traditional classroom model. Given that this exam took place near the onset of the truly blended classroom period, I did anticipate that results may not show statistically significant changes; however, it was interesting to see what steps were being made in the desired direction.

Following the treatment period, I asked students to voluntarily participate in a Plus (+) / Delta (Δ) focus group (Thorpe, 2018). Students were invited to a half hour

meeting in which they were asked to consider the benefits of incorporating technology-based resources in the classroom. They were asked to focus on changes to their engagement and performance throughout the treatment period. They were also given an opportunity to share which resources they preferred to keep as part of the day-to-day routine. Conversely, the group was asked to make suggestions for improvement on the tools or processes they did not find as valuable. They were asked to consider how the treatment could be changed so that it would be more favorable for the rest of the school year and for future classes. Individual comments were recorded by students on Post-It notes so that feedback was captured in the students own words without instructor intervention or bias. These ideas were then discussed and placed on larger focus group pages for further review. Comments were then analyzed based on the themes of engagement and performance. Given the homogeneity of the group, and the common learning background, students were not easily placed into specific subgroups, and instead, feedback was analyzed for the entire group without separation (Appendix F).

The final component of the research process was to have students complete the 2018 AP Chemistry Practice Exam. My goal was to have students find a greater level of success on the AP exam. As exam results are not available until three days following the capstone presentation, I asked students to complete the practice test so that I could calculate anticipated exam scores. These exam scores were then compared to historical data for my classes over the last three years. Past scores have dictated a need for a change in the way the content is presented to students. Exam results have shown that students have mastered many chemistry concepts, but not to a depth that earns a three or

four on the actual exam. Students know individual topics but struggle to make connections between topics. For this reason, I proposed the above methodology to remove background lectures, excessive amounts of time spent going over homework problems, and time lost through questions that did not get to the heart of the material. By blending the classroom, students had little choice but to engage, at least in part, independently and gain confidence in their ability to complete high level work. Our class time was able to shift to higher level application of the content and our additional time was used to prepare for the AP exam in a manner that boosted confidence and promoted connection and retention of key concepts.

Qualitative data from this study included post-Plickers discussions, surveys, student questions, perspectives on blended resources, engagement in exam prep, and the Plus (+) / Delta (Δ) focus group. All were assessed based on student perception of how the blended treatment worked to increase their class engagement and performance. Other data that was reviewed included student perspective on individual blended tools, depth of knowledge with respect to student questions, and suggestions for which resources to keep, refine, or replace.

Quantitative data from this study was taken from surveys, the Mastering Chemistry instructor interface, quiz scores, midterm scores, and AP practice exam scores. Each of these data sources was analyzed with respect to a null hypothesis equal to no treatment effect. The alternative hypothesis was that if the treatment was effective, students should see a statistically significant gain in performance and engagement on class activities and assessments. A look at mean quiz scores, score range, standard

deviation, and normalized gains provided insight as to the effectiveness of this research. Individual survey questions were assessed for changes in student perceptions of engagement and resource preference. All data was analyzed at a 95% confidence level, 5% α level, with a Wilcoxon Rank-Sum test being used to analyze the quiz data based on non-normal distribution. Additionally, a numerical count was done to determine the number of students achieving scores of 90% or higher on pretests and the two versions of the post-test. AP midterm and final exam data were compared to results from previous classes in which a very traditional instructional approach had been implemented.

This study will go on beyond the scope of this action research project to continue to move the class confidently towards a more blended environment. With various tools at students' disposal, they now have the means to move forward and continue to personalize their learning and advocate for their learning needs. The data from this research will be used to support the blending of additional classrooms within our district and can serve as a tool in assessing this blended model as compared to other blended philosophies.

DATA AND ANALYSIS

All students in the AP chemistry class received the treatment and a variety of pre- and post-treatment data were analyzed. Quantitative data included quiz scores, Likert surveys, completion rates, and anticipated AP Exam scores. Qualitative data was obtained through a student focus group, classroom observation, and individual communication. All data was analyzed with respect to the questions of whether a blended learning environment increased student engagement and performance in a junior and senior level AP chemistry course.

Engagement

One purpose for this research was to measure student engagement in their learning in AP chemistry. At the onset of the course 20% of students regularly completed practice homework problems. Another 20% of students would put forth some effort on homework. This left 60% of the students rarely, or never engaging in follow-up practice problems outside of the body of the lesson. At the commencement of the treatment period, homework was moved to Pearson's Mastering Chemistry Program (2018, Pearson). At the end of the second term 14 of 15 students had completed at least 10% of the assigned problems. Still, only one student was highly engaged, completing most of the homework. During the pre-treatment period and term two, homework completion was reported in our student record system but was not a part of a student's overall course grade. In term three I added an incidental point value to homework completion. During term three, homework could potentially impact a student's grade by raising it or lowering it less than a percentage point. This is enough to potentially move a student one grade mark level (i.e. from a B- to a B). Term three homework completion rose to 67% of the students completing 90% or more of the assigned work. Another 20% of the students were moderately engaged and completed a portion of the homework, leaving only two students showing minimal engagement in the homework with a low completion rate. All students in term three engaged in some amount of practice work outside of examples that were embedded into the classroom content.

Data was kept with respect to student engagement on AP free response practice passages. During the pre-treatment period students were reluctant to attempt the passage,

often leaving the page blank or responding with a confidence related note. During the treatment period more and more students made attempts on practice passages. At the final check of the treatment period, students completed a full AP practice exam. There were seven free response passages. Students attempted these passages 82.9% of the time. Additionally, students made attempts on content not yet studied in class. When content was unknown, some students exhibited creative problem-solving skills by selecting appropriate formulas from the formula sheet and noted connections to familiar content.

Initially, students were reluctant to participate in class discussions. Despite students having a foundation in chemistry, my questions would often go unanswered. At the end of the treatment period I observed that half of the class was regularly participating in whole group discussion or problem solving, while all students were willing to ask questions. At the onset of the class, students would not ask in-lesson questions in front of peers. Post-treatment, engaging in the lesson through appropriate questioning was a classroom norm.

Performance

Beginning in September 2018 and continuing through March 2019, I collected and quantitatively analyzed pretest and post-test quiz scores in my junior and senior level AP chemistry course ($N=15$). This time coincided with the first three terms of the school year. Each new chapter began with a pretest. Students who earned a 90% or higher on the pretest earned an exemption from homework problems, homework checks, and the post chapter quiz, unless they wished to demonstrate advanced understanding of the content. All other students completed activities throughout the chapter and took the first

version of the summative assessment. Again, if a student earned a 90% or higher on the first post-test, they could consider the chapter work complete, unless they wished to demonstrate additional academic growth. However, any student who did not meet the benchmark on the first summative assessment was required to update their quiz, do additional studying, and complete a second version of the post-test. Figure 1 below illustrates the students' performance on each chapter pretest and post-test. It is important to note that the data presented for chapters two and three was collected prior to the treatment period and was primarily review material. The data for all following chapters was collected during the treatment period as instruction shifted away from review and into new concepts. The data shown includes the final score which was recorded in their grade book following both versions of the summative assessment. Figure 2 graphically displays the normalized gains for the pretest and final recorded score on the post-test as a class average after all retakes and studying had occurred. Finally, Figure 3 shows the number of students scoring at or above the 90% benchmark on each of the three assessments.

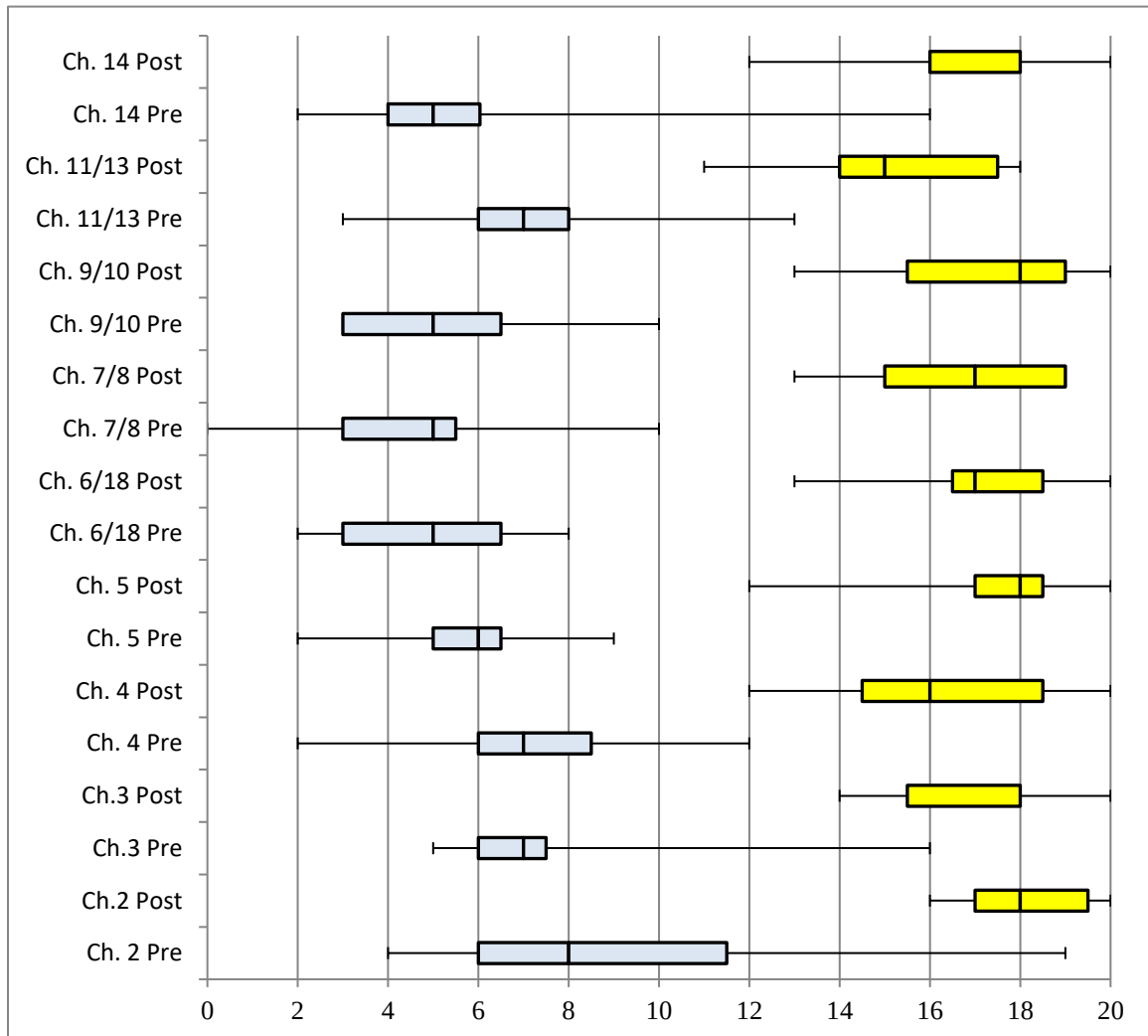


Figure 1. Class pretest and post-test scores prior to treatment, chapters two and three, and during treatment, chapters four through fourteen and eighteen, ($N=15$).

