

THE USE OF COMPUTER-BASED AND INQUIRY-BASED
LEARNING ACTIVITIES TO DIFFERENTIATE INSTRUCTION FOR
HIGH SCHOOL CHEMISTRY

by

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ABSTRACT

Annville-Cleona High School is a small school located in southeastern Pennsylvania. The school only offers one chemistry course: “College Prep Chemistry”. Students’ abilities in science vary greatly within each section of this course. Scores on the Pennsylvania, high-stakes biology exam range from below basic to advanced. Students’ math abilities also vary as some are enrolled in AP Calculus, while others are enrolled in Algebra II. It is challenging to meet the needs of these diverse learners in a single classroom.

In this research project, self-paced learning activities were created to teach advanced students challenging topics that were not part of the core curriculum and to provide remediation for students who were struggling with core topics. Video lessons and guided inquiries were used to teach the advanced topics, and video lessons alone were used as remediation. Instantaneous feedback via formative assessments was a key component of these learning activities.

The research was conducted during the unit on molecules and compounds. Two of the four sections served as the treatment group and the other two sections served as the comparison group. Most students in the treatment group and all the students in the comparison group received the core curriculum. Formative assessments were given after each topic was taught to identify students who did not master the topic. Students in the treatment group who scored poorly on a formative assessment were assigned the remediation video lesson. Twelve advanced students in the treatment group learned three challenging topics in addition to the core topics.

The results showed that computer-based and inquiry-based learning activities were effective tools for differentiating instruction. About three-fourths of the time advanced students mastered the additional, challenging topics. Over two-thirds of the struggling students were able to improve their understanding of a topic from basic to proficient or advanced after completing the remedial video lesson. Furthermore, students had favorable attitudes about video lessons. Student surveys showed that almost two-thirds of the students liked video lessons and more than 80% of them liked the instantaneous feedback they received from these lessons.

INTRODUCTION AND BACKGROUND

Annville-Cleona High School is a small school in Lebanon County, Pennsylvania. It is located 20 miles east of the state capital, Harrisburg, and 76 miles northwest of Philadelphia. The school has 520 students in grades nine through twelve. There is little ethnic diversity with over 92% of the students classified as white (not Hispanic). About 20% of the students are economically disadvantaged, 15% are in special education, and only 1% are English language learners (School Performance Profile: Annville-Cleona HS (2013-2014), n.d.). The school has limited science offerings, and college-prep chemistry is the only chemistry course offered to students. Consequently, student ability varies greatly. In the same class there are students who have scored “advanced” on Pennsylvania’s standardized Biology Keystone exam and students who have scored “below basic” on the same exam. Similarly, students’ math abilities vary greatly as some students are taking AP Calculus, while others are taking Algebra II.

The pace of the course does not allow all of the Pennsylvania state content standards for chemistry to be covered. The reason for this is two-fold. First, I employ almost exclusively inquiry-based, small-group learning activities including labs, process oriented guided inquiry learning (POGIL) materials and my own guided inquiries. Very little information is covered by lecture. Second, because there is such a wide range of learning abilities, we move through the curriculum at a pace that accommodates most learners. While all students are developing higher order thinking skills, the advanced and struggling students are underserved. Advanced students who are going on to study science, engineering or medicine do not learn important concepts such as gas laws,

stoichiometry, acid-base reactions and nuclear chemistry. On the other end of the spectrum, students who require remediation must come after school. Many choose not to.

My goal is to be able to offer an honors chemistry experience for my advanced students; and the core curriculum for the rest of my students, including the necessary remediation for my struggling students. The curriculum will remain primarily inquiry-based, small-group learning activities. However, in order to differentiate the instruction, I intend to use video lessons and guided inquiries integrated with instantaneous formative assessment feedback. The overarching research question I seek to answer is, “can computer-based and inquiry-based learning activities that integrate instantaneous formative assessment feedback be used to maximize the learning of advanced, proficient and struggling science students within the same chemistry classroom?” The answer to this research question is dependent on the outcome of three more specific research questions. First, “does the use of computer-based and inquiry-based learning activities that integrate instantaneous formative assessment feedback increase student learning of advanced chemistry topics?” Second, “does the use of computer-based learning activities that integrate instantaneous formative assessment feedback for remediation increase learning for struggling students?” Third, “how do students believe computer-based and inquiry-based learning activities that integrate instantaneous formative assessment feedback impact their education?”

CONCEPTUAL FRAMEWORK

At the heart of the four research questions is the concept of differentiated instruction. This literature review starts with the concepts of differentiated instruction.

From there the literature is reviewed for teaching tools that facilitate differentiated instruction. Specifically, the review focuses on tools for teaching advanced chemistry topics and remediation for college-prep chemistry topics. Since the learning of advanced topics and remediation are taking place in the classroom simultaneously, learning activities need to utilize student-centered instruction such as video lessons, guided inquiries and computer-based activities, including formative assessment. Past studies provide insight into the benefits and limitations of these instructional tools for teaching advanced and struggling students. Finally, students' attitudes toward these learning activities are explored.

The Case for Differentiated Instruction

Schools and teachers are expected to educate students of all learning abilities and cultural backgrounds. Many states, including Pennsylvania, are focused not only on the academic achievement of every student, but also their academic growth. Pennsylvania school performance ratings and teacher evaluations are based on several metrics including the percentage of students scoring proficient or advanced on end-of-course standardized tests and the percentage of students who demonstrated a year's worth of academic growth for each year in school (Rules and Regulations Educators Effectiveness Rating Tool; Classroom Teachers, June 22, 2013; and PA School Performance Profile Executive Summary, n.d.). This dual measure of academic achievement requires schools to effectively educate students of all learning abilities. Teachers must help students who are struggling close the achievement gap and become proficient. This clearly requires students to experience more than a year's worth of academic growth in a school year.

Teachers must also help advanced students experience at least a year's worth of academic growth in a school year. It is not acceptable to let an advanced student's learning languish, even though that student may still score advanced on the next standardized test (Richards & Omdal, 2007). While high school chemistry courses in Pennsylvania do not have a standardized, end-of-course exam that affects schools' performance ratings and teachers' evaluations, maximizing the academic achievement and academic growth of every student is a worthwhile objective.

All schools face the challenge of educating a diverse population of learners. Small schools are especially challenged, because limited course offerings and limited number of sections for each course often require students of very diverse academic abilities to learn the course content in one, heterogeneous classroom. Often teachers must, in the same classroom, provide remediation to students who learn at a slow pace and provide a year's worth of academic growth to advanced students who learn at a rapid pace (Smit & Humpert, 2012).

Differentiated instruction is a teaching strategy for meeting the needs of individual students within a single classroom. Meaningful differentiated instruction requires teachers to acknowledge that their students come to class with diverse cultural and academic backgrounds as well as different cognitive abilities and learning styles. Furthermore, teachers must accept that it is their responsibility to adjust their teaching methods to the students' needs, and not the students' responsibility to adjust their learning style to fit the teacher's methods (Smit & Humpert, 2012). Manthey (2007) suggests that a modified, personalized approach to instruction that focuses on the

individual learner may often preclude the need for intervention. Differentiation involves adjusting one or more of the following aspects of instruction to fit the needs of each student: content, process and/or products. Teachers that internalize differentiated instruction adjust one or more of these aspects daily and adopt a coaching role. This is in contrast to teachers who do not internalize differentiated instruction. These teachers intermittently plan adjustments to their content, process and/or products in advance. Their class-as-a-whole perspective prevents them from having the flexibility to differentiate instruction when needed instead of as planned (Smit & Humpert, 2012).

Individualized instruction is ideal, and is often practiced in special education where individualized education plans are required by law and small class sizes with para educators to assist the teacher are the norm. Individualized instruction is not feasible in the regular classroom where classroom sizes are much larger and the teacher is the lone educator in the room. Tiered instruction is a form of differentiated instruction that provides customized instruction to homogeneous groups of students, instead of individual students. Differentiating instruction for three tiers of learners: struggling, proficient and advanced, is achievable in a regular classroom setting. This tiered approach allows teachers to tailor instruction for the struggling and advanced students who are often underserved in a whole-class instructional approach. Advanced students have the opportunity to have a year's worth of academic growth because they can move through the curriculum at a faster pace and learn advanced topics that the other two groups will not learn. Struggling students will have a better chance of closing the achievement gap because they will learn at a rate that more closely matches their cognitive ability and the

teacher will be able to spend more time developing their cognitive abilities. Finally, these student groupings are flexible and change based on students' pre-existing knowledge at the start of each unit (Richards & Omdal, 2007; Smit & Humpert, 2012).

Instructional Tools

Numerous studies show that student-centered, inquiry-based activities are effective instructional tools. Roehrig and Garrow (2007) investigated the effect teacher implementation of an inquiry-based chemistry curriculum had on student achievement. Four chemistry teachers and 288 chemistry students participated in the study. The teachers and students were from two different high schools within the same urban school district. Student achievement on the Weather Unit exam was measured. This exam included several questions about gas laws and states of matter. Two of the four teachers' styles were student-centered and well suited to an inquiry-based curriculum. The other two teachers' styles were teacher-centered and more suited to a traditional classroom. All four teachers implemented the same inquiry-based chemistry curriculum. However, the students who experienced a student-centered classroom performed better than the students who experienced a teacher-led classroom.

Khan, Hussain, Ali, Majoka, and Ramzan (2011) investigated the effectiveness of inquiry-based instruction as a supplemental strategy in teaching chemistry. The study also explored its effectiveness for high and low intelligence students. The participants were 70 tenth-grade chemistry students from an all-girls public school. The test group and control group were taught by the same teacher using traditional teaching strategies. However, inquiry-based methods were used to supplement the test group's instruction.

Achievement scores were measured before and after the instruction. Inquiry-based instruction improved student achievement. Pre-test scores were statistically similar for all the control and test groups that follow. Overall, students in the test group scored significantly higher on the post-test compared to the control group. High-intelligence students in the test group scored significantly higher on the post-test than high-intelligence students in the control group. Low-intelligence students from the test group did not perform better than the low-intelligence students from the control group.

Thirty-nine teachers from a professional development cohort at Rice University participated in a “data-first” professional development course (Nichol, Szymczyk, & Hutchinson, 2014). The data-first approach to teaching introductory chemistry and AP Chemistry placed a greater emphasis on conceptual understanding instead of memorization of facts. The teachers completed the Chemistry Concept Reasoning Test (CCRT) and Mole Concept test before and after the module. The class average on the CCRT and Mole Concept test were significantly higher for the post-test compared to the pre-test. Ninety-six percent of the teachers believed that the data-first approach improved their understanding and teaching of chemistry, and their use of the data-first approach in the classroom increased the students’ level of scientific inquiry.