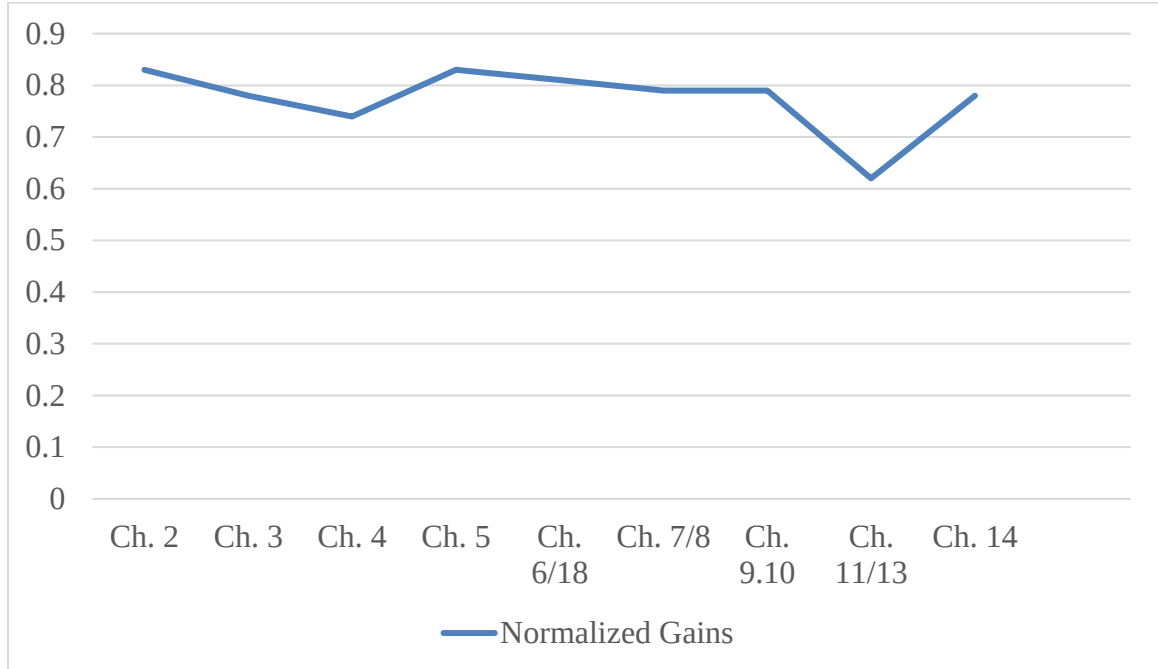


Figure 2. Normalized gains prior to treatment, chapters two and three, and during treatment, chapters four through fourteen and eighteen, ($N = 15$).

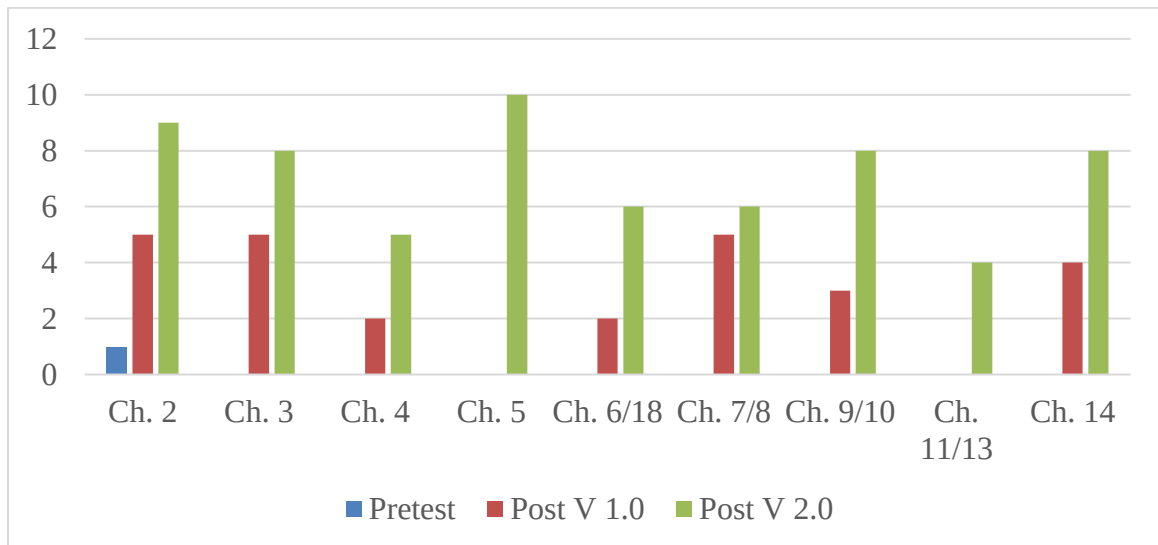


Figure 3. Number of students scoring at, or above, 90% on the chapter assessments, ($N=15$).

The above data was statistically analyzed to keep it in the context of relating the blended format to increased student performance. The data in Figure 1 above indicates

that students made significant gains on quizzes during the traditional classroom learning period and the blended treatment period (Table 2).

Table 2

Statistical Analysis of Pre-treatment and Post-treatment Pretest and Post-test Scores

	Pretest	Final Post-Test
Chapter 2*	Mean = 9.07 Median = 8 Range = 15 Std. Dev. = 4.13	Mean = 18.1 Median = 18 Range = 4 Std. Dev. = 1.53
Chapter 3*	Mean = 7.73 Median = 7 Range = 11 Std. Dev. = 3.15	Mean = 17.1 Median = 18 Range = 6 Std. Dev. = 1.77
Chapter 4	Mean = 6.93 Median = 7 Range = 10 Std. Dev. = 2.71	Mean = 16.4 Median = 16 Range = 8 Std. Dev. = 2.69
Chapter 5	Mean = 5.47 Median = 6 Range = 7 Std. Dev. = 1.81	Mean = 17.53 Median = 18 Range = 6 Std. Dev. = 2.01
Chapter 6 and 18	Mean = 4.8 Median = 5 Range = 6 Std. Dev. = 2.04	Mean = 17.1 Median = 17 Range = 7 Std. Dev. = 1.94
Chapter 7 and 8	Mean = 4.27 Median = 5 Range = 10 Std. Dev. = 2.43	Mean = 16.5 Median = 17 Range = 6 Std. Dev. = 2.26
Chapter 9 and 10	Mean = 5.33 Median = 5 Range = 7 Std. Dev. = 2.13	Mean = 17.13 Median = 18.0 Range = 7.0 Std. Dev. = 2.23
Chapter 11 – 13	Mean = 7.5 Median = 7 Range = 10 Std. Dev. = 2.74	Mean = 15.4 Median = 15 Range = 7 Std. Dev. = 2.24
Chapter 14	Mean = 6.07 Median = 5 Range = 14 Std. Dev. = 3.89	Mean = 16.9 Median = 18 Range = 8 Std. Dev. = 2.38

A closer look at the data in Table 2 indicates that the median assessment scores significantly increased both before, and during, the treatment period. In several instances the group score range decreased between pre- and post-assessment, leading to a lower standard deviation in scores. The range in scores also tended to narrow as students learned the material.

While the normalized gain data suggested a large effect size, a Wilcoxon Rank-Sum test for paired data was used to further analyze each chapter's results for statistically significant gains. A two-sided test was implemented throughout the analysis, since the teaching method could result in higher or lower assessment scores. I selected a confidence level of 95% and an alpha value of 5%. For all trials the hypothesis was that the blending treatment had a positive impact on student performance between the pretest and the post-test ($H_A = \text{treatment effect}$). The alternative hypothesis was that the treatment had no effect ($H_o = 0$). It was discovered that during the pre-treatment period the traditional teaching method did, in fact, have a statistically significant impact on student learning. With p-values of 0.000714 and 0.000686 for chapters two and three respectively, it can be stated that the traditional method significantly improved student performance during a chapter of study. The hypothesis proved true throughout the treatment period, as well. Wilcoxon Rank-Sum p-values ranged from 0.0005967 to 0.001078, indicating students experienced academic growth regardless of methodology.

Supplementary data was collected at the end of the first semester in the form of a practice AP exam including only topics that the students had previously studied in the AP chemistry class. To that point, the class had been one of the highest academically

achieving classes that I had, with the lowest class score being a single B-. Students underperformed on this midterm, AP exam, assessment. The class average was 2.45 as compared to previous years scores which had ranged from 2.78 to 3.47. The score range was more homogeneous than in the past, with students scoring in the 1.4 to 4.2 range on the test. Traditionally, student scores equalized to a range of 1 to 4.6. The midterm AP exam was scored more generously, awarding students decimal value points at equal intervals between the traditional AP whole number grading scale.

As a predictor of actual AP chemistry exam performance in May, students completed the 2018 AP College Board AP Chemistry Practice Exam (College Board, 2018). This exam consisted of 50 multiple choice questions and 7 free response passages. Students completed the practice exam over two block periods. At the time of the practice test, there were 28 points that the students had not yet encountered in their class work, including equilibrium and electrochemistry. Yet, scores on this exam were already in line with actual AP exam results from previous years. Historically, 10% of my students have scored a 3 on the exam. Based on the pretest results, two out of fifteen students were already at this level, with several students having scores that indicate they could move into the 3 range as additional instruction and review took place. Raw scores on the practice test ranged from 18 to 59.25, with the class average being 32. On average, students earning an additional 12 points out of the 28 remaining to be learned, would find themselves at a score of 3, potentially making them my highest achieving class to date on the AP chemistry exam.

Student Perspective

On October 23, 2018 students in the AP chemistry course were asked to complete two surveys. Both surveys were completed anonymously and were given and collected by a guest teacher to ensure that I did not know who completed the specific survey. The first survey gave students an opportunity to reflect on their engagement and performance in AP chemistry. The second survey asked students to determine how much they valued the use of a variety of tools and teaching methods in the AP chemistry classroom. Both surveys were created using a five category Likert format. The exact same surveys were given by a guest teacher at the close of the treatment period on April 3, 2019 so that I could determine if the students felt more engaged in the blended classroom, if they believed that there was a positive change in their performance due to the blended classroom, and if their perceptions on technology-based tools became more favorable during the treatment period. I have rearranged the question order from the original *Survey on Engagement and Performance in AP Chemistry* to reflect four categories: self-regulation, intrinsic motivation, engagement, and performance (Table 3).