The use of technology in the classroom is increasing. Computer-based instruction has two strategic benefits. First it provides instruction in the digital world that students live in. Students already use smart phones, lab tops, and tablets daily to communicate and learn outside the classroom. Integrating technology into the classroom is a logical and necessary step in making education relevant in students’ lives. Second, computer-

based instruction is an ideal platform for differentiating instruction. Content, process and products are readily customized to meet the needs of individual students or tiered groups of students. The WebQuest model is an example of integrating technology into student-centered, inquiry-based learning. Dodge, a co-author of the model, describes WebQuest as “an inquiry-oriented activity in which some or all of the information that learners interact with comes from resources on the Internet” (Schweizer, & Kossow, 2007, p.29). Teachers can create WebQuests for any topic. The model has five key components: introduction, task, process, evaluation and conclusion. For a given topic, the teacher can modify these components to meet the needs of the groups of students. Content can be differentiated by simply giving different topics to different students. Both process and product can be differentiated by modifying the task, process and evaluation sections of the WebQuest (Schweizer, & Kossow, 2007, p.29).

Studies show that computer-based instruction is an effective way to deliver both regular and remedial instruction. Hannafin and Foshay (2008) researched the effectiveness of a computer-based instruction (CBI) math remediation strategy. Students from a working, middle-class, high school on Cape Cod participated in this longitudinal study from the time they were in eighth grade through the end of tenth grade. All students who failed the math portion of Massachusetts’ eighth grade, high-stakes assessment were enrolled in a math remediation course at the beginning of tenth grade. The class met daily for 45 minutes and used CBI. The study compared the eighth grade and tenth grade math assessment results of students who passed the eighth grade test and did not take the remediation course with students who failed the eighth grade test and did

take the remediation course. Both the CBI and non-CBI groups significantly improved their math scores from eighth grade to tenth grade. The non-CBI group that passed the eighth grade test still had a higher average score on the tenth grade test than the CBI students. However, the CBI group that failed the eighth grade test showed a larger improvement between their eighth grade scores and their tenth grade scores than the non-CBI students. Therefore, computer-based instruction helped failing students narrow the achievement gap.

Rae and Samuels (2011) showed that a computer-based personalized system of instruction (PSI) was effective in teaching cognitive skills. The study involved large classes of computer science students learning discrete mathematics at two different UK higher education institutions. The study included whole cohorts and “at risk” cohorts. Computer-assisted PSIs were used for several whole-class cohorts at one university and used only for at-risk cohorts at the other university. The students’ final course grades were used to measure academic achievement. Students in each cohort were assessed during a semester that used PSI and a semester that used traditional lecture. The pass rate of at-risk students who attended 40% or more of the intervention classes was significantly higher than the pass rate for at-risk students that did not have the PSI intervention class.

Flipped or inverted classrooms are a recent trend over the past five years. There are both critics and proponents of the instructional strategy. Critics cite that flipped classrooms are nothing more than the modification of the traditional lecture method of teaching to incorporate computer technology (Goodwin & Miller, 2012). They contend that students who do not learn from traditional lecture are not any more capable of

learning from video podcast lectures. Furthermore, students may choose not to watch the podcast lectures. Proponents of flipped classrooms argue that the strategy enables teachers to effectively differentiate instruction. Students are able to learn at their own pace. Freed up from delivering instructional, teachers use class time to observe student performance and give customized instruction to individual students or small groups of students based on what they are struggling with at the time they are struggling with it.

Video podcasts allow students to replay lectures whenever they need to review the material. Unlike a live lecture where students must take notes and process information at the pace the teacher gives the lecture, students can take notes and process information from a podcast at their pace (Morgan, 2014). A survey of 453 teachers who flipped their classrooms showed that most found it helpful for teaching students at both ends of the learning spectrum, special education students and advanced placement students (Goodwin, & Miller, 2013).

Kay and Kletskin (2012) evaluated the effectiveness of video podcasts as a remediation tool for students that did not have the necessary pre-calculus skills to learn calculus. Two-hundred eighty-eight undergraduate students enrolled in a first-year calculus course at a small university located in a metropolitan setting were given access to a series of video podcasts one week before taking a pre-calculus diagnostic test early in the course. Students completed an attitudes survey about the podcasts after they received their diagnostic test grade. Two-thirds of the students completing the survey watched the video podcasts. Almost 90% of the students using the podcasts found them useful, and felt their pre-calculus knowledge increased as a result of watching the video podcasts.

A recent investigation by Teo, Tan, Yan, Teo, and Yeo (2014) explored the use of flipped instruction in preparing students for lab practicals and improving their understanding of the lab concepts. Thirty-two first and second year undergraduate education students taking chemistry lab courses were provided flipped instruction for two of the lab practicals during the course. Student interviews and artefacts were used to qualitatively assess the effectiveness of the flipped instruction. The flipped instruction increased student engagement during the lab practical and increased their understanding of the procedures and concepts involved. This study showed that flipped instruction is effective for laboratory instruction.

While scientific research is limited, Goodwin and Miller (2013) suggest educators consider more than this limited research when deciding to flip their classrooms,

The lack of hard scientific evidence doesn't mean teachers should not flip their classrooms; indeed, if we only implemented strategies supported by decades of research, we'd never try anything new. Until researchers are able to provide reliable data, perhaps the best we can do is to ask, do the purported benefits of flipped classrooms reflect research-based principles of effective teaching and learning? (p.78)

Student Attitudes

Students' attitudes toward their education are an important component of academic success. Yeh (2010) reviewed and synthesized findings from past research studies on student performance, motivation and self-perception as well as the use of individualized instruction and assessment to narrow the achievement gap between above-average and below-average students. These studies show that students have higher motivation and achievement if they believe they control their success in school. Adjusting task difficulty to a 77% success rate is optimal for maximizing student

motivation and achievement. Therefore, individualized learning activities coupled with rapid feedback on formative assessments increases student performance. In this environment, the teacher functions as a tutor providing targeted, individualized instruction.

In the previously mentioned research by Rae and Samuels (2011), students were taught for a half-year using the traditional lecture format, and they were taught the other half of the year using computer-based PSI. Students' approaches to learning for both instructional formats were measured with the R-SPQ-2F questionnaire. Students indicated that PSI required them to be more engaged in learning and less passive than they were in the traditional lecture format.

Tabor and Minch (2013) investigated the effect of digital technology on student engagement. One-hundred seventy-four juniors and seniors from three different undergraduate information technology courses participated in the study during the fall semesters of 2009 and 2010. The course was taught using video pre-lectures and other digital media from the internet. Class time was used for discussion, hands-on labs, small-group projects, and assessments. Students were also required to produce digital projects in lieu of the traditional written essays and research papers. The students were surveyed at the start, middle and end of the course to assess their use of and attitudes toward digital learning media. Slightly more than half the students felt the use of digital instructional materials and producing their own digital materials enhanced their learning. Slightly over half the students preferred producing a digital media project over a traditional report even though most students agreed it was more work. Only one-fourth of the students

preferred video lectures over traditional lectures, while just fewer than half the students preferred attending traditional lectures over watching video lectures.

Summary

Our society requires schools to provide an effective education to all students regardless of their academic background and skills. Often students with vastly different backgrounds and skills are in the same classroom. Teachers must be able to remediate struggling learners so they become proficient learners; and they must be able to instruct advanced students so they attain a year's worth of academic growth. Differentiated instruction allows teachers to modify the instructional content, process and/or product, in order to meet the needs of struggling, proficient and advanced learners. Research shows that computer-based learning including video podcasts are effective in customizing instruction to individual students or tiers of students. The research further shows that computer-based learning and podcasts are effective remediation tools for struggling learners. These learning tools also promote higher order thinking skills which benefit all learners.

Student attitudes toward learning are an important part of academic achievement. Research shows that students who believe they control their success are more motivated and have higher academic achievement than students who do not believe they control their success. Students who feel challenged, but not overwhelmed, by the difficulty and pace of instruction are also more motivated and have higher academic achievement. Computer-based, guided-inquiry learning activities are able to achieve both these objectives. Students feel more control with computer-based learning activities because

they learn at their own pace. Teachers can adjust the difficulty of the curriculum for each individual student or tier of students so they are challenged but not overwhelmed. Finally, computer-based quizzes provide instantaneous, formative feedback to students about their learning at the end of each module, which studies show increases student engagement.

METHODOLOGY

I wanted to find a treatment that provided an accelerated learning environment for advanced students, a challenging core curriculum for proficient students, and effective remediation for struggling students. This all took place within the confines of a single chemistry classroom. In this section, the treatment and its implementation as well as the data collection methods are laid out in detail. The ultimate goal of the classroom research project was to determine if the use of computer-based and inquiry-based learning activities coupled with instantaneous feedback on formative assessments could be used to increase the learning of advanced and struggling students. The research methodology for this project received an exemption by Montana State University's Institutional Review Board and compliance for working with human subjects was maintained.

Participants

The research participants were my four college-prep, chemistry sections. There were a total of 75 students, 72 juniors and 3 seniors. There was a wide range of science and math abilities among the students. Nineteen of these students scored advanced on the Biology Keystone exam, while 34 students scored proficient and 22 students scored basic or below basic. Nineteen students were taking a math course that was above their grade level (calculus or AP calculus), 26 students were taking a math course that was on their grade level (precalculus or probability and statistics), and 29 students were taking a math

course below their grade level (algebra II, geometry or business math). Two sections received the treatment and two sections were the comparison group.

The sections were put into the treatment or comparison group so the academic abilities of the two groups were similar. Student scores on the chemistry pre-assessment they took at the start of the school year and their year-to-date test and quiz scores were used to measure their chemistry ability. A t-test showed that the treatment group ($N=35$) and comparison group ($N=40$) year-to-date scores were not significantly different at a 95% confidence interval (see Table 1). Students in the treatment group were designated as advanced or core students based on their chemistry pre-assessment and year-to-date test scores as well as their anticipated college major. Students planning to major in science, engineering or medicine were designated advanced, unless their scores were below the class average.

Table 1
Treatment and Comparison Groups Year-to-Date Assessment Scores

Group	Mean (%)	SD (%)	N
Treatment	74.2	13.2	35
Comparison	73.6	9.8	40

Note. The unpaired, two-tailed t-test yielded a p-value of 0.8224, which is not statistically different at a 95% confidence interval.

Treatment

The treatment was used during the unit on molecules and compounds, which lasted eight weeks. The curriculum was broken into core topics and advanced topics. The core topics covered the Pennsylvania State Standards for chemistry and included:

- models of molecules
- laws of definite proportions and multiple proportions

- valence electrons and the octet rule
- covalent, ionic and metallic bonds
- polyatomic ions
- Lewis dot structures and the octet rule
- Valence shell electron pair repulsion (VSEPR) theory and molecular shapes with an emphasis on two, three and four electron group central atoms
- bond dipoles, molecular dipoles and intermolecular forces
- nomenclature and formula writing for covalent and ionic compounds

The advanced requirements represented topics and academic rigor typically found in honors and accelerated chemistry curricula, such as:

- expanded valence shells, and formal charges
- VSEPR theory and molecular shapes with an emphasis on five and six electron group central atoms
- nomenclature and formula writing for alkanes, alkenes and alkynes

Advanced students in the treatment group learned both the advanced and core topics. The other students in this group only learned the core topics. Students who struggled with a core topic were assigned a computer-based remediation activity for that topic. All students in the comparison group learned the core topics. They were not assigned advanced topics or computer-based remediation activities.

The learning activities for the core topics consisted mostly of POGILs, guided inquiries and labs with a few lectures. Video lessons were created for all core topics and were used as a remediation tool. More information about video lessons can be found in

Appendix D. Students were given a short, formative assessment at the end of each core topic. This was corrected and returned to them the same day or the next day. Students in the treatment group who scored poorly on the assessment were assigned the corresponding video lesson as a remediation activity. Students in the comparison group who scored poorly were not assigned the video lesson. They could seek my help during class or after school as has been their usual source of remediation throughout the course.

I created a video lesson, podcast, a guided inquiry and a computer simulation lab to teach the advanced topics. The advanced students in the treatment group were assigned the three advanced topics after they completed the corresponding core topics. They learned the advanced topics while the other students continued to learn the core topics. A video lesson was used to teach the students how to use formal charge to predict when a compound has an incomplete or expanded octet as well as draw the correct Lewis dot structure. A guided inquiry and computer simulation lab were used to teach the students how to apply the VSEPR theory to compounds with expanded octets, in order to determine their electron group and molecular shapes. Finally, a podcast was used to learn nomenclature and formula writing for simple alkanes, alkenes and alkynes.

Instantaneous, formative assessment feedback was another cornerstone of the treatment. Questions were embedded within each video lesson. Students were required to answer questions inserted at key points in the video lesson. These questions required students to process and make sense of the information they had just watched. Questions were typically placed every one to two minutes throughout the lesson. Students received instantaneous feedback on their answers as they answered the questions. They had the

option to go back and watch the video again and resubmit explanations for the questions they got wrong. The software required the students to watch the entire video during the first viewing. They could not fast forward through the video to get to the questions. During the second viewing, students could go directly to the specific segments and questions they wanted to review. There are several software platforms that can be used to create these video lessons. I used the one from Playposit, which was formerly known as Educanon. The guided inquiries required students to read text and interpret visual models that took the students step-by-step through the key concepts of the topic. Students had to answer questions throughout the guided inquiry that required them to process and make sense of the information they had just read. They were able to check their answers online and, if they were in class, ask for help if they were struggling with a concept. The computer simulation lab used the molecule shapes simulation from University of Colorado's PhET website (PhET Molecule Shapes Simulation, n.d.). The students used the simulation to construct molecules with expanded octets. Then the students had to construct three-dimensional models of various compounds and show me their models. This allowed me to give students instantaneous feedback on the shapes they selected for each compound.

Data Collection

Data collection included student attitude data as well as student learning data. Students' attitudes in both the treatment and comparison groups were measured at the beginning, mid-point and conclusion of the research project. Three Likert scale surveys were used to collect this information. The surveys can be found in Appendix A. All

three surveys measured student attitudes toward school, science and chemistry in general. Questions were added to the mid-point and conclusion surveys to assess students' attitudes toward specific learning activities, and to understand how well they felt each learning activity supported their learning. The surveys were patterned after the Chemistry Attitude Scale (Marasigan & Espinosa, 2014) and the Colorado Learning Attitudes about Science Survey – Chemistry version (n.d).

Similarly, selected students were interviewed at the mid-point and conclusion of the unit. These interviews focused on students' attitudes toward the remediation and advanced topic learning activities as well as their attitudes toward the other learning activities we've been using throughout the year. While the surveys were administered to all students in both groups, only eight students in the treatment group were interviewed. A male and female advanced student and a male and female remediation student from each of the two treatment sections were interviewed in the middle of the unit. These same students, except for one remediation student, were interviewed at the end of the unit.

Several summative assessments were used throughout the unit to measure student learning. These instruments can be found in Appendix B. The unit exam that was used for the past three years was used as the pre- and post-test to quantitatively measure student learning in both groups over the course of the research project. Lesson quizzes were given at the end of four lessons to measure student learning in both groups. The lesson quizzes for the advanced students in the treatment group had additional questions about the advanced topics they learned, in order to measure how well they learned these

topics. Short formative assessments were included at the end of each the nine core topics and three advanced topics to measure student learning. Selected formative assessments can be found in Appendix C. All students in both groups took the core topic formative assessments. Students in the treatment group who did not perform well on a formative assessment were assigned the remediation video lesson for that topic. The advanced students in the treatment group took the advanced topic formative assessments in addition to the formative assessments everyone else took. Table 2 summarizes the data used to evaluate the effectiveness of the treatment and answer the research questions.

Table 2
Triangulation Matrix

Focus Question	Data Source		
<i>Primary Question:</i> 1. Can computer-based and inquiry-based learning activities that integrate instantaneous formative assessment feedback be used to maximize the learning of advanced, proficient and struggling science students within the same chemistry classroom?	Pre- and Post- Test, Lesson Quizzes, and Formative Assessments	Student Pre-, Mid-Point, and Post-Surveys	Student Mid-Point and Post-Student Interviews
<i>Sub-Questions:</i> 2. Does the use of computer-based and inquiry-based learning activities that integrate instantaneous formative assessment feedback increase student learning of advanced chemistry topics?	Formative Assessments	Lesson Quizzes	Mid-Point and Post-Unit Student Surveys and Interviews
3. Does the use of computer-based learning activities that integrate instantaneous formative assessment feedback for remediation increase learning for struggling students?	Formative Assessments	Lesson Quizzes	Mid-Point and Post-Unit Student Surveys and Interviews
4. How do students believe computer-based and inquiry-based learning activities that integrate instantaneous formative assessment feedback impact their education?	Pre-Unit Student Surveys and Interviews	Mid-Point Student Surveys and Interviews	Post-Unit Student Surveys and Interviews

DATA AND ANALYSIS

This classroom research project sought to determine if computer-based and inquiry-based learning activities could effectively differentiate instruction to diverse learners in a single chemistry classroom. The answer to this overarching research question was dependent on the outcome of the three research sub-questions, which focused on teaching advanced topics, remediating struggling students, and understanding student attitudes toward these learning activities. Therefore, this section focuses on answering these three sub-questions, first, before answering the primary research question in the subsequent section.

Learning Advanced Topics

One facet of this research project explored the question, “does the use of computer-based and inquiry-based learning activities that integrate instantaneous formative assessment feedback increase student learning of advanced chemistry topics?” During the unit on molecules and compounds twelve advanced students were taught three advanced topics:

- application of formal charge to predict compounds with incomplete and expanded octets
- application of VSEPR theory to determine the shapes of molecules with expanded octets
- application of nomenclature and formula writing protocols for simple alkanes, alkenes and alkynes

The formative assessment, quiz assessment and student survey data showed that students were able to learn these advanced topics using a video lesson, a guided inquiry combined with a simulation lab and a podcast.

Students watched a video lesson to learn formal charge and how to predict when exceptions to the octet rule exist. Formative assessment questions were embedded in the video. Six out of 12 students scored advanced on the formative assessment, while the other six were proficient (see Table 3). At the end of each lesson, which typically lasted six to eight class periods, the advanced students' understanding of an advanced topic was assessed on the end-of-lesson quiz. The formal charge quiz assessment results were lower than the formative assessment results, but still showed that the majority of the students mastered the topic. Three students were advanced and four were proficient, while four students scored basic (see Table 4).

Table 3
Student Learning of Advanced Topics – Formative Assessments

Topic	Learning Activity	Advanced	Proficient	Basic
Formal Charge	video lesson	6	6	0
VSEPR Theory	guided inquiry/ simulation lab	12	0	0
Organic Nomenclature	podcast	10	2	0

Note. Advanced > 90%, Proficient 70% - 89%, and Basic < 70%. (N=12).

Table 4
Student Learning of Advanced Topics – Quiz Assessments

Topic	Learning Activity	Advanced	Proficient	Basic
Formal Charge	video lesson	3	4	4
VSEPR Theory	guided inquiry/ simulation lab	4	6	2
Organic Nomenclature	podcast	5	4	3

Note. For formal charge (N=11) and for the other two topics (N=12).

Students completed five-point Likert scale surveys at the midpoint and end of the unit. As part of these surveys they were asked if video lessons were the best way for them to learn new concepts. At the midpoint of the unit, nine of the ten advanced students who completed both surveys disagreed that video lessons helped them learn new concepts. Two of these nine strongly disagreed. One student neither agreed nor disagreed that video lessons helped them learn new topics. However, most of their opinions were more favorable by the end of the unit. Three students agreed that video lessons were helpful, three had a neutral opinion, four still disagreed, but no one strongly disagreed (see Table 5). A key feature of the video lessons was that students needed to answer questions throughout the lesson and received instantaneous feedback on their answer. Students were also asked if this feedback helped them learn concepts. At both the midpoint and end of the unit the overall opinion of the advanced students on instantaneous feedback was favorable. At the mid-point, six agreed that it was helpful and the other four were neutral. At the end of the unit, the opinions were more polarized, but still overall positive. Three students strongly agreed that the feedback was helpful, four students agreed, one was neutral, while two disagreed and no one strongly disagreed that it was helpful (see Table 5).