Table 3

Survey on Engagement and Performance in AP Chemistry Survey Alignment

Self-Regulation (Students taking ownership) Questions: 1, 2, 7, 9, 12, 13, 18, 24, 25	Intrinsic Motivation (Student perceived competency) Questions: 8, 11, 15, 16, 23
Engagement (Student participation) Questions: 4, 10, 14, 19, 21, 22	Performance (Academic outcomes) Questions: 3, 5, 6, 17, 20, 26

The data in this survey was collected using a five-point Likert scale. A summary of the questions as arranged by category show the differences between pre-treatment and post-treatment responses (Table 4).

Table 4
Engagement and Performance in AP Chemistry Survey Categorized Differences

	SD	D	N	A	SA
Self-Regulation					
1. I think a lot about how I am doing in class.	-	-	-1	+3	-2
2. I enjoy routine.	-	-	-3	+1	+2
7. I learn from my mistakes.	-	-	-	-	-
9. I usually only have to make a mistake one time in order to learn from it.	-	-4	+5	-1	-
12. I incorporate feedback when updating work.	-	+1	+2	-2	-1
13. There is usually more than one way to accomplish something.	-	-	-2	+2	-
18. I ask for help when I need it.	-	-	+1	-1	-
24. I have time in class to have my questions answered.	-	-1	+4	-4	+1
25. I have time in class to complete homework and practice exercises.	-	+1	-	-4	+3
Intrinsic Motivation					
8. After completing practice problems I feel competent.	-	-6	+2	+5	-1
11. I am satisfied with my performance on quizzes.	-1	+3	-4	+2	-
15. I put a lot of effort into doing well.	-	-	-	-	-
16. I value timely feedback.	-	-	-	+1	-1
23. I will meet my goals for AP chemistry	-	-	+2	+1	-3
Engagement					
4. I have set a goal for AP chemistry.	-	-	-	+1	-
10. I prefer to use a variety of resources to reinforce my learning.	-	-2	-7	+9	-
14. I am engaged in all aspects of AP chemistry.	-	-	+1	+1	-2
19. I think online resources provide a path to personalizing my learning.	+1	-	-1	-1	+1
21. I find resources for help when I need them.	-	-	-	-1	+1
22. I think online resources help me to be more engaged in class.	+2	-1	-3	+3	-1
Performance					
3. I do well at homework completion.	+3	-	-3	-	-
5. Completing practice exercises has value.	-	-1	+2	+3	-4
6. I feel prepared for the AP chemistry exam.	-	-1	+3	-3	+1
17. It is important for me to do well on quizzes.	-	-	-	+2	-2
20. I feel confident in my ability to earn a 3 on the AP chemistry exam.	-	-1	+1	+1	-1
26. I attempt to earn a 90% on the first quiz version.	+1	-	+3	-2	-2

Note. SD = Strongly Disagree, D = Disagree, N = Neutral, A = Agree, SA = Strongly Agree. (N=15).

Following this survey, I broke down the data a bit more to determine the area of most need for my students. To do this, I assigned each response a point value: strongly disagree = -2; disagree = -1; neutral = 0; agree = +1; and, strongly agree = +2. I then took the sum of all responses within a category and divided that by the number of questions in the category. This provided a manageable composite score that I could then use to analyze the data and make comparisons between categories (Table 5)

Table 5

Survey on Engagement and Performance in AP Chemistry Survey Composite

Self-Regulation (Students taking ownership) Questions: 1, 2, 7, 9, 12, 13, 18, 24, 25 Pre-Treatment composite = 15 Post Treatment Composite = 15.8	Intrinsic Motivation (Student perceived competency) Questions: 8, 11, 15, 16, 23 Pre-Treatment composite = 14.4 Post Treatment Composite = 15.2
Engagement (Student participation) Questions: 4, 10, 14, 19, 21, 22 Pre-Treatment composite = 7.33 Post Treatment Composite = 8.5	Performance (Academic outcomes) Questions: 3, 5, 6, 17, 20, 26 Pre-Treatment composite = 14 Post Treatment Composite = 10.7

Prior to the treatment, Table 5 tells us that students believed they were doing well in the categories of self-regulation, intrinsic motivation, and performance, but that they were not feeling overly engaged. After the treatment had taken place, students were feeling more engaged. They also believed that they were better at self-regulation and their intrinsic motivation had grown. The data suggests that students were feeling less positive about their performance, while at the same time the survey results showed that more students felt an increased level of confidence with respect to the AP exam.

The results of the final survey prompted a deeper statistical look at several questions to see if there was a change in perspective related to the intrinsic motivation and student confidence after completing homework and feeling satisfaction in quiz

scores. I analyzed student engagement with a more detailed look at the two questions related to using a variety of resources to reinforce learning and using online resources to provide a path to personalizing individual learning. Finally, I decided to see if students felt more prepared for the AP chemistry exam following the treatment period. The data generally shows a shift towards more positive responses (Figure 4).

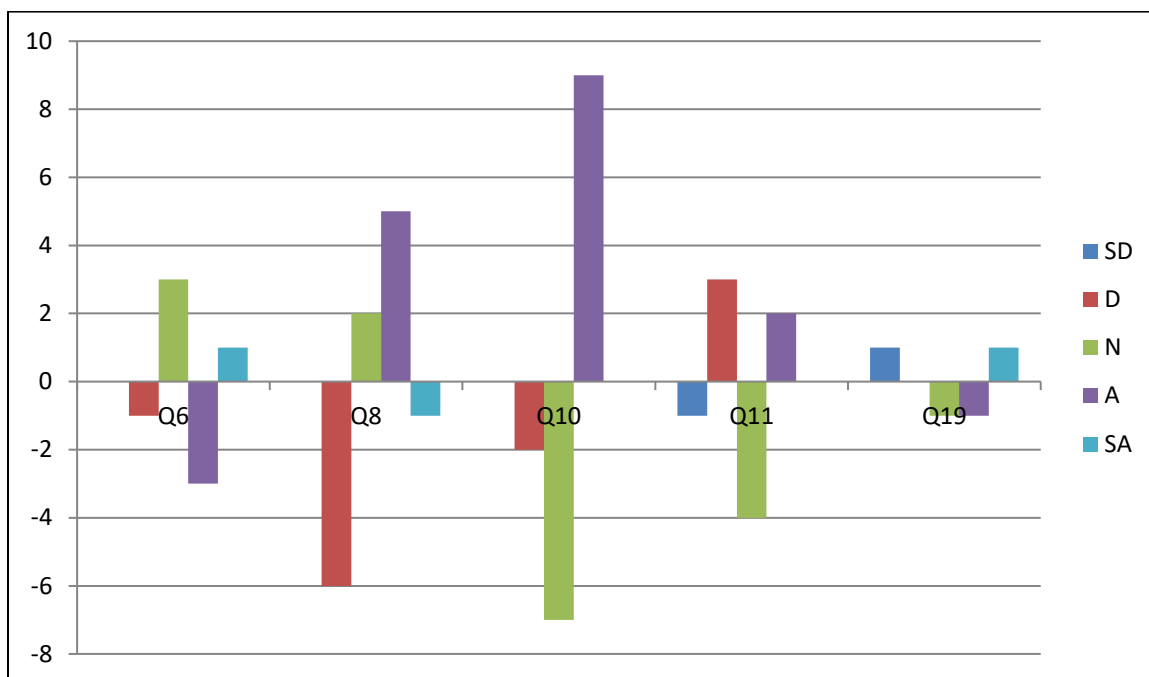


Figure 4. Engagement and performance survey results for specific questions. Note: questions 6 = performance on the AP exam, question 8 = perceived competence following practice problems, question 10 = preference for a variety of resources to reinforce learning, question 11 = satisfaction with quiz performance, and question 19 = online resources promoting personalization, ($N=15$).

The same questions were then analyzed using a Fisher's exact test for count data given that there was a low response count and there were empty data cells. This test was conducted at a 95% confidence interval with an alpha value of 5%. Tests were two sided. As with the Wilcoxon test, the hypothesis was that the blending treatment had a positive

impact on student engagement and performance between the pre-treatment and the post-treatment (H_A = treatment effect). The alternative hypothesis was that the treatment had no effect ($H_0 = 0$). With respect to question six, *I feel prepared for the AP chemistry Exam*, the data says that the change in perception would be seen 58.32% of the time, indicating that the treatment did not have a direct impact. When considering question eight, *after completing practice problems I feel competent*, the Fisher test produced a p-value of 0.02504. This indicates that there is a statistical significance to practice problem completion and how students feel about their ability to solve this type of problem again. The Fisher results also showed a statistical difference for the question, *I prefer to use a variety of resources to reinforce my learning*. This question had a Fisher result of 0.11%, strongly suggesting that the treatment had an impact on opening student's eyes to the possibility of incorporating a variety of resources into a traditional education system. Question eleven asked students to respond to the prompt, *I am satisfied with my performance on chapter quizzes*. The statistical analysis gave a p-value of 0.3784 which forces us to fail to reject the null hypothesis. I was also forced to fail to reject the null hypothesis for question 19, *I think online resources provide a path to personalizing my learning*. With a p-value of 0.3005 I cannot state that the treatment had an impact on this student perception.

As part of this study, I wanted to explore which instruction resources students found valuable so that I would be able to further incorporate them into my best practice. I asked students to complete a second survey, *Survey on Educational Tools for AP Chemistry*, to reflect on three distinct categories, including technology-based tools,

traditional practices, and classroom procedures (Table 6). This table includes the same composite score analysis that was used for specific questions in the engagement and performance survey.

Table 6

Survey on Educational Tools for AP Chemistry Composite

Technology Based Tools (Technology rich and blended resources) Questions: 1, 5, 9, 11, 13, 18, 19 Pre-Treatment composite = 1.29 Post Treatment composite = 3.14	Traditional Practices (Classical education without technology) Questions: 2, 3, 4, 6, 10, 12, 14, 16, 17 Pre-Treatment composite = 16.8 Post Treatment composite = 16.9	Classroom Procedures (Tools available to Students through best practice) Questions: 7, 8, 15 Pre-Treatment composite = 26.7 Post Treatment composite = 23.7
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The data in this survey was collected using a five-point Likert scale. A summary of the questions, as arranged by category, shows the differences between the pre-treatment and post-treatment responses (Table 7). An overview of the data continued to show that these students are steeped in a traditional education system and value traditional classroom practices. While students are neutral with respect to utilizing technology-based instruments for portions of their background learning and reinforcement, they did begin to recognize value in using tools outside of the instructor. Again, we can see that the students value class work time where they have direct access to an instructor and appreciate the opportunity to improve their quiz scores through a retake.

Table 7

Survey on Educational Tools for AP Chemistry Categorized Differences

	SD	D	N	A	SA
Technology Based Tools					
1. Teacher created video lessons that I view on my own.	+1	-	-1	+2	-2
5. Question of the day warm-ups.	-	-2	-1	+1	+2
9. Mastering Chemistry online homework.	+1	-	-2	-1	+2
11. Interactive virtual resources.	-1	+2	+1	-1	-
13. Online video lessons (created by others).	-1	+1	-1	-1	+2
18. Kahoot reviews.	-	+1	-	-	-1
19. Quizlet flashcards.	-2	-1	-	+2	+1
Traditional Practices					
2. Traditional in-class notes.	-	-	-	-2	+2
3. Text book homework problems.	-1	+1	-1	+3	-2
4. Traditional lectures.	-	-2	-1	-2	+5
6. In-class, full class practice problems.	-	-	+1	+2	-3
10. Homework checks.	+1	+2	-3	-2	+2
12. Group collaboration with teacher support.	-1	-	+1	+1	-1
14. AP practice problems.	-	-	-	+1	-1
16. Lab activities.	-1	-	+2	+6	-4
17. Independent projects.	-	-	+1	+2	-2
Classroom Procedures					
7. Daily work time.	-	-	+1	+4	-5
8. Individual help from the teacher.	-	-	-	-2	+2
15. Chapter quiz retakes.	-	-	-	+1	-4

Note. SD = Strongly Disagree, D = Disagree, N = Neutral, A = Agree, SA = Strongly Agree. (N=15).

Following the post-treatment collection of data for this second survey I again analyze a few questions in more depth. I was specifically interested to see if there were changes to how much students valued the traditional lecture, how they valued the online Mastering Chemistry homework, and how they valued interactive virtual activities.

Figure 5 shows a graphical representation of responses for these questions.

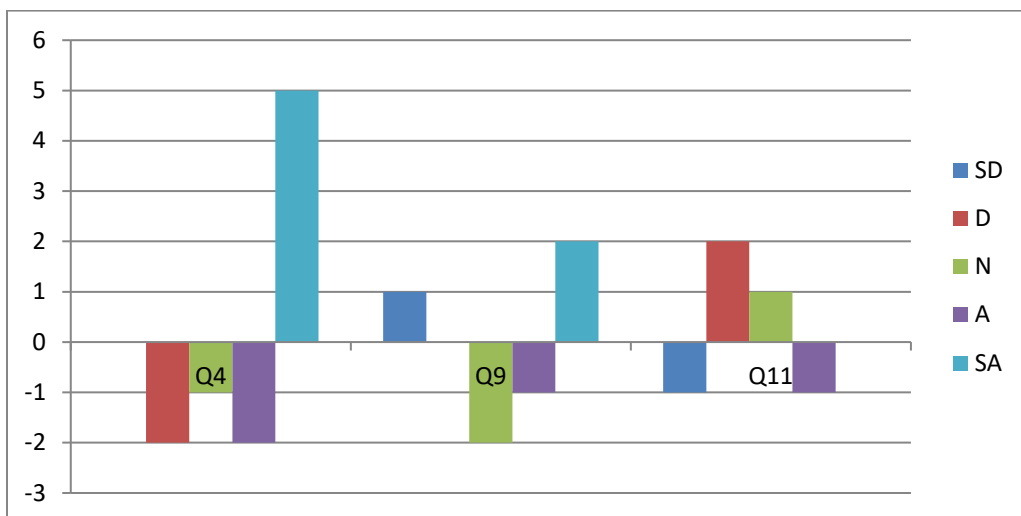


Figure 5. AP chemistry instrument survey results for specific questions. Note: questions 4 = valuing traditional lectures, question 9 = valuing Mastering Chemistry, question 11 = valuing interactive virtual resources, (N=15).

To further test for any statistical significance to these responses, a Fisher's exact test for count data was again employed. The confidence interval remained at 95% with an alpha value of 5%. Two tailed tests were conducted since student opinion could sway to either the positive or negative tail. The hypothesis for these tests was that the treatment had an impact on student responses (H_A = treatment effect) while the alternative hypothesis was that the treatment had no effect ($H_0 = 0$). Analysis of question four, *Traditional Lectures*, with a p-value of 0.3005 indicated that there was no treatment effect and students still preferred traditional lectures. Analysis of question nine, *Mastering Chemistry online homework*, showed that 75.97% of the time you could expect the same pre- and post-treatment responses. Students went into the treatment saying they would not like the online homework and statistically they remained soundly with that perspective; however, when looking at individual numbers, it can be observed that two students strongly agreed with the value of online homework. Fewer students had a

neutral response to the validity of online homework and they began to separate themselves into two passionate groups. The final question that I wanted to focus on was question eleven, *Interactive Virtual Resources*. The data showed that more students were more in favor of using online resources; however, statistically, the change was insignificant with a p-value of 0.9249. When analyzing the overall *Educational Tools* survey, the data that continues to stand out the most is the high value that students continued to place on the traditional classroom environment and the very slow shift in mindset regarding the value of technology-based educational tools. Throughout the school year, the classroom procedures were held in high regard by students; these tools supported both types of learning.

Qualitative Data

Throughout the treatment period I continuously collected qualitative data through: the interactions that I had with students, and the observed interactions students had with each other. Student interaction data supported the quantitative results that developed throughout the school year. As students progressed through the treatment period they became more confident in their chemistry skills and moved beyond basic procedural questions related to problem solving. Even though frustration occasionally ensued, students reassured each other with comments such as, "I recognized everything that was being asked. I just need to figure out how I'm going to remember how to do all of this." This statement was an indication that students recognized the need to be deeply engaged in the content of the course and placed the learning squarely on their own shoulders. On another occasion a student came to me during the quiz and recognized an answer that was

true most of the time, but also recognized that there were exceptions to the rule. Rather than asking if they were doing the problem correctly, or asking for clarification, they simply wanted to confirm that questions should always be answered with the best answer, the one that is true every time. When studying kinetics, a student wondered aloud, “How do you determine the rate of change when a catalyst is involved?” We had strictly been looking at concentration change, but the student was contemplating content beyond the scope of the AP class, which lead to an interesting brainstorming session within the body of the lesson. The confidence that was demonstrated through greater depth of knowledge questioning became apparent when students participated in a chemistry demonstration at the middle school. A middle school student made a connection to one group’s Ruben tube. While the principle is not entirely the same, the student was able to eloquently respond to the student’s comment and clarify the science in a way that connected with younger students.

At the end of the treatment period, I invited students to provide face-to-face feedback through a Plus (+) / Delta (Δ) focus group. Eleven of the fifteen students volunteered their time and ten were ultimately available on the day of the focus group. First, I asked students to focus on what went well during the treatment period and what they would suggest keeping or enhancing for the rest of this school year, as well as for future classes. Students indicated that the pretests were an incredibly valuable tool. They admitted that they hadn’t always tried the hardest on them but valued them because they could get a preview on the topics that they were going to learn. This led to connections throughout the lesson, and an invaluable study tool prior to the summative. Students also

valued the traditional lecture. They stated that I should never completely remove this from the class because the chemistry content requires an instructor to guide the learning. They appreciated the flexibility offered during the blended segment. Though one student admitted, “homework and labs can easily be pushed off [or] forgotten about.”

Navigating away from the traditional, two students noted that they did appreciate being able to explore additional tools that supported their learning, and three additional students specifically stated that the resources that were selected were quality resources. The students discussed how we connected the content to the real world and that they really enjoyed the opportunity to share their learning with other students.

One final positive finding was regarding students stepping up to the rigor of an AP class. Students appreciated the opportunity to raise their quiz score by completing a second quiz version, but they also recognized this as an opportunity to continue to work on the content and understand it at a higher level. One student specifically addressed the rigor of the second exam stating that,

Version two should be harder. You’ve seen [the] content twice. You should be able to apply your skills. Also, teachers, in general, should add more, ‘explain your thinking’ questions to high level assessment so that they can see where students are getting hung up in the process.

Students continued this thought by admitting that they would like to see AP questions and free response passages on their summative assessments, even though they recognized that this would stretch many students. One student remarked, “It will push people on time, but will also force them to show their knowledge. It is also better prep for the AP exam.” In general, students regarded assessment as an opportunity and were pushing for higher level content and a higher level of accountability.

While some of the pluses and deltas intermingled during the discussion, it became clear that there were some rubs for students during the blending period. Most students did not care for Pearson's Mastering Chemistry. They felt that we needed to spend more time reviewing problems in class or that the problems that were assigned needed to have more step-by-step feedback. One student failed to recognize the application of the content and felt that the online questions were sometimes, "out of the blue." Another student stated, "I don't get anything out of it and I think we should go back to bookwork because I can understand those problems." In general, students said that they used the homework as a review for quizzes rather than throughout the unit. This led to a request for a separate set of review questions at the end of each unit.

Students continued to focus the delta portion of the discussion on resources to help them be better prepared for the summative assessment, as well as the AP exam. They wanted the in-class quizzes to look more like the AP exam questions. One suggestion was to use the same formatting and open space on the paper that AP uses. Another was to group questions so that three or four related to one prompt. One student summed it up like this, "Make quizzes the same format, spacing, everything. The AP practice test feels too new." In preparation for these assessments, students requested more work, more practice, and more labs. They didn't like pre-lab quizzes but wanted post-lab assessment with more application. In general, students wanted to be more immersed in the application of the content.

The data analysis showed that students did make gains in performance on assessments during the treatment period. Students maintained their pre-treatment

performance on assessment and they also maintained their level of performance when the content became the most rigorous and most applicable to AP chemistry exam content. Students changed their superficial, confidence-based line of questioning to questions that connected topics or reached beyond the scope of what they were required to know. This class began to recognize the value in utilizing resources other than direct instruction to support their learning. And, when questioned directly, students were able to eloquently express their appreciations for traditional learning and make suggestions as to how to increase the rigor required of the learners.

INTERPRETATION AND CONCLUSION

With the introduction of one-to-one technology at Kiel High School, I have found students to be less engaged in the traditional classroom settings and more disposed to work in groups, or independently, in a technology supported environment. Surveys have shown that more and more students prefer to be given some freedom and flexibility in their learning while still having the support of an instructor for direct instruction, clarification, extension, and remediation. The blended classroom setting can provide students with a mix of traditional and technology-based resources. Blended does not have to equal technology; conversely, it can be flexibility in timing, alternative learning paths, hands-on activities, alternate seating, and much, much more. A blended setting allows a teacher to meet students where they are in their learning path, giving students the ownership of working on what they need to work on to best support their goals. I had to be comfortable relinquishing complete control over student activity in the class, exercising mutual respect so that that I would recognize when students needed either

more, or less, from me. It is interesting to note that most students feel they are good at self-regulation, regularly incorporating feedback into their learning, and are learning from their mistakes. Furthermore, as is expected from an advanced placement class, learners are highly motivated to do well and are not entirely satisfied with their performance on assessments. And, despite not being satisfied with their assessment performance, they still feel as if they are prepared to earn a 3 on the AP exam.

The post-treatment survey suggested that students valued classroom procedures even more after the treatment period. I interpret this to mean that they need this time to confirm that they are heading in the right direction as they begin to personalize their learning path. This is a new journey for students, and they are not ready to step away from all the tradition that they are accustomed to. Students recognized that there is more than one way to get things done. They just need the support to build their own confidence as they walk this blended path.