Students used a guided inquiry, simulation lab and their newly acquired knowledge of formal charge to learn how to apply VSEPR theory to compounds with expanded octets, in order to determine their electron group and molecular shapes. The students worked in four groups of three. I assessed their understanding and gave them feedback throughout the simulation lab as they built their shapes. I also assessed their

completed lab. All twelve students scored advanced in their formative assessment (see Table 3). Again, the quiz assessments were lower than the formative assessment. However, ten of the twelve students mastered the concepts. Four were advanced, six were proficient, while only two were basic (see Table 4). Student's opinions on how helpful guided inquiries were in learning new topics were mixed. In the middle of the unit one of the two students strongly agreed that they were helpful, another agreed, four were neutral and three disagreed that they were helpful. Their opinions had shifted only slightly by the end of the unit. One student strongly agreed that guided inquiries were helpful, three agreed, three were neutral, one disagreed and two strongly disagreed that they were helpful (see Table 5).

Table 5
Student Learning of Advanced Topics – Student Surveys Mid and Post Unit

Question (Likert Score)		5	4	3	2	1
I find that video lessons are the best way for me to learn a new chemistry concept.	Mid	0	0	1	7	2
	Post	0	3	3	4	0
I learn new chemistry concepts best by working individually on a guided inquiry.	Mid	2	1	4	3	0
	Post	1	3	3	1	2
Getting instantaneous feedback from online quizzes helps me learn new chemistry concepts.	Mid	0	6	4	0	0
	Post	3	4	1	2	0
Answering questions during a video lesson helps me learn the material better than watching the same podcast without questions.	Mid	0	5	1	4	0
	Post	2	5	2	1	0

Note. 5=Strongly Agree, 4=Agree, 3=Neither Agree nor Disagree, 2=Disagree, 1=Strongly Disagree. (N=10).

Students watched a video podcast to learn nomenclature and formula writing for simple alkanes, alkenes and alkynes. The differences between video lessons and podcasts were when the formative assessment questions were asked, when the student received

feedback and how the students watched the video. The video lessons had formative assessment questions embedded throughout the video, the students received instantaneous feedback, and they could not fast forward through sections. With the podcasts the students took a paper and pencil formative assessment after they finished watching the video, I returned their assessments with feedback either the same day or the next day, and they could fast forward through the podcast as much as they wanted to.

The majority of the students were able to learn nomenclature with the podcast. Ten students scored advanced on the formative assessment, while the other two scored proficient (see Table 3). The quiz assessment showed that five students had an advanced understanding of the nomenclature and formula writing concepts, four had a proficient understanding and three had not mastered the concept and scored basic (see Table 4). Students were asked if answering the questions during the video lesson helped them learn the material better than watching a podcast without the questions embedded in the video. In the middle of the unit, the students were evenly split about whether video lessons or podcasts were best. Five students agreed that the embedded questions increased their understanding of the material, one had a neutral opinion, while four students disagreed that it helped. By the end of the unit, opinions had shifted in favor of the embedded questions. Two strongly agreed they helped, five agreed they helped, two were neutral and one disagreed that they helped (see Table 5).

Remediation for Struggling Students

The second facet of this research project was to determine if the use of computer-based learning activities that integrate instantaneous formative assessment feedback for

remediation increased learning for struggling students. Students completed formative assessments after each of the nine core topics were taught. Students in the treatment group who scored poorly on a formative assessment were assigned a video lesson to watch. Students in the comparison group were not assigned the video lesson. The data indicate that the video lessons may have increased student learning when used as a remediation tool, but the data is not overwhelmingly decisive.

Formative assessments, which were embedded in the video lesson, showed that the video lessons increased students' learning to proficient or advanced 69% of the time (see Table 6). All the students assigned a remedial video lesson scored basic on their initial formative assessment at the end of the core topic. There were a total of 94 remediation assignments. About 35% of these assignments were not completed. Of the 61 assignments that were completed, 13% of the time students improved to the advanced level, 56% of the time students improved to the proficient level, while 31% of the time students remained at a basic level. The four video lessons on the octet rule and Lewis dot structures, ionic Lewis dot structures, bond polarity and molecular polarity were the most effective. Of the students completing these video lessons, 80% or more of them scored advanced or proficient.

Table 6
Remediation of Core Topics – Formative Assessments

Topic	N	Adv.	Prof.	Basic	DNF
Molecular Models, Laws of Definite and Multiple Proportions	17	2	6	6	3
Octet Rule and Lewis Dot Structures	5	0	3	0	2
Chemical Bonds	15	0	6	5	4
Ionic Lewis Dot Structures	11	2	4	1	4
Covalent Lewis Dot Structures	8	0	4	2	2
Molecular Shapes	5	0	1	1	3
Bond Polarity	10	1	4	1	4
Molecular Polarity	17	2	6	2	7
Ionic Nomenclature	6	1	0	1	4
	94	8	34	19	33

Note. Advanced > 90%, Proficient 70% - 89%, Basic < 70%, and DNF=did not finish.

Quizzes given at the end of each lesson indicated that the video lessons may have improved student learning. The treatment group of students who completed a video lesson after scoring poorly on a formative assessment had higher average quiz scores compared to the comparison group of students who did not complete a video lesson after scoring poorly on the same formative assessments (see Table 7). The treatment group averaged 68.8% on all four quizzes, while the comparison group averaged 64.4%. A two-tailed, unpaired t-test yielded a p-value of 0.0849, which indicated that the two group means were not significantly different at a 95% confidence level. The average quiz scores were higher for the treatment group in three of the four quizzes. The chemical bonds quiz had the largest difference in average scores, 65.7% compared to 57.4%, and the lowest p-value, 0.0583. However, this was still not a significant difference at a 95% confidence level. The comparison group had a higher average score than the treatment group, 65.3% compared to 62.5%, for the molecular shapes quiz. As with the other quizzes, this difference was not significant.

Table 7
Remedial Students' Quiz Scores: Treatment and Comparison Groups

Quiz	Mean (%)		SD (%)		N		P-value
	Treat.	Comp.	Treat.	Comp.	Treat.	Comp.	
Molecules and Compounds	75.5	73.9	11.1	10.3	15	26	0.6440
Chemical Bonds	65.7	57.4	10.4	12.0	12	19	0.0583
Molecular Shapes	62.5	65.3	8.2	12.3	3	9	0.7342
Intermolecular Forces	65.0	59.9	12.1	16.3	12	31	0.3322
All Quizzes	68.8	64.2	12.1	14.9	42	85	0.0849

Note. The unpaired, two-tailed, t-test p-values indicate that the group means are not statistically different at a 95% confidence interval.

By the end of the unit, most students in the treatment group believed that the video lessons were the best way for them to learn topics they were struggling to master. At the midpoint of the unit, students did not hold as favorable a view. Only 20% of the students agreed or strongly agreed that the video lessons were the best remediation tool, while 50% disagreed or strongly disagreed they were the best method ($N=24$). However, by the end of the unit 50% of the students agreed or strongly agreed that video lessons were the best remediation method, and only 29% disagreed or strongly disagreed that they were the best method (see Table 8). Fourteen of the 24 students had a more favorable view of video lessons at the end of the unit than they reported in the middle of the unit, while only one student had a less favorable view. The other nine students had not changed their view.

Students placed a high value on the questions embedded in the videos and the instantaneous feedback they received. At the midpoint of the unit, 63% of the students agreed or strongly agreed that the questions helped them learn the material better than if

they watched the same video without the questions, while only 8% of the students disagreed or strongly disagreed with the statement ($N=24$). The favorable rating had increased to 79% by the end of the unit, while the unfavorable rating stayed at 8% (see Table 8). Students overwhelmingly believed that the instantaneous feedback they received helped them learn. In the mid-unit survey, 71% of the students agreed or strongly agreed that the feedback helped them learn the remedial topic, while only 8% disagreed or strongly disagreed that it helped ($N=24$). By the end of the unit, 79% had a favorable opinion of the instantaneous feedback, while the unfavorable rating remained at 8% (see Table 8).

Table 8
Student Learning of Remediation Topics – Student Surveys Mid and Post Unit

Question (Likert Score)		5	4	3	2	1
When I am struggling to learn a concept, I learn it best by watching a video lesson or podcast.	Mid	1	4	7	9	3
	Post	1	11	5	6	1
Getting instantaneous feedback from online quizzes helps me learn chemistry concepts that I'm struggling with.	Mid	2	15	5	2	0
	Post	4	15	3	1	1
Answering questions during a video lesson helps me learn the material better than watching the same podcast without questions.	Mid	3	12	3	5	1
	Post	10	9	3	1	1

Note. 5=Strongly Agree, 4=Agree, 3=Neither Agree nor Disagree, 2=Disagree, 1=Strongly Disagree. ($N=24$).

Student Attitudes about the Learning Activities

The third and final facet of this research project focused on how students believed computer-based and inquiry-based learning activities that integrate instantaneous formative assessment feedback impacted their education. Students had a positive attitude toward video lessons, which were computer-based learning activities, especially as they

became more familiar with them. In the middle of the unit, only 17% of the 53 students agreed or strongly agreed that video lessons were the best way to learn new topics, and 49% disagreed or strongly disagreed. By the end of the unit student attitudes had changed substantially. Forty-three percent of these students agreed or strongly agreed that video lessons were the best way to learn new topics, while only 32% of the students disagreed or strong disagreed (see Table 9). Students also grew to like learning new concepts through video lessons. Twenty-three percent of the students agreed or strongly agreed that they liked learning through video lessons at the midpoint, but this number grew to 53% by the end of the unit ($N=53$). Students dislike or strong dislike of learning through video lessons decreased from 49% in the middle of the unit to only 30% at the end of the unit (see Table 9).

Table 9
Attitudes about Video Lessons - Student Surveys Mid and Post Unit

Question (Likert Score)		5	4	3	2	1
I find that video lessons are the best way for me to learn a new chemistry concept.	Mid	2	7	18	19	7
	Post	6	17	13	8	9
I like using video lessons to learn a new chemistry concept.	Mid	2	10	15	17	9
	Post	7	21	9	9	7

Note. 5=Strongly Agree, 4=Agree, 3=Neither Agree nor Disagree, 2=Disagree, 1=Strongly Disagree. ($N=53$).

Students continued to have a favorable attitude toward both process oriented guided inquiry learning (POGILs) and teacher-generated guided inquiries. While video lessons were used infrequently prior to the start of the research unit, POGILs and guided inquiries were used frequently throughout the year. So students were familiar with both when they answered the mid-unit survey. At the midpoint, 47% of the students agreed or

strongly agreed that they learned new concepts best through POGILs and only 21% disagreed or strongly disagreed ($N=53$). Students' attitudes declined slightly by the end of the unit, with 40% agreeing or strongly agreeing that POGILs were still the best way to learn, and 23% disagreeing or strongly disagreeing (see Table 10). Students also liked learning with POGILs. In the middle of the unit, 53% either liked or strongly liked learning with POGILs and only 21% disliked or strongly disliked them ($N=53$). These favorable ratings slipped slightly as the unit went on. By the end of the unit, 45% liked or strongly liked the POGILs and 25% disliked or strongly disliked them (see Table 10).

Table 10

Attitudes about Inquiry-Based Activities – Student Surveys Mid and Post Unit

Question (Likert Score)		5	4	3	2	1
I learn new chemistry concepts best when I work in a small group to complete a POGIL.	Mid	1	24	17	9	2
	Post	2	19	20	9	3
I like learning new chemistry concepts by completing a POGIL in small groups.	Mid	3	25	14	10	1
	Post	4	20	16	11	2
I learn new chemistry concepts best by working individually on a guided inquiry.	Mid	7	18	14	13	1
	Post	4	15	20	11	3
I like learning new chemistry concepts by working individually on a guided inquiry.	Mid	6	18	11	16	2
	Post	4	17	15	11	6

Note. 5=Strongly Agree, 4=Agree, 3=Neither Agree nor Disagree, 2=Disagree, 1=Strongly Disagree. ($N=53$).

Students' opinions of teacher-generated guided inquiries were very similar to their opinions about POGILs. The mid-unit survey showed that 47% of the students agreed or strongly agreed that guided inquiries were the best way to learn new topics, whereas 26% disagreed or strongly disagreed ($N=53$). The favorable ratings dropped by the end of the unit, but the number of students who agreed and strongly agreed still outpaced the number of students that disagreed or strongly disagreed, 35% and 26%, respectively (see

Table 10). Students also liked learning with guided inquiries. The mid-unit survey showed that 45% of the students liked or strongly liked guided inquiries compared to 34% that disliked or strongly disliked them ($N=53$). These results dropped by the end of the unit to 40% and 32% (see Table 10). In my interviews with students at the end of the unit I asked them to rank the usefulness of several learning activities, including video lessons and guided inquiries. Three of the seven students ranked video lessons as the best learning activity, while two ranked guided inquiries as the best learning activity. One advanced student who gave guided inquiries his top ranking said, “I have freedom to work through it at my own pace.” This feeling was shared by most of the advanced and struggling students that I interviewed.

Students liked embedded questions while watching video podcasts and believed it enhanced their learning. About half of the 53 students responded on the mid-unit survey that they liked or strongly liked learning with video lessons compared to 32% that disliked or strongly disliked video lessons (see Table 11). When it came to student learning, 74% of the students reported on the post-unit survey that they agreed or strongly agreed that the questions embedded in the video lessons helped them learn better than watching the same video without questions ($N=53$). This was up substantially from the mid-unit survey when only 57% agreed or strongly agreed that the embedded questions helped them learn. The number of students who disagreed that the questions helped them learn dropped substantially from 25% in the middle of the unit to 8% by the end of the unit (see Table 11). In my student interviews a recurring theme among advanced and struggling students was that the embedded questions made them stay engaged with the

material. One struggling student said, “I like the video lessons better because I have to pay attention to answer the questions.” An advanced student voiced a similar sentiment, “I like the video lessons because you have to interact with it. You are forced to learn because of the questions.”

Table 11

Attitudes about Embedded Questions – Student Surveys Mid and Post Unit

Question (Likert Score)		5	4	3	2	1
Answering questions during a video lesson helps me learn the material better than watching the same podcast without questions.	Mid	4	26	10	10	3
	Post	14	25	10	2	2
I like video lessons with embedded questions better than watching the same podcast without questions.	Mid	3	24	9	11	6

Note. 5=Strongly Agree, 4=Agree, 3=Neither Agree nor Disagree, 2=Disagree, 1=Strongly Disagree. ($N=53$).

Students overwhelmingly appreciated and valued the instantaneous feedback they got from the video lessons. At the mid-point 51% agreed or strongly agreed that the feedback helped them learn new concepts compared to only 11% who disagreed or strongly disagreed ($N=53$). By the end of the unit, 66% agreed or strongly agreed, while 13% disagreed or strongly disagreed (see Table 12). When video lessons were used as a remediation tool the students’ attitudes about the instantaneous feedback were even more positive. At the mid-point, 68% agreed or strongly agreed that the feedback helped them learn topics they were struggling to learn ($N=53$). Only 8% disagreed or strongly disagreed. At the end of the unit, the 8% figure remained the same, but the number of students who agreed or strongly agreed increased to 75% (see Table 12).

Table 12
Attitudes about Instantaneous Feedback – Students Surveys Mid and Post Unit

Question (Likert Score)		5	4	3	2	1
Getting instantaneous feedback from online quizzes helps me learn new chemistry concepts.	Mid	2	25	20	6	0
	Post	9	26	11	6	1
Getting instantaneous feedback from online quizzes helps me learn chemistry concepts that I'm struggling with.	Mid	4	32	13	4	0
	Post	9	31	9	3	1
The first thing I do when I get feedback from a video lesson is go back through the video and try to understand the questions I got wrong.	Mid	3	26	14	8	2
The first thing I do when I get feedback from a video lesson is ask a classmate or the teacher to help me understand the question I got wrong.	Mid	0	23	18	11	1
When I get feedback from a video lesson I move on to the next assignment without trying to understand the questions I got wrong.	Mid	0	5	15	25	8

Note. 5=Strongly Agree, 4=Agree, 3=Neither Agree nor Disagree, 2=Disagree, 1=Strongly Disagree. (N=53).

Most students used the feedback as an indicator that they needed to study the material more. Fifty-five percent of the students agreed or strongly agreed that when they got a question wrong they went back through the video to try to understand why they got the question wrong (N=53). Forty three percent agreed or strongly agreed that they asked a classmate or me for help in understanding why they got a question wrong. Only, 9% of the students agreed that they moved on to the next assignment without trying to understand why they got a question wrong (see Table 12). I saw this same theme in the student interviews. Students said they went back and reviewed the material in their own way. One student said he, “looked at the correct answer and if it made sense I kept going, but if it didn’t make sense I went back and watched the section of the video

again.” Another said she, “went back and re-watched the segments I got wrong.”

Another would “go back and take notes on what I missed the first time.”

INTERPRETATION AND CONCLUSION

The results of my research project showed that computer-based and inquiry-based learning activities were effective tools for differentiating instruction to high school chemistry students. Furthermore, students had favorable attitudes about these learning activities.

The driving force for this research project was to be able to better serve both the advanced and struggling students in my classroom of diverse learners. Typically, advanced learners quickly mastered the topics taught in my college-prep chemistry class and were bored with the slow pace of the class. However, in this research project I taught formal charge, molecular shapes for expanded octets, and basic organic nomenclature to twelve students in the treatment group. Three-fourths of the time, these advanced students mastered these challenging topics through video lessons, podcasts, guided inquiries and computer simulations that they completed at their own pace. These findings were similar to those of Khan, Hussain, Ali, Majoka, and Ramzan (2011). They investigated the effectiveness of inquiry-based instruction as a supplemental strategy in teaching chemistry and found that advanced students scored higher when inquiry-based learning activities were used to supplement the traditional lecture format. Goodwin and Miller (2013) surveyed 453 teachers who found that using video podcasts instead of the live lecture format was more helpful for teaching advanced placement students.

Struggling students had the opposite experience of the advanced students. They often struggled to learn the concepts and found that the pace of the class was too fast. I used video lessons in this research project as a remediation tool for the treatment group. Because of the targeted content of each video lesson, I was able to individualize remediation. Students were only assigned remediation lessons for the specific topics they struggled with. The results showed that over two-thirds of the students were able to improve their understanding of a topic from basic to proficient or advanced after completing the video lesson. Quiz scores, while not statistically different, were higher for struggling students who completed the remedial video lessons than the scores for struggling students in the control group, 68.8% compared to 64.2%. The literature supports this finding. Hannfin and Foshay (2008) found that computer-based instruction narrowed the achievement gap for tenth-graders who struggled with math. Rae and Samuels (2011) also found that a computerized personal system of instruction improved the passing rate of “at-risk” students. The Goodwin and Miller (2013) survey of 453 teachers also found that most teachers prefer video podcasts over live lectures for teaching students at the low-end of the learning spectrum.

The combination of keeping advanced students challenged and providing remediation for struggling students improved student learning in the treatment group compared to the control group. Students in the treatment group had an average normalized gain of 54.5% in their pre-test and post-test scores compared to the comparison group, which only had a 49.9% normalized gain (see Table 13).

Table 13
Treatment and Comparison Groups Pre and Post Test Scores

Group	N	Average Pre-Test Score (%)	Average Post-Test Score (%)	Average Normalized Gain (%)
Treatment	35	28.9	67.6	54.5
Comparison	40	27.8	63.8	49.9

I was pleased that my students' attitudes toward the video lessons became much more positive as they progressed through the unit. Almost three times as many students disagreed as agreed that video lessons were the best way to learn new concepts at the mid-point of the unit. They had only used video lessons occasionally prior to the start of this unit. Their unfamiliarity with them may have been the reason for their negative view. By the end of the unit, more students agreed than disagreed that video lessons were the best way to learn new concepts (see Figure 1). Similarly, students liked using video lessons more as they became more familiar with them. About twice as many students disagreed as agreed that they liked learning new concepts with video lessons at the mid-point of the unit. These results had flipped by the end of the unit. Almost twice as many students agreed as disagreed that they liked using video lessons (see Figure 1).