When students experienced resources that they deemed as helpful, they put more time and effort into using them. By slowly releasing resources to students they learned to monitor their own conceptual growth and came to appreciate the ability to advocate for their learning needs. Their increased performance and engagement were noted in the assessment results throughout the course. Traditionally, term three becomes the most challenging. Students now recognize that they are entering the second credit of the class and that this is their only yearlong block course. They have also recognized that they have moved well beyond the basic content and are now using their background in chemistry as a solid foundation for some of the most challenging, and most highly

represented topics, found on the AP exam. Yet, this year, I did not see a major dip in performance or a lack of energy or engagement. We missed the slump and continued to navigate forward, with students taking ownership for the class and even making suggestions as to which resources they would like to see more of. Caner's research told me right up front that I should not expect statistical proof that blending leads to increased performance in the classroom (Caner, 2014). Kintu, however, gave me hope that student would feel more engaged in a classroom that implements a mix of structured learning, prompt feedback, and quality technology-based resources (Kintu, 2017). I found both studies to be accurate in predicting the outcomes of this research.

A truly blended setting may not be appropriate for all students; conversely, a purely traditional setting also does not serve most students well. This group of students was open and honest with me throughout the research period. They were able to offer feedback and suggestions that were appropriate and looked beyond just their needs as an individual, and instead reflected upon what would benefit their classmates and future classes. We began as a diverse group of learners with specific learning needs and ended in the same fashion. Along the way, students were able to demonstrate high levels of achievement and readiness for this year's AP chemistry exam. They remained engaged, even when the course began to feel interminable and the content became challenging.

There are implications for this research beyond just the AP chemistry classroom. As students move into their post-secondary education, those who have experienced the blended classroom may be more prepared to take ownership of their learning. They will have experienced the freedom of making decisions regarding which resources support

their learning style and allow them to find success. Students will also recognize that the engagement component of their education impacts their performance. The more engaged the student is in their learning, the more it seems to correlate to higher performance level and retained problem-solving skills.

Those students and teachers focusing on the processes associated with Science, Technology, Engineering, and Math (STEM) careers will also benefit from the blended learning platform. By utilizing appropriate resources that are both succinct and age appropriate, individuals will become more engaged in the problem-solving process, giving them the confidence to both make mistakes and learn from those mistakes. As individuals gain confidence in their skills and begin to analyze issues at a greater depth, they will be able to develop creative solutions to tasks before them. The blended classroom may not only lead to a personalized education for students, it can also lead to personalized problem-solving skills that have implications well beyond the classroom. Students can continue to learn by doing throughout their life. Students may also be more prepared to navigate towards solutions to those problems that we don't yet realize exist.

Blending a classroom can also have a profound effect on the educator. As the teacher discovers and releases new resources, they must be open to hearing and responding to the feedback that the students are giving. Students may also present new resources to the teacher. In this way, the instructor also continues a lifelong learning path and can model the value of analyzing varied resources. The instructor can share ownership of the classroom and work with the students rather than for them.

I must remember that the research states that blending is a process that can take three to five years. This was the first step in a very systematic process to put new resources into the hands of students. The deliberate release of materials gave students the time to process through how to use the new resource in a manner that worked for them. By allowing time between the introduction of each new resource, students did not have to choose between learning how to implement the resource or learning the content. The resource should support the learning; it was then up to the student to determine the value in the resource. In conclusion, this study showed that students in a blended setting are more engaged in their learning and they are able to maintain their performance on a variety of assessments.

VALUE

We live in a world that is increasingly rich in technological advancements and resources, with new information being disseminated daily. It is important that students have access to appropriate online resources which will enhance their engagement and learning outcomes. It is equally important that students have access to flexibility in their learning location and timeframe, as well as access to all the traditional resources. A blended classroom supports our district's mindset of improvement for all. It creates intrinsic motivation and can support essential learning targets while maintaining rigor. It gives students ownership of their learning while freeing up my time, so that I can act as mentor.

The introduction of a blended classroom to students is supported by both the state of Wisconsin Department of Instruction (DPI) and by the National Science Teachers

Association (NSTA, 2016). Both entities have encouraged the use of online resources in conjunction with direct teacher support. NSTA believes that incorporating online resources can provide students with updated and accurate visuals of the content. Online resources also allow for research and inquiry investigations that are not practical in the face-to-face setting (NSTA, 2016). Furthermore, the Wisconsin DPI has partnered with several online schools to create the Wisconsin Digital Learning Collaborative (WDLC). As a teacher with the Collaborative, I know that this partnership has fostered a rich online and blended learning partnership within our state. DPI recognizes that blended learning presents differently in different settings at different academic levels (Mertes, 2012). It is through this partnership that I can collaborate and help foster growth in the online and blended environments. It is my goal to share this research not only with my local peers, but also with the Collaborative through professional development events. Within our district we are building a network of teachers who are beginning the blended education journey. Collaboratively we work together to share our strengths, weaknesses, discoveries, and most importantly, impacts on, and feedback from, the students. I anticipate that this project will become a valued resource in support of blended learning within our district.

Moving forward, I wish to continue with the process of blending the AP chemistry course. Based on student feedback, I'm already analyzing the assigned questions more closely to make sure that they are completing questions with "advanced feedback." I'm also putting all the homework for a chapter together into one larger assignment to make the online navigation simpler and less visually overwhelming. By

combining the chapter homework into one assignment, students will only see one assignment and one adaptive follow-up, rather than seeing a dozen or more items associated with a chapter. Students will also have the option of completing the exact same problems on paper. Despite student perception, the online homework problems were the exact same problems that I assigned from the text; now they will be able to use the resource that is the best for them. I will also continue to assign some point value to the homework problems. Students are asking for more rigor, and so I will need to consider if I wish to grade students based on completion or if I wish to grade them on accuracy. I am considering leaving the homework open for the entire term and giving students unlimited attempts so that they can keep going back to learn from their previous mistakes. I also heard my students when they said they enjoyed having Quizlet's online flash cards and end of chapter reviews for each chapter. I'm considering how I will add AP passages and multiple-choice questions to end of chapter quizzes and do even more work to help prepare students for their AP chemistry exam. I want to dig deeper into creating or adding "Dynamic Learning Modules" that Pearson has embedded into the online resources. I would like to incorporate instructor resources that break down larger lessons and allow students to interact with these resources in a flipped style. I'm also looking at moving the homework checks into an online forum so that students can complete them when they are ready, rather than during a prescribed class time. Ideally, this class will be much more fluid moving forward, where students know exactly the material that I will present on a given day and can tune in if they feel it has value. Otherwise, students can continue to utilize a variety of resources to move themselves

through the content in the time and setting that meets their learning needs, while still being directly supported by me. During this process, students can also be charged with sharing valuable resources that they find, further making this the students' path to success. Ultimately, students should be able to ebb and flow with their understanding of the content, exploring extension opportunities or remediation where applicable, all while finding greater success with the content.

I believe blended learning will continue to move education into the twenty first century. We have the technology at our hands, we have innovative teachers, and innovative classroom spaces. We should consider embracing this change and meet our learners in this fast-paced world in which we live. I believe that this will work in other classes and can be implemented across content areas. I envision more collaboration between various content areas as those of us exploring the blended pathway work together and share our vision. If more teachers embrace the blended model, I could see our school moving in a direction where students are even given the opportunity to engage in the fully blended model of learning, spending time in the setting that makes them the most comfortable, or provides the most support, in the moment. This process will be a journey that takes several years. All involved will need to be willing to hold each other accountable. This process becomes very transparent when one individual does not live up to their expectations. It's not possible for the instructor or the students to hide from their responsibilities, rather, it is essential that everyone work together towards the success of everyone. "Computers can never replace a great teacher," (Staker, 2019). And, teacher value may increase as students recognize that we are supporting and

confirming their learning path, rather than just telling students to trust what we choose to share. I don't believe that the human touch should ever be removed from education. My students benefit from direct interactions with staff and peers. I grow as a professional and can better assist students that I have a relationship with. Students, at some point, will want, or need, guidance in their learning path.

I have also grown through this process. By implementing the initial stages of blending a classroom using sound research and student feedback, I have become more aware of the diverse learning styles that are present in my classroom. I was regularly reminded that what works well for one student may have no benefit to another. I became aware that student perspectives on blended learning may stem from previous experiences that they had in an online or blended course. I recognized that students may use the resources in a completely creative way that I had not initially intended. I also discovered that students, when given the chance, truly want to make education a safe and fruitful venture for all. And finally, I was again reminded that I cannot do more about the student's final performance than they do; I can be their biggest advocate, but ultimately it is up to the individual student to engage and perform.

The true measure of this project will come to light in July 2019 when the AP chemistry scores are returned to the students. As an instructor, I will use this performance as an indicator of how to move forward with this project. I will be able to compare the impact that the blended classroom had on student retention and compare the results to previous years where students engaged in a very traditional AP chemistry classroom setting. The ultimate measure will be the satisfaction that the students feel

with their performance on this high-stake test, and how much of the material they retain and can rely on in their future courses and careers. If past student comments are any indicator, I would anticipate that this year's AP chemistry students will have a reliable chemistry foundation that they can readily build on when they take their next college chemistry course. I would also anticipate that this group would move forward and be able to analyze a problem and work to solve it in a creative manner, while collaborating with others, and seeking assistance from a variety of resources as needed.

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APPENDICES

APPENDIX A
INSTITUTIONAL REVIEW BOARD
FOR THE PROTECTION OF HUMAN SUBJECTS EXEMPTION



INSTITUTIONAL REVIEW BOARD
For the Protection of Human Subjects
FWA 00000165

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MEMORANDUM

TO: Jennifer Owen and Marcie Reuer

FROM: Mark Quinn *Mark Quinn Ch.*
 Chair, Institutional Review Board for the Protection of Human Subjects

DATE: October 17, 2018

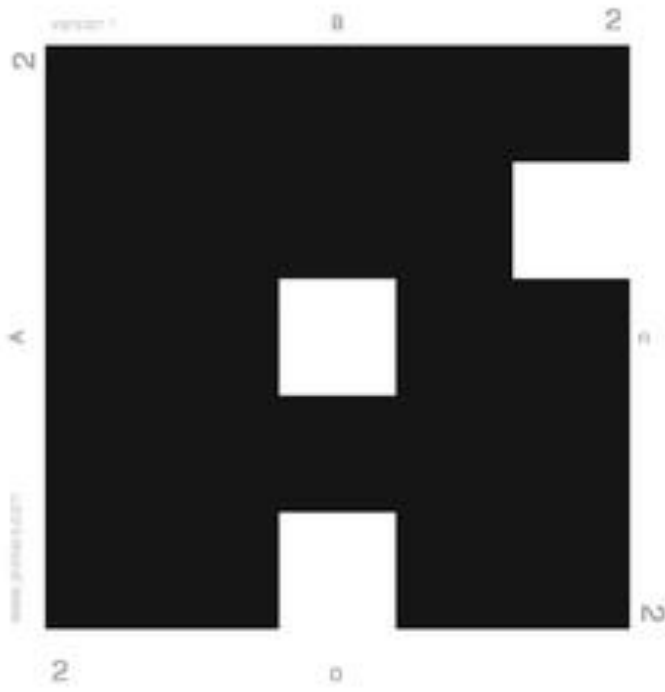
RE: "The Impacts of Blending the High School Advanced Placement Chemistry Classroom on Student Engagement and Performance" [JO101718-EX]

The above research, described in your submission of October 12, 2018, is exempt from the requirement of review by the Institutional Review Board in accordance with the Code of Federal regulations, Part 46, section 101. The specific paragraph which applies to your research is:

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

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

APPENDIX B
EXAMPLE PLICKERS CARD



APPENDIX C

SURVEY ON ENGAGEMENT AND PERFORMANCE IN AP CHEMISTRY

For each of the following statements, please answer by circling the response that best describes your opinion. This survey is anonymous. There are no right or wrong answers. Answer honestly.

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

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
I think a lot about how I am doing in class.	1	2	3	4	5
I enjoy routine.	1	2	3	4	5
I do well at homework completion.	1	2	3	4	5
I have set a goal for AP chemistry.	1	2	3	4	5
Completing practice exercises has value.	1	2	3	4	5
I feel prepared for the AP chemistry AP chemistry.	1	2	3	4	5
I learn from my mistakes.	1	2	3	4	5
After completing practice problems, I feel competent.	1	2	3	4	5
I usually only have to make a mistake one time in order to learn from it.	1	2	3	4	5
I prefer to use a variety of resources to reinforce my learning.	1	2	3	4	5
I am satisfied with my performance on chapter quizzes.	1	2	3	4	5
I incorporate feedback when updating work.	1	2	3	4	5
There is usually more than one way to accomplish something.	1	2	3	4	5
I am engaged in all aspects of AP chemistry.	1	2	3	4	5
I put a lot of effort into doing well.	1	2	3	4	5
I value timely feedback	1	2	3	4	5
It is important for me to do well on quizzes.	1	2	3	4	5
I ask for help when I need it.	1	2	3	4	5

I think online resources provide a path to personalizing my learning.	1	2	3	4	5
I feel confident in my ability to earn a 3 on the AP chemistry exam.	1	2	3	4	5
I find resources for help when I need them.	1	2	3	4	5
I think online resources help me to be more engaged in class.	1	2	3	4	5
I will meet my goals for AP chemistry.	1	2	3	4	5
I have time in class to have my questions answered.	1	2	3	4	5
I have time in class to complete homework and practice exercises.	1	2	3	4	5
I attempt to earn a 90% on the first version of each chapter quiz.	1	2	3	4	5

Note: This survey includes questions, or modified questions, originally presented in the Intrinsic Motivation Inventory (IMI) and The Self-Regulation Questionnaire (SRQ).

APPENDIX D

SURVEY ON EDUCATIONAL TOOLS FOR AP CHEMISTRY

For each of the following statements, please answer by circling the response that best describes how you value each resource. This survey is anonymous. There are no right or wrong answers. Answer honestly.

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

I find value in...	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Teacher created video lessons that I view on my own.	1	2	3	4	5
Traditional in-class notes.	1	2	3	4	5
Text book homework problems.	1	2	3	4	5
Traditional lectures.	1	2	3	4	5
Question of the Day warm-ups.	1	2	3	4	5
In-class full class practice problems.	1	2	3	4	5
Daily work time.	1	2	3	4	5
Individual help from the teacher.	1	2	3	4	5
Mastering Chemistry online homework.	1	2	3	4	5
Homework checks.	1	2	3	4	5
Interactive virtual activities.	1	2	3	4	5
Group collaboration with teacher support.	1	2	3	4	5
Online video lessons (created by others).	1	2	3	4	5
AP practice problems.	1	2	3	4	5
Chapter quiz retakes.	1	2	3	4	5
Lab activities.	1	2	3	4	5
Independent projects.	1	2	3	4	5
Kahoot reviews.	1	2	3	4	5
Quizlet flash cards.	1	2	3	4	5

APPENDIX E

SAMPLE PRE- AND POST-CHAPTER ASSESSMENTS

Chapter 6 & 18: ΔH , ΔS , ΔG (Thermodynamics) - Pretest**Name:** _____

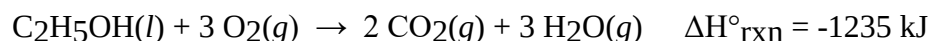
1) Energy that is associated with the temperature of an object is called

- A) kinetic energy.
- B) thermal energy.
- C) potential energy.
- D) chemical energy.
- E) mechanical energy.

2) Which of the following signs on q and w represent a system that is doing work on the surroundings, as well as losing heat to the surroundings?

- A) $q = -$, $w = -$
- B) $q = +$, $w = +$
- C) $q = -$, $w = +$
- D) $q = +$, $w = -$
- E) None of these represent the system referenced above.

3) A 21.8 g sample of ethanol ($\text{C}_2\text{H}_5\text{OH}$) is burned in a bomb calorimeter, according to the following reaction. If the temperature rises from 25.0 to 62.3°C, determine the heat capacity of the calorimeter. The molar mass of ethanol is 46.07 g/mol.

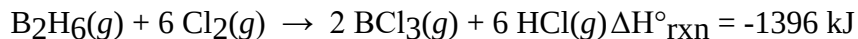


- A) 4.99 kJ/°C
- B) 5.65 kJ/°C
- C) 63.7 kJ/°C
- D) 33.1 kJ/°C
- E) 15.7 kJ/°C

4) Which statement is FALSE?

- A) An exothermic reaction gives off heat to the surroundings.
- B) Enthalpy is the sum of a system's internal energy and the product of pressure and volume.
- C) ΔE_{rxn} is a measure of heat.
- D) ΔH_{rxn} is the heat of reaction.
- E) Endothermic has a positive ΔH .

5) According to the following reaction, how much energy is **evolved** during the reaction of 32.5 g B₂H₆ and 72.5 g Cl₂? The molar mass of B₂H₆ is 27.67 g/mol.



- A) 1640 kJ
- B) 238 kJ
- C) 1430 kJ
- D) 3070 kJ
- E) 429 kJ

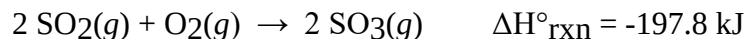
6) A 100.0 mL sample of 0.300 M NaOH is mixed with a 100.0 mL sample of 0.300 M HNO₃ in a coffee cup calorimeter. If both solutions were initially at 35.00°C and the temperature of the resulting solution was recorded as 37.00°C, determine the $\Delta H^\circ_{\text{rxn}}$ (in units of kJ/mol NaOH) for the neutralization reaction between aqueous NaOH and HCl. Assume 1) that no heat is lost to the calorimeter or the surroundings, and 2) that the density and the heat capacity of the resulting solution are the same as water.

- A) -55.7 kJ/mol NaOH
- B) -169 kJ/mol NaOH
- C) -16.7 kJ/mol NaOH
- D) -27.9 kJ/mol NaOH
- E) -34.4 kJ/mol NaOH

7) Use the standard reaction enthalpies given below to determine $\Delta H^\circ_{\text{rxn}}$ for the following reaction:



Given:



- A) -494.6 kJ
- B) -692.4 kJ
- C) -791.4 kJ
- D) 1583 kJ
- E) -293.0 kJ

8) Use the ΔH°_f and $\Delta H^\circ_{\text{rxn}}$ information provided to calculate ΔH°_f for IF:



IF₇(g) -941

IF₅(g) -840

- A) 101 kJ/mol
- B) -146 kJ/mol
- C) -190. kJ/mol
- D) -95 kJ/mol
- E) 24 kJ/mol

9) Define *molar heat capacity*.

- A) the quantity of heat required to raise the temperature of 1 mole of a substance by 1°C
- B) the quantity of heat required to change a system's temperature by 1°F
- C) the quantity of heat required to raise the temperature of 1 gram of a substance by 1°C
- D) the quantity of heat required to raise the temperature of 1 gram of a substance by 1°F
- E) the quantity of heat required to lower the temperature of 1 liter of a substance by 1°C

10) Which of the following substances (with specific heat capacity provided) would show the **greatest** temperature change upon absorbing 100.0 J of heat?

- A) 10.0 g Ag, $C_{\text{Ag}} = 0.235 \text{ J/g}^\circ\text{C}$
- B) 10.0 g Pb, $C_{\text{Pb}} = 0.160 \text{ J/g}^\circ\text{C}$
- C) 10.0 g water, $C_{\text{water}} = 4.18 \text{ J/g}^\circ\text{C}$
- D) 10.0 g Fe, $C_{\text{Fe}} = 0.449 \text{ J/g}^\circ\text{C}$
- E) 10.0 g Ca, $C_{\text{Ca}} = 0.650 \text{ J/g}^\circ\text{C}$

11) The specific heat capacity of liquid mercury is 0.14 J/gK. How many joules of heat are needed to raise the temperature of 7.25 g of mercury from 36.0°C to 75.0°C?

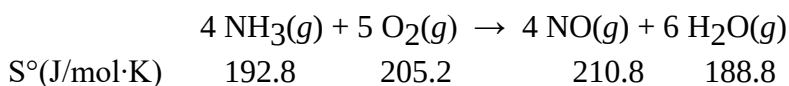
- A) $2.0 \times 10^3 \text{ J}$
- B) 40 J
- C) 113 J
- D) $5.0 \times 10^{-4} \text{ J}$
- E) 2.1 J

- 12) Which of the following statements is TRUE?
- A) There is a "heat tax" for every energy transaction.
 - B) A spontaneous reaction is always a fast reaction.
 - C) The entropy of a system always decreases for a spontaneous process.
 - D) Perpetual motion machines are a possibility in the near future.
 - E) None of the above is true.
- 13) Identify the process that is endothermic.
- A) vaporization
 - B) deposition
 - C) freezing
 - D) condensation
- 14) Consider a reaction that has a positive ΔH and a positive ΔS . Which of the following statements is TRUE?
- A) This reaction will be spontaneous only at low temperatures.
 - B) This reaction will be spontaneous at all temperatures.
 - C) This reaction will be nonspontaneous at all temperatures.
 - D) This reaction will be nonspontaneous only at low temperatures.
 - E) It is not possible to determine without more information.
- 15) Consider a reaction that has a negative ΔH and a negative ΔS . Which of the following statements is TRUE?
- A) This reaction will be spontaneous only at low temperatures.
 - B) This reaction will be spontaneous at all temperatures.
 - C) This reaction will be nonspontaneous at all temperatures.
 - D) This reaction will be nonspontaneous only at low temperatures.
 - E) It is not possible to determine without more information.
- 16) Place the following in order of **decreasing** molar entropy at 298 K.
- H_2 Cl_2 F_2
- A) $H_2 > Cl_2 > F_2$
 - B) $Cl_2 > H_2 > F_2$
 - C) $F_2 > Cl_2 > H_2$
 - D) $H_2 > F_2 > Cl_2$
 - E) $Cl_2 > F_2 > H_2$

17) Which of the following processes has a $\Delta S < 0$?