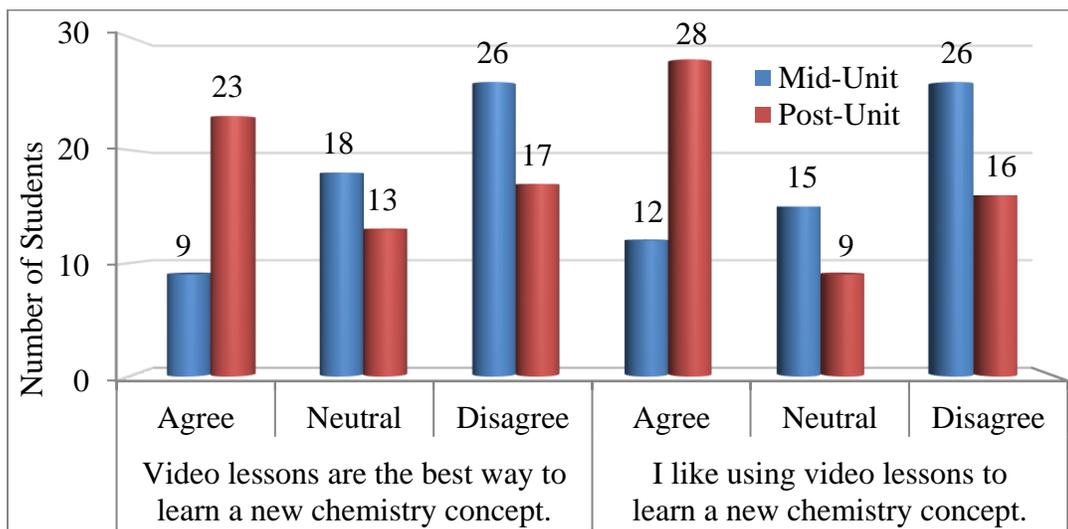


Figure 1 – Student attitudes about using video lessons to learn new concepts, (N=53).

Students strongly appreciated instantaneous feedback. Five times as many students agreed as disagreed that instantaneous feedback from online quizzes was helpful in learning new concepts. Instantaneous feedback was even more valuable to students when they were struggling to learn a concept. Ten times as many students agreed as disagreed that instantaneous feedback helped them learn these concepts (see Figure 2).

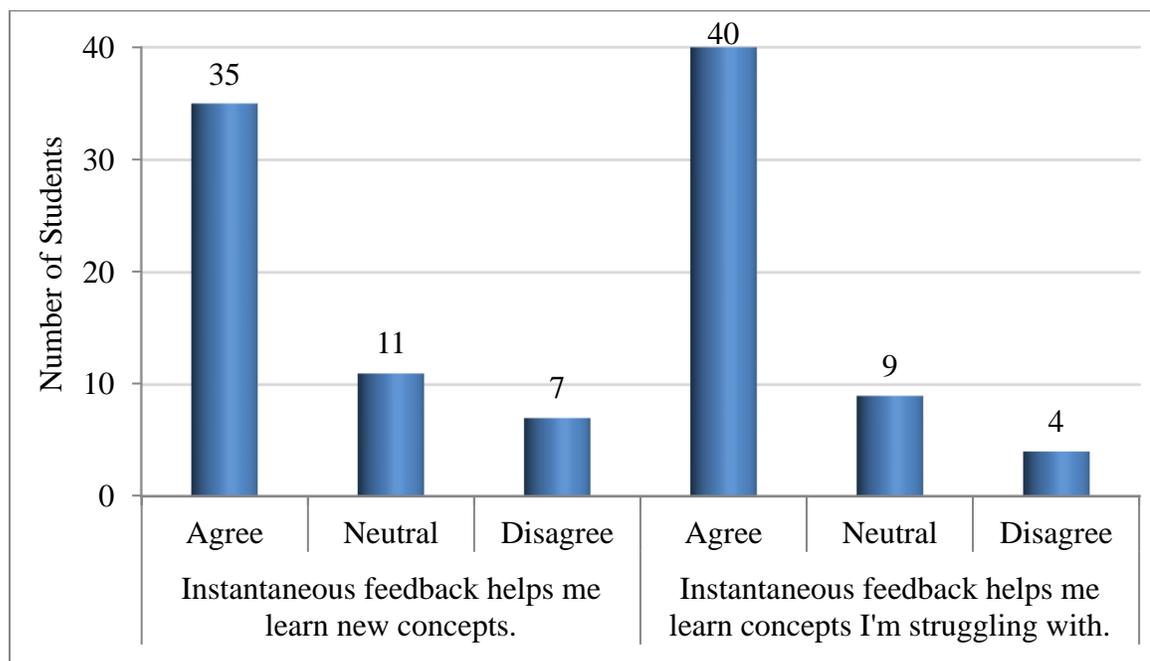


Figure 2. Student attitudes about instantaneous feedback from online quizzes, ($N=53$).

Yeh (2010) found in a review of the literature that student motivation and achievement improved when students felt in control of their learning and individual learning activities with rapid feedback improved student achievement. Video lessons met these requirements. In student interviews, both advanced and struggling students cited that being able to learn at their own pace was a benefit. Students were also in control of how they acted on the feedback they received. As was discussed in the Student Attitudes

section of the Data Analysis, most students, in their own way, tried to understand why they got a question wrong. For some students finding out the correct answer made sense to them and they moved on. For others they went back and reviewed the section of the podcast that pertained to the questions. Still others went back to the section and took additional notes. Students were also able to move on without trying to understand why they got a question wrong. The fact that very few students chose that option indicated their willingness to correct their misconceptions.

VALUE

I had never doubted the need for differentiated instruction in my classroom, but I had questioned how I could meet the needs of three distinct groups of students in a forty-two minute class period. This research project has answered many questions I had about differentiating instruction and raised several new questions for me to consider. The two most important things I learned were that students valued immediate feedback and they liked computer-based learning activities that they can do at their own pace. Furthermore, these activities increased student learning for both advanced and struggling students. My advanced students were able to use computer-based and inquiry-based activities to learn additional, challenging topics with minimal direct instruction from me. Students who struggled to learn a topic the first time it was taught were able to use video lessons to improve their understanding of that topic. Creating video lessons required a lot of time upfront. However, it allowed me to deliver instructional content to three distinct groups of learners within the same class period. This wasn't possible with direct instruction because there wasn't enough time to directly deliver three sets of instructional content.

Based on the results of my research, I feel confident that I can differentiate instruction to my chemistry students. I will create a remediation video lesson for each core topic in the curriculum. Students who are absent from class can also use these video lessons to learn the content they missed. I'll review each unit in the curriculum for opportunities to add challenging topics for my more advanced students. Learning activities for these topics will include video lessons, computer simulations and guided inquiries. As I mentioned earlier, one of the two most important things I learned was how much students valued instantaneous feedback. I already incorporate online assessments that provide students with instantaneous feedback in some of my lessons. I will incorporate these types of formative assessments more often throughout the course.

New questions were raised that I need to address. Most pressing is the fact that one-third of the students who were assigned a remediation video lesson did not complete it. Most of the incomplete assignments were from the same handful of students who often did not complete their regular assignments. The challenge is how to engage these disengaged students. Another question I need to address is how to better explain the concept of differentiated instruction to my advanced students. The students accepted the challenge of learning these additional topics. However, I found out through student interviews that some of them did not think it was fair that these topics were graded. Finally, when creating video lessons I need to balance instructional content and duration. Most of the students I interviewed said that if the video lesson was too long they stopped being engaged. There was no consensus on how long too long was. Some said ten minutes was the cut-off, others said 20 minutes, and a few couldn't give a specific time.

Very few of my video lessons were under ten minutes. Many of them were around 20 minutes. My goal for future video lessons will be to thoroughly explain the topic with supporting examples in ten to 15 minutes.

In closing, I am an inquiry-based teacher that wants students to be in charge of their learning. I prefer to help guide students individually or in small groups as they learn a topic, instead of standing in front of the class delivering content. My classroom research project has shown me how I can use this approach to differentiate instruction.

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APPENDICES

APPENDIX A

STUDENT ATTITUDE DATA COLLECTION INSTRUMENTS

Chemistry Attitude Pre-Unit Survey

Your participation in this survey is voluntary and does not affect your course grade.

Please answer the questions thoughtfully and truthfully.

1. I want to learn chemistry.
Strongly Disagree 1 2 3 4 5 Strongly Agree
2. I believe that my logical and critical thinking will improve by studying chemistry.
Strongly Disagree 1 2 3 4 5 Strongly Agree
3. I believe that chemistry benefits our society/community.
Strongly Disagree 1 2 3 4 5 Strongly Agree
4. Chemistry makes me curious and motivated to learn more about scientific and chemical concepts.
Strongly Disagree 1 2 3 4 5 Strongly Agree
5. I learn chemistry best when I work in small groups.
Strongly Disagree 1 2 3 4 5 Strongly Agree
6. I feel a sense of accomplishment every time I perform well in chemistry.
Strongly Disagree 1 2 3 4 5 Strongly Agree
7. To learn chemistry I have to memorize a lot of facts.
Strongly Disagree 1 2 3 4 5 Strongly Agree
8. I enjoy laboratory explorations and investigations.
Strongly Disagree 1 2 3 4 5 Strongly Agree
9. I believe it is important for everyone in our society/community to understand basic chemistry.
Strongly Disagree 1 2 3 4 5 Strongly Agree
10. Chemistry is difficult for me to learn.
Strongly Disagree 1 2 3 4 5 Strongly Agree
11. I believe that this course improves my reasoning skills.
Strongly Disagree 1 2 3 4 5 Strongly Agree
12. I am confused in my chemistry class.
Strongly Disagree 1 2 3 4 5 Strongly Agree
13. I believe we should learn more challenging topics.
Strongly Disagree 1 2 3 4 5 Strongly Agree

14. I am hesitant to participate in chemistry class discussions.
Strongly Disagree 1 2 3 4 5 Strongly Agree
15. I am hesitant to participate within my small group.
Strongly Disagree 1 2 3 4 5 Strongly Agree
16. I learn chemistry best when we whiteboard our scientific models and discuss them as a class.
Strongly Disagree 1 2 3 4 5 Strongly Agree
17. I am not satisfied until I understand why something works the way it does.
Strongly Disagree 1 2 3 4 5 Strongly Agree
18. I learn chemistry best when I write my lab reports.
Strongly Disagree 1 2 3 4 5 Strongly Agree
19. I learn chemistry best when the teacher lectures.
Strongly Disagree 1 2 3 4 5 Strongly Agree
20. To learn chemistry I need to understand the concepts and how to apply them to different situations.
Strongly Disagree 1 2 3 4 5 Strongly Agree
21. Nearly everyone is capable of understanding chemistry if they work at it.
Strongly Disagree 1 2 3 4 5 Strongly Agree
22. I like chemistry as a subject.
Strongly Disagree 1 2 3 4 5 Strongly Agree
23. I believe the class should move at a slower pace.
Strongly Disagree 1 2 3 4 5 Strongly Agree
24. I learn chemistry best when I do lots of practice problems.
Strongly Disagree 1 2 3 4 5 Strongly Agree
25. For me studying chemistry is just a waste of time.
Strongly Disagree 1 2 3 4 5 Strongly Agree

Chemistry Attitude Mid-Unit Survey

Your participation in this survey is voluntary and does not affect your course grade.