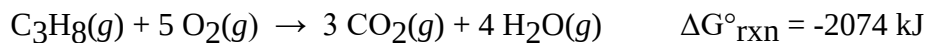
- A) ethanol freezes
- B) isopropyl alcohol condenses
- C) 2-propanol (g , at 555 K) $\rightarrow$ 2-propanol (g , at 400 K)
- D) carbon dioxide(g) $\rightarrow$ carbon dioxide(s)
- E) All of the above processes have a $\Delta S < 0$.

18) Calculate $\Delta S^\circ_{\text{rxn}}$ for the following reaction. The S° for each species is shown below the reaction.

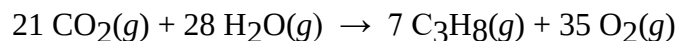


- A) -287.4 J/K
- B) -401.2 J/K
- C) +160.0 J/K
- D) +336.6 J/K
- E) +178.8 J/K

19) Given the following equation,

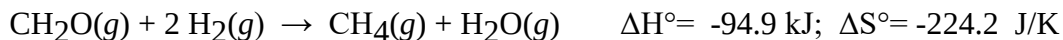


Calculate $\Delta G^\circ_{\text{rxn}}$ for the following reaction.



- A) -2074 kJ
- B) +14518 kJ
- C) -14518 kJ
- D) +2074 kJ
- E) -296 KJ

20) Estimate $\Delta G^\circ_{\text{rxn}}$ for the following reaction at 449.0 K.



- A) +5.8 kJ
- B) -12.9 kJ
- C) -101 kJ
- D) -5.8 kJ
- E) -4.2 kJ

Chapter 6 & 18: ΔH , ΔS , ΔG (Thermodynamics) – Summative Version 1

Name: _____

1) Define *heat*.

- A) the flow of energy caused by a chemical reaction
- B) the flow of energy caused by a temperature difference
- C) the result of a force acting through a distance
- D) the capacity to do work
- E) a chemical reaction

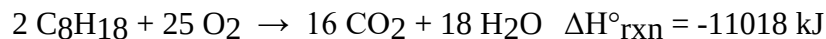
2) The law of _____ states that energy that can be neither created nor destroyed.

- A) kinetic energy
- B) the consecration of energy
- C) potential energy
- D) the conservation of energy
- E) thermochemistry

3) An endothermic reaction has

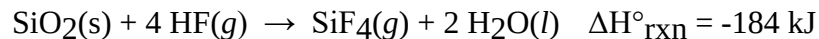
- A) a negative ΔH , absorbs heat from the surroundings, and feels cold to the touch.
- B) a positive ΔH , gives off heat to the surroundings, and feels warm to the touch.
- C) a negative ΔH , gives off heat to the surroundings, and feels warm to the touch.
- D) a positive ΔH , absorbs heat from the surroundings, and feels cold to the touch.
- E) a positive ΔH , absorbs heat from the surroundings, and feels warm to the touch.

4) Using the following equation for the combustion of octane, calculate the heat associated with the combustion of 100.0 g of octane assuming complete combustion. The molar mass of octane is 114.33 g/mole. The molar mass of oxygen is 31.9988 g/mole.



- A) -535.4 kJ
- B) -4819 kJ
- C) -602.3 kJ
- D) -385.5 kJ
- E) -11018 kJ

5) According to the following thermochemical equation, what mass of HF (in g) must react in order to produce 345 kJ of energy? Assume excess SiO₂.

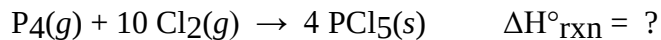


- A) 42.7 g
- B) 37.5 g
- C) 150. g
- D) 107 g
- E) 173 g

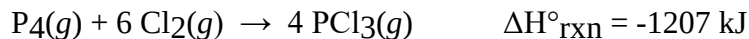
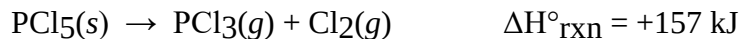
6) A piece of iron (mass = 25.0 g) at 398 K is placed in a styrofoam coffee cup containing 25.0 mL of water at 298 K. Assuming that no heat is lost to the cup or the surroundings, what will the final temperature of the water be? The specific heat capacity of iron = 0.449 J/g°C and water = 4.18 J/g°C.

- A) 348 K
- B) 308 K
- C) 287 K
- D) 325 K
- E) 388 K

7) Use the standard reaction enthalpies given below to determine $\Delta H^\circ_{\text{rxn}}$ for the following reaction:

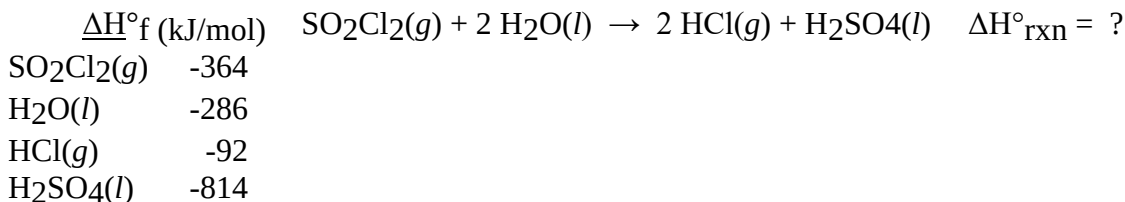


Given:



- A) -1835 kJ
- B) -1364 kJ
- C) -1050. kJ
- D) -1786 kJ
- E) -2100. kJ

8) Use the ΔH°_f information provided to calculate $\Delta H^\circ_{\text{rxn}}$ for the following:



- A) -256 kJ
- B) +161 kJ
- C) -62 kJ
- D) +800. kJ
- E) -422 kJ

9) Which of the following statements is TRUE?

- A) The burning of fossil fuels contributes to global warming.
- B) Cars that run on hydrogen fuel cells are environmentally friendly.
- C) The more energy produced per kg of CO_2 produced, the better the fuel.
- D) Acid rain is one of the problems associated with the combustion of fossil fuels.
- E) All of the above are true.

10) Which of the following is TRUE if $\Delta E_{\text{sys}} = -100 \text{ J}$?

- A) The system is gaining 100 J, while the surroundings are losing 100 J.
- B) The system is losing 100 J, while the surroundings are gaining 100 J.
- C) Both the system and the surroundings are gaining 100 J.
- D) Both the system and the surroundings are losing 100 J.
- E) None of the above is true.

11) Which of the following (with specific heat capacity provided) would show the **smallest** temperature change upon gaining 200.0 J of heat?

- A) 50.0 g water, $C_{\text{water}} = 4.18|1.23 \text{ J/g}^\circ\text{C}$
- B) 50.0 g Fe, $C_{\text{Fe}} = 0.449 \text{ J/g}^\circ\text{C}$
- C) 25.0 g granite, $C_{\text{granite}} = 0.79 \text{ J/g}^\circ\text{C}$
- D) 25.0 g Pb, $C_{\text{Pb}} = 0.128 \text{ J/g}^\circ\text{C}$
- E) 25.0 g Ag, $C_{\text{Ag}} = 0.235 \text{ J/g}^\circ\text{C}$

12) Calculate the amount of heat (in kJ) necessary to raise the temperature of 51.8 g benzene by 52.6 K. The specific heat capacity of benzene is 1.05 J/g°C.

- A) 1.81 kJ
- B) 16.6 kJ
- C) 2.59 kJ
- D) 2.86 kJ
- E) 3.85 kJ

13) Identify the process that is spontaneous.

- A) rusting of iron
- B) electrolysis
- C) browning of bread
- D) photosynthesis
- E) frying an egg

14) Consider a reaction that has a negative ΔH and a positive ΔS . Which of the following statements is TRUE?

- A) This reaction will be spontaneous only at high temperatures.
- B) This reaction will be spontaneous at all temperatures.
- C) This reaction will be nonspontaneous at all temperatures.
- D) This reaction will be nonspontaneous only at high temperatures.
- E) It is not possible to determine without more information.

15) Consider a reaction that has a negative ΔH and a negative ΔS . Which of the following statements is TRUE?

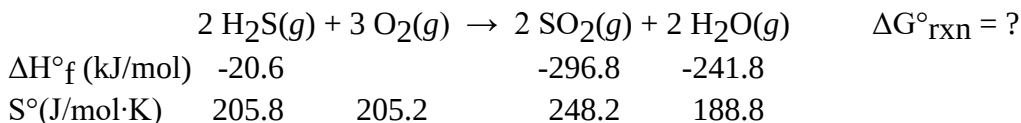
- A) This reaction will be spontaneous only at high temperatures.
- B) This reaction will be spontaneous at all temperatures.
- C) This reaction will be nonspontaneous at all temperatures.
- D) This reaction will be nonspontaneous only at high temperatures.
- E) It is not possible to determine without more information.

16) Place the following in order of **decreasing** standard molar entropy.



- A) $\text{N}_2\text{O}_4 > \text{NO}_2 > \text{NO}$
- B) $\text{NO} > \text{NO}_2 > \text{N}_2\text{O}_4$
- C) $\text{N}_2\text{O}_4 > \text{NO} > \text{NO}_2$
- D) $\text{NO} > \text{N}_2\text{O}_4 > \text{NO}_2$
- E) $\text{NO}_2 > \text{NO} > \text{N}_2\text{O}_4$

17) Calculate the $\Delta G^\circ_{\text{rxn}}$ using the following information. Assume a standard temperature of 25°C.

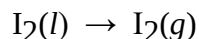


- A) -990.3 kJ
- B) +108.2 kJ
- C) -466.1 kJ
- D) +676.2 kJ
- E) -147.1 kJ

18) Which of the following processes has a $\Delta S > 0$?

- A) $2 \text{NH}_3(g) + \text{CO}_2(g) \rightarrow \text{NH}_2\text{CONH}_2(aq) + \text{H}_2\text{O}(l)$
- B) lithium fluoride forms from its elements
- C) $2 \text{HCl}(g) \rightarrow \text{H}_2(g) + \text{Cl}_2(l)$
- D) cesium chloride dissolves in pure water
- E) All of the above processes have a $\Delta S > 0$.

19) For the following example, identify the following.



- A) a negative ΔH and a negative ΔS
- B) a positive ΔH and a negative ΔS
- C) a negative ΔH and a positive ΔS
- D) a positive ΔH and a positive ΔS
- E) It is not possible to determine without more information.

20) Estimate $\Delta G^\circ_{\text{rxn}}$ for the following reaction at 417 K.



- A) +61.9 kJ
- B) -66.3 kJ
- C) +66.3 kJ
- D) -250 kJ
- E) +250 kJ

Chapter 6 & 18: ΔH , ΔS , ΔG (Thermodynamics) – Summative Version 2**Name:** _____

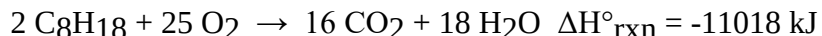
1) Energy that is associated with the temperature of an object is called

- A) kinetic energy.
- B) thermal energy.
- C) potential energy.
- D) chemical energy.
- E) mechanical energy.

2) An exothermic reaction has

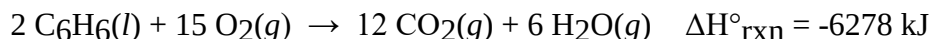
- A) a negative ΔH , absorbs heat from the surroundings, and feels cold to the touch.
- B) a positive ΔH , gives off heat to the surroundings, and feels warm to the touch.
- C) a negative ΔH , gives off heat to the surroundings, and feels warm to the touch.
- D) a positive ΔH , absorbs heat from the surroundings, and feels cold to the touch.
- E) a positive ΔH , absorbs heat from the surroundings, and feels warm to the touch.

3) Using the following equation for the combustion of octane, calculate the heat associated with the combustion of excess octane with 100.0 g of oxygen assuming complete combustion. The molar mass of octane is 114.33 g/mole. The molar mass of oxygen is 31.9988 g/mole.



- A) -17220 kJ
- B) -2152 kJ
- C) -4304 kJ
- D) -11018 kJ
- E) -1377 kJ

4) What volume of benzene (C_6H_6 , $d = 0.88 \text{ g/mL}$, molar mass = 78.11 g/mol) is required to produce $1.5 \times 10^3 \text{ kJ}$ of heat according to the following reaction?



- A) 75 mL
- B) 37 mL
- C) 21 mL
- D) 19 mL
- E) 42 mL

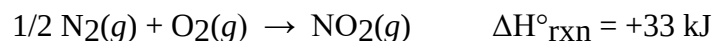
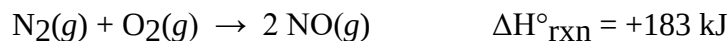
5) A student is preparing to perform a series of calorimetry experiments. She first wishes to determine the calorimeter constant (C_{cal}) for her coffee cup calorimeter. She pours a 50.0 mL sample of water at 345 K into the calorimeter containing a 50.0 mL sample of water at 298 K. She carefully records the final temperature of the water as 317 K. What is the value of C_{cal} for the calorimeter?

- A) 19 J/K
- B) 28 J/K
- C) 99 J/K
- D) 21 J/K
- E) 76 J/K

6) Use the standard reaction enthalpies given below to determine $\Delta H^\circ_{\text{rxn}}$ for the following reaction:

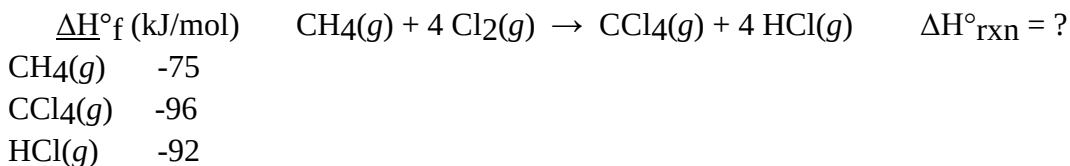


Given:



- A) -150. kJ
- B) -117 kJ
- C) -333 kJ
- D) +115 kJ
- E) +238 kJ

7) Use the information provided to determine $\Delta H^\circ_{\text{rxn}}$ for the following reaction:

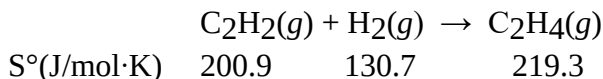


- A) -389 kJ
- B) -113 kJ
- C) +113 kJ
- D) -71 kJ
- E) +79 kJ

- 8) Which of the following is TRUE if $\Delta E_{\text{sys}} = 260 \text{ J}$?
- A) The system is gaining 260 J, while the surroundings are losing 260 J.
 - B) The system is losing 260 J, while the surroundings are gaining 260 J.
 - C) Both the system and the surroundings are gaining 260 J.
 - D) Both the system and the surroundings are losing 260 J.
 - E) None of the above is true.
- 9) Define *specific heat capacity*.
- A) the quantity of heat required to raise the temperature of 1 mole of a substance by 1°C
 - B) the quantity of heat required to change a system's temperature by 1°C
 - C) the quantity of heat required to raise the temperature of 1 gram of a substance by 1°C
 - D) the quantity of heat required to raise the temperature of 1 kilogram of a substance by 1°F
 - E) the quantity of heat required to raise the temperature of 1 liter of a substance by 1°F
- 10) Which of the following (with specific heat capacity provided) would show the **largest** temperature change upon gaining 200.0 J of heat?
- A) 50.0 g ethanol, $C_{\text{ethanol}} = 2.42 \text{ J/g}^\circ\text{C}$
 - B) 50.0 g Zn, $C_{\text{Zn}} = 0.39 \text{ J/g}^\circ\text{C}$
 - C) 25.0 g sand, $C_{\text{sand}} = 0.84 \text{ J/g}^\circ\text{C}$
 - D) 25.0 g Au, $C_{\text{Au}} = 0.128 \text{ J/g}^\circ\text{C}$
 - E) 25.0 g Ag, $C_{\text{Ag}} = 0.235 \text{ J/g}^\circ\text{C}$
- 11) Calculate the amount of heat (in kJ) required to raise the temperature of a 88.0 g sample of ethanol from 298.0 K to 405.0 K. The specific heat capacity of ethanol is $2.42 \text{ J/g}^\circ\text{C}$.
- A) 57.0 kJ
 - B) 22.8 kJ
 - C) 73.6 kJ
 - D) 30.4 kJ
 - E) 11.9 kJ
- 12) A spontaneous reaction occurs
- A) with expansion of the volume.
 - B) with the application of cold.
 - C) with the application of heat.
 - D) without ongoing outside intervention.
 - E) with a catalyst.

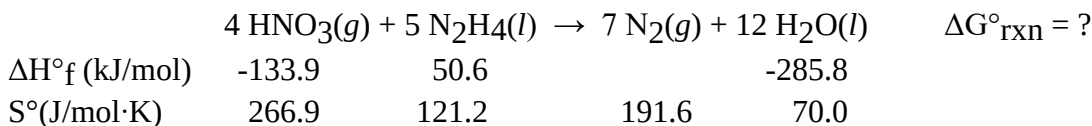
- 13) Identify the process in which the entropy increases.
- A) a decrease in the number of moles of a gas during a chemical reaction
 - B) the phase transition from a gas to a liquid
 - C) the phase transition from a solid to a gas
 - D) the phase transition from a gas to a solid
 - E) the phase transition from a liquid to a solid
- 14) Consider a reaction that has a positive ΔH and a positive ΔS . Which of the following statements is TRUE?
- A) This reaction will be spontaneous only at high temperatures.
 - B) This reaction will be spontaneous at all temperatures.
 - C) This reaction will be nonspontaneous at all temperatures.
 - D) This reaction will be nonspontaneous only at high temperatures.
 - E) It is not possible to determine without more information.
- 15) Consider a reaction that has a positive ΔH and a negative ΔS . Which of the following statements is TRUE?
- A) This reaction will be spontaneous only at high temperatures.
 - B) This reaction will be spontaneous at all temperatures.
 - C) This reaction will be nonspontaneous at all temperatures.
 - D) This reaction will be nonspontaneous only at high temperatures.
 - E) It is not possible to determine without more information.
- 16) Place the following in order of **increasing** entropy at 298 K.
- Ne Xe He Ar Kr
- A) He < Kr < Ne < Ar < Xe
 - B) Xe < Kr < Ar < Ne < He
 - C) Ar < He < Ar < Ne < Kr
 - D) Ar < Ne < Xe < Kr < He
 - E) He < Ne < Ar < Kr < Xe

17) Calculate $\Delta S^\circ_{\text{rxn}}$ for the following reaction. The S° for each species is shown below the reaction.



- A) +112.3 J/K
- B) +550.9 J/K
- C) -112.3 J/K
- D) +337.1 J/K
- E) -550.9 J/K

18) Calculate the $\Delta G^\circ_{\text{rxn}}$ using the following information. Assume a standard temperature of 25°C.

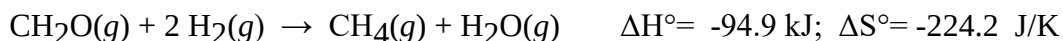


- A) $+4.90 \times 10^3 \text{ kJ}$
- B) $+3.90 \times 10^3 \text{ kJ}$
- C) $-2.04 \times 10^3 \text{ kJ}$
- D) $-3.15 \times 10^3 \text{ kJ}$
- E) $-3.30 \times 10^3 \text{ kJ}$

19) Which of the following processes has a $\Delta S > 0$?

- A) $\text{SO}_2(l) \rightarrow \text{SO}_2(s)$
- B) $\text{N}_2(g) + 3 \text{H}_2(g) \rightarrow 2 \text{NH}_3(g)$
- C) $\text{CH}_4(g) + \text{H}_2\text{O}(g) \rightarrow \text{CO}(g) + 3 \text{H}_2(g)$
- D) $\text{K}_2\text{CO}_3(s) + \text{H}_2\text{O}(g) + \text{CO}_2(g) \rightarrow 2 \text{KHCO}_3(s)$
- E) All of the above processes have a $\Delta S > 0$.

20) Estimate $\Delta G^\circ_{\text{rxn}}$ for the following reaction at 449.0 K.



- A) +5.8 kJ
- B) -12.9 kJ
- C) -101 kJ
- D) -5.8 kJ
- E) -4.2 kJ

APPENDIX F

POST TREATMENT FOCUS GROUP – PLUS (+) / DELTA (Δ) OUTLINE

POST TREATMENT FOCUS GROUP - PLUS (+) / DELTA (Δ)

I will incorporate the Plus (+) / Delta (Δ) method for reflection on the blended experience.

Read the following statement to students: **Participation in this research interview is voluntary and participation or non-participation will not affect your grades or class standing in any way.**

As we complete this interview, please keep in mind:

- the tools which we have used (Mastering, virtual simulations, virtual labs, Plickers, Kahoot, Quizlet, tutorial videos, etc)
- your personal engagement level both with the blended tools and during traditional class time
- your performance both before and after the treatment period

Students record responses on pink (Plus) Post-It notes and purple (Delta) Post-It notes when prompted. Discussion will follow. Post-It notes will be placed on larger flip-chart paper at the end of the discussion for future review. Students will not record their names on their comments.

PLUS

1. Identify what worked well for you during the treatment period and what you would like to keep as part of our class practices moving forward.

DELTA

1. Identify areas for improvement. What could make the blended process more effective?

Note that deltas should be reasonable and involve a suggestion for a future action.