Please answer the questions thoughtfully and truthfully.

1. When I am struggling to learn a concept I prefer to meet with the teacher for extra help outside of class.
Strongly Disagree 1 2 3 4 5 Strongly Agree
2. When I am struggling to learn a concept I can best learn it if I see the teacher for extra help outside of class.
Strongly Disagree 1 2 3 4 5 Strongly Agree
3. I find that video lessons are the best way for me to learn a new chemistry concept.
Strongly Disagree 1 2 3 4 5 Strongly Agree
4. I like using video lessons to learn a new chemistry concept.
Strongly Disagree 1 2 3 4 5 Strongly Agree
5. I learn new chemistry concepts best when I work in a small group to complete a POGIL.
Strongly Disagree 1 2 3 4 5 Strongly Agree
6. I like learning new chemistry concepts by completing a POGIL in small groups.
Strongly Disagree 1 2 3 4 5 Strongly Agree
7. When I am struggling to learn a concept, I learn it best by watching a video lesson or podcast.
Strongly Disagree 1 2 3 4 5 Strongly Agree
8. I learn new chemistry concepts best by working individually on a guided inquiry.
Strongly Disagree 1 2 3 4 5 Strongly Agree
9. I like learning new chemistry concepts by working individually on a guided inquiry.
Strongly Disagree 1 2 3 4 5 Strongly Agree
10. Getting instantaneous feedback from online quizzes helps me learn chemistry concepts that I'm struggling with.
Strongly Disagree 1 2 3 4 5 Strongly Agree
11. Getting instantaneous feedback from online quizzes helps me learn new chemistry concepts.
Strongly Disagree 1 2 3 4 5 Strongly Agree

12. Answering questions during a video lesson helps me learn the material better than watching the same podcast without questions.
Strongly Disagree 1 2 3 4 5 Strongly Agree
13. I like video lessons with embedded questions better than watching the same podcast without questions.
Strongly Disagree 1 2 3 4 5 Strongly Agree
14. The first thing I do when I get feedback from a video lesson is go back through the video lesson and try to understand the questions that I got wrong.
Strongly Disagree 1 2 3 4 5 Strongly Agree
15. The first thing I do when I get feedback from a video lesson is ask a classmate or the teacher to help me understand the questions that I got wrong.
Strongly Disagree 1 2 3 4 5 Strongly Agree
16. When I get feedback from a video lesson I move on to the next assignment without trying to understand the questions I got wrong.
Strongly Disagree 1 2 3 4 5 Strongly Agree
17. When I'm struggling to learn a new chemistry concept, doing lots of practice problems helps.
Strongly Disagree 1 2 3 4 5 Strongly Agree
18. I learn new chemistry topics best when the teacher lectures.
Strongly Disagree 1 2 3 4 5 Strongly Agree
19. I like teacher lectures when it comes to learning new chemistry topics.
Strongly Disagree 1 2 3 4 5 Strongly Agree

Chemistry Attitude Post-Unit Survey

Your participation in this survey is voluntary and does not affect your course grade.

Please answer the questions thoughtfully and truthfully.

1. I want to learn chemistry.
Strongly Disagree 1 2 3 4 5 Strongly Agree
2. I believe that my logical and critical thinking will improve by studying chemistry.
Strongly Disagree 1 2 3 4 5 Strongly Agree
3. I believe that chemistry benefits our society/community.
Strongly Disagree 1 2 3 4 5 Strongly Agree
4. Chemistry makes me curious and motivated to learn more about scientific and chemical concepts.
Strongly Disagree 1 2 3 4 5 Strongly Agree
5. I learn chemistry best when I work in small groups.
Strongly Disagree 1 2 3 4 5 Strongly Agree
6. I feel a sense of accomplishment every time I perform well in chemistry.
Strongly Disagree 1 2 3 4 5 Strongly Agree
7. To learn chemistry I have to memorize a lot of facts.
Strongly Disagree 1 2 3 4 5 Strongly Agree
8. I enjoy laboratory explorations and investigations.
Strongly Disagree 1 2 3 4 5 Strongly Agree
9. I believe it is important for everyone in our society/community to understand basic chemistry.
Strongly Disagree 1 2 3 4 5 Strongly Agree
10. Chemistry is difficult for me to learn.
Strongly Disagree 1 2 3 4 5 Strongly Agree
11. I believe that this course improves my reasoning skills.
Strongly Disagree 1 2 3 4 5 Strongly Agree
12. I am confused in my chemistry class.
Strongly Disagree 1 2 3 4 5 Strongly Agree
13. I believe we should learn more challenging topics.
Strongly Disagree 1 2 3 4 5 Strongly Agree

14. I am hesitant to participate in chemistry class discussions.
Strongly Disagree 1 2 3 4 5 Strongly Agree
15. I am hesitant to participate within my small group.
Strongly Disagree 1 2 3 4 5 Strongly Agree
16. I learn chemistry best when we whiteboard our scientific models and discuss them as a class.
Strongly Disagree 1 2 3 4 5 Strongly Agree
17. I am not satisfied until I understand why something works the way it does.
Strongly Disagree 1 2 3 4 5 Strongly Agree
18. I learn chemistry best when I write my lab reports.
Strongly Disagree 1 2 3 4 5 Strongly Agree
19. To learn chemistry I need to understand the concepts and how to apply them to different situations.
Strongly Disagree 1 2 3 4 5 Strongly Agree
20. Nearly everyone is capable of understanding chemistry if they work at it.
Strongly Disagree 1 2 3 4 5 Strongly Agree
21. I like chemistry as a subject.
Strongly Disagree 1 2 3 4 5 Strongly Agree
22. I believe the class should move at a slower pace.
Strongly Disagree 1 2 3 4 5 Strongly Agree
23. For me studying chemistry is just a waste of time.
Strongly Disagree 1 2 3 4 5 Strongly Agree
24. When I am struggling to learn a concept I prefer to meet with the teacher for extra help outside of class.
Strongly Disagree 1 2 3 4 5 Strongly Agree
25. When I am struggling to learn a concept I can best learn it if I see the teacher for extra help outside of class.
Strongly Disagree 1 2 3 4 5 Strongly Agree
26. I find that video lessons are the best way for me to learn a new chemistry concept.
Strongly Disagree 1 2 3 4 5 Strongly Agree

27. I like using video lessons to learn a new chemistry concept.
Strongly Disagree 1 2 3 4 5 Strongly Agree
28. I learn new chemistry concepts best when I work in a small group to complete a POGIL.
Strongly Disagree 1 2 3 4 5 Strongly Agree
29. I like learning new chemistry concepts by completing a POGIL in small groups.
Strongly Disagree 1 2 3 4 5 Strongly Agree
30. When I am struggling to learn a concept, I learn it best by watching a video lesson or podcast.
Strongly Disagree 1 2 3 4 5 Strongly Agree
31. I learn new chemistry concepts best by working individually on a guided inquiry.
Strongly Disagree 1 2 3 4 5 Strongly Agree
32. I like learning new chemistry concepts by working individually on a guided inquiry.
Strongly Disagree 1 2 3 4 5 Strongly Agree
33. Getting instantaneous feedback from online quizzes helps me learn chemistry concepts that I'm struggling with.
Strongly Disagree 1 2 3 4 5 Strongly Agree
34. Getting instantaneous feedback from online quizzes helps me learn new chemistry concepts.
Strongly Disagree 1 2 3 4 5 Strongly Agree
35. Answering questions during a video lesson helps me learn the material better than watching the same podcast without questions.
Strongly Disagree 1 2 3 4 5 Strongly Agree

Mid-Unit Student Interview Questions

1. How do you go about learning the chemistry topics?
2. Throughout this course we've used several different types of learning activities such as guided inquiries, POGILs, video lessons, computer simulations, lab and lecture.
3. Which of these do you find help you learn?
4. Which do you find do not help you learn?
5. Why does [fill in the learning activity] work best for you?
6. Why doesn't [fill in the learning activity] work for you?

Questions for Advanced Students (Remedial Students skip to #18)

7. Tell me about the strategy you used for learning the advanced topics?
8. What is your overall opinion of the video lessons?
9. What did you like about them?
10. What didn't you like about them?
11. What could be done to make them a more effective learning tool?
12. What is your overall opinion of the guided inquiries?
13. What did you like about them?
14. What didn't you like about them?
15. What could be done to make them a more effective learning tool?
16. Did you or didn't you like getting instantaneous feedback from the video lessons and online quizzes?
17. How did you use this feedback to help you learn?

Questions for Remedial Students (Advanced Students skip to #25)

18. Tell me about the strategy you used to learn the topics you were struggling with?
19. What is your overall opinion of the video lessons?
20. What did you like about them?
21. What didn't you like about them?
22. Did you or didn't you like getting instantaneous feedback from the video lessons?
23. How did you use this feedback to help you learn?
24. What could be done to make the video lessons a more effective learning tool?
25. Overall, how would you rate the way the Molecules & Compounds unit was taught compared to the other units?
26. What could I do differently to improve the way the unit was taught?

Post-Unit Student Interview Questions

Throughout this course we've used several different types of learning activities such as guided inquiries, POGILs, video lessons, computer simulations, lab and lecture.

1. How would you compare and contrast video lessons and podcasts?
2. What do like about video lessons?
3. What do like about podcasts?
4. What don't you like about video lessons?
5. What don't you like about podcasts?
6. Do you think pictures and images enhance or detract from the podcasts and video lessons?
7. Which do you prefer podcasts or video lessons?
8. Guided inquiries
 - a. What did you like about them?
 - b. What didn't you like about them?
9. Compare and contrast "wet" labs and computer simulation labs.
10. What did you like about the wet labs?
11. What did you like about the computer simulation labs?
12. What didn't you like about the "wet" labs?
13. What didn't you like about the computer simulation labs?
14. Which do you prefer "wet" labs or computer simulation labs?
15. Rank the learning activities from most helpful to least helpful: podcast/video lesson, lab/simulation, guided inquiry.

APPENDIX B

STUDENT LEARNING DATA SUMMATIVE ASSESSMENTS

- _____ 9. Bonding in molecules or ions that cannot be correctly represented by a single Lewis structure is
- a. covalent bonding.
 - b. resonance.
 - c. single bonding.
 - d. double bonding.
- _____ 10. In metals, the valence electrons
- a. are attached to particular positive ions.
 - b. are shared by all of the atoms.
 - c. are immobile.
 - d. form covalent bonds.
- _____ 11. According to VSEPR theory, the electrostatic repulsion between electron pairs surrounding an atom causes
- a. an electron sea to form.
 - b. positive ions to form.
 - c. these pairs to be separated as far as possible.
 - d. light to reflect.
- _____ 12. If two covalently bonded atoms are identical, the bond is
- a. nonpolar covalent.
 - b. polar covalent.
 - c. nonionic.
 - d. coordinate covalent.
- _____ 13. Atoms are _____ when they are combined.
- a. more stable
 - b. less stable
 - c. not bound together
 - d. at a high potential energy
- _____ 14. Bonds between atoms with a difference in electronegativity greater than 1.8 are considered
- a. ionic.
 - b. pure covalent.
 - c. polar covalent.
 - d. nonpolar covalent.
- _____ 15. What group of elements satisfies the octet rule by losing two electrons?
- a. halogen
 - b. noble gas
 - c. alkali metal
 - d. alkaline-earth metal
- _____ 16. The chemical bond formed when two atoms share electrons is called a(n)
- a. ionic bond.
 - b. orbital bond.
 - c. Lewis structure.
 - d. covalent bond.
- _____ 17. A chemical bond resulting from the electrostatic attraction between positive and negative ions is called a(n)
- a. covalent bond.
 - b. ionic bond.
 - c. charged bond.
 - d. dipole bond.

Visual Models, Molecular Shapes and Intermolecular Forces. *Be sure to include all drawings, names and explanations that each problem asks for. Remember to use the appropriate conventions to show objects on the plane of your paper, projecting in front of your paper and extending behind your piece of paper. If a molecule has resonance structures you do not need to draw all the resonance structures.*

30. For the chlorate polyatomic ion, ClO_3^{1-} : 1) draw the Lewis dot structure, 2) draw the electron arrangement shape using the ball and stick model, 3) name the electron arrangement shape, 4) draw the molecular shape using the structural formula model and 5) name the molecular shape.
31. For the compound nitrogen trihydride, NH_3 : 1) draw the Lewis dot structure, 2) draw the electron arrangement shape using the ball and stick model, 3) name the electron arrangement shape, 4) draw the molecular shape using the structural formula model and 5) name the molecular shape. On your molecular shape: 6) show the partial charges, 7) draw the bond dipoles and 8) draw the molecular dipole. Finally, 9) list the strongest intermolecular force, and 10) identify whether the molecule is polar or non-polar.
32. For the compound sulfur trioxide, SO_3 : 1) draw the Lewis dot structure, 2) draw the electron arrangement shape using the ball and stick model, 3) name the electron arrangement shape, 4) draw the molecular shape using the structural formula model, and 5) name the molecular shape. On your molecular shape: 6) show the partial charges, 7) draw the bond dipoles and 8) draw the molecular dipole. Finally, 9) list the strongest intermolecular force, and 10) identify whether the molecule is polar or non-polar.

Chemistry Molecules & Compounds Quiz

Multiple Choice. *Identify the choice that best completes the statement or answers the question.*

- _____ 1. An atom is
- the smallest unit of matter that maintains its chemical identity.
 - the smallest unit of a compound.
 - always made of carbon.
 - smaller than an electron.
- _____ 2. A compound is
- a pure substance that cannot be broken down into simpler, stable substances.
 - a substance, made of two or more atoms that are chemically bonded, that can be broken down into simpler, stable substances.
 - the smallest unit of matter that maintains its chemical identity.
 - any substance, whether it is chemically bonded or not.
- _____ 3. Atoms naturally move
- toward high potential energy.
 - toward more stability.
 - toward less stability.
 - away from each other.
- _____ 4. How many more electrons does gallium need to satisfy the octet rule?
- 1
 - 3
 - 5
 - 8
- _____ 5. How many fewer electrons does carbon need to satisfy the octet rule?
- 2
 - 4
 - 6
 - 7
- _____ 6. How many fewer electrons does barium need to satisfy the octet rule?
- 2
 - 4
 - 6
 - 7
- _____ 7. Aluminum must gain ___ electrons or lose ___ electrons to satisfy the octet rule?
- 2, 6
 - 3, 5
 - 3, 3
 - 5, 3

- _____ 16. A chemical formula includes the symbols of the elements in the compound and subscripts that indicate the
- atomic mass of each element.
 - number of atoms or ions of each element that are combined in the compound.
 - formula mass.
 - charges on the elements or ions.

Completion. *Complete each statement.*

17. The two types of matter that are pure substances are _____ and _____.

Short Answer. *Use complete sentences to answer the questions.*

- Why are molecules and atoms similar?
- Why are elements and compounds similar?
- Why do most atoms form chemical bonds?

Visual Models. Draw the appropriate visual models of the elements and/or molecules below.

- Draw the Lewis structure for bromine.
- Draw the Lewis structure for silicon.
- Draw a ball-and-stick model of a water molecule.
- Draw a solid sphere model of a hydrochloric acid molecule (one hydrogen atom and one chlorine atom).
- Draw a structural formula model of a sulfur trioxide molecule (three oxygen atoms and one central sulfur atom).

Chemistry: Chemical Bonds Quiz

Multiple Choice. *Identify the choice that best completes the statement or answers the question.*

- _____ 1. Most chemical bonds are
a. purely ionic. c. partly ionic and partly covalent.
b. purely covalent. d. metallic.
- _____ 2. As atoms bond with each other, they
a. increase their potential energy, thus creating less-stable arrangements of matter.
b. decrease their potential energy, thus creating less-stable arrangements of matter.
c. increase their potential energy, thus creating more-stable arrangements of matter.
d. decrease their potential energy, thus creating more-stable arrangements of matter.
- _____ 3. How many extra electrons are in the Lewis structure of the phosphate ion, PO_4^{3-} ?
a. 0 c. 3
b. 2 d. 4
- _____ 4. Multiple covalent bonds may occur in atoms that contain carbon, nitrogen, or
a. chlorine. c. oxygen.
b. hydrogen. d. helium.
- _____ 5. When a stable covalent bond forms, the stability of the atoms
a. increases. c. remains constant.
b. decreases. d. becomes zero.
- _____ 6. A neutral group of atoms held together by covalent bonds is a
a. molecular formula. c. polyatomic ion.
b. chemical formula. d. molecule.
- _____ 7. Nonpolar covalent bonds are not common because
a. one atom usually attracts electrons more strongly than the other.
b. ions always form when atoms join.
c. the electrons usually remain equally distant from both atoms.
d. dipoles are rare in nature.

- ___ 8. The chemical formula for an ionic compound represents the
- number of atoms in each molecule.
 - number of ions in each molecule.
 - ratio of the combined ions present in a sample.
 - total number of ions in the crystal lattice.
- ___ 9. In drawing a Lewis structure, the central atom is generally the
- atom with the greatest mass.
 - atom with the highest atomic number.
 - atom with the fewest electrons.
 - least electronegative atom.
- ___ 10. The electrons involved in the formation of a chemical bond are called
- dipoles.
 - s* electrons.
 - Lewis electrons.
 - valence electrons.
- ___ 11. After drawing a Lewis structure, one should
- determine the number of each type of atom in the molecule.
 - add unshared pairs of electrons around nonmetal atoms.
 - confirm that the total number of valence electrons used equals the number available.
 - determine the electronegativity of each atom.
- ___ 12. Bonding in molecules or ions that cannot be correctly represented by a single Lewis structure is
- polyatomic.
 - resonance.
 - single bonding.
 - double bonding.
- ___ 13. The type of bond in Br₂ (electronegativity for Br is 2.8) is
- nonpolar covalent.
 - polar covalent.
 - pure ionic.
 - metallic.
- ___ 14. A chemical bond formed by the attraction between positive ions and surrounding mobile electrons is a(n)
- nonpolar covalent bond.
 - ionic bond.
 - polar covalent bond.
 - metallic bond.
- ___ 15. What is the correct Lewis structure for hydrogen chloride, HCl?



- A
- B
- C
- D

- _____ 25. In drawing a Lewis structure, each nonmetal atom except hydrogen should be surrounded by
- a. 2 electrons.
 - b. 4 electrons.
 - c. 8 electrons.
 - d. 10 electrons.
- _____ 26. The substance whose Lewis structure shows three covalent bonds is
- a. H₂O.
 - b. CH₂Cl₂.
 - c. NH₃.
 - d. CCl₄.
- _____ 27. If the atoms that share electrons have an unequal attraction for the electrons, the bond is called
- a. nonpolar.
 - b. polar.
 - c. ionic.
 - d. dipolar.
- _____ 28. Chemists once theorized that a molecule that contains a single bond and a double bond split its time existing as one of these two structures. This effect became known as
- a. alternation.
 - b. resonance.
 - c. multiple bonding.
 - d. single-double bonding.
- _____ 29. The chemical formula for water, a covalent compound, is H₂O. This formula is an example of a(n)
- a. formula unit.
 - b. Lewis structure.
 - c. ionic formula.
 - d. molecular formula.
- _____ 30. If two covalently bonded atoms are identical, the bond is
- a. nonpolar covalent.
 - b. polar covalent.
 - c. dipole covalent.
 - d. coordinate covalent.

Short Answer. *Use complete sentences to answer the questions.*

31. Explain why metals are good conductors of electricity.
32. Differentiate between an ionic compound and a molecular compound.

Lewis Dot Structures. *Draw the Lewis dot structure for the molecules and polyatomic ions below. Show all lone pair and bonding pairs of electrons, and indicate any unbalanced charge. Show all resonance structures if they exist.*

33. Ozone, O₃

34. Carbon disulfide, CS₂.

35. Nitrate ion, NO₃⁻

Chemistry: Molecular Shapes Quiz

Multiple Choice. *Identify the choice that best completes the statement or answers the question.*

- _____ 1. According to VSEPR theory, the shape of a molecule whose central atom has two bonds and no lone pairs of electron is
- | | |
|---------------------|----------------|
| a. trigonal-planar. | c. linear. |
| b. tetrahedral. | d. octahedral. |
- _____ 2. The concept that electrostatic repulsion between electron pairs surrounding an atom causes these pairs to be separated as far as possible is the foundation of
- | | |
|-----------------------------|----------------------------|
| a. VSEPR theory. | c. the electron-sea model. |
| b. the hybridization model. | d. Lewis theory. |
- _____ 3. According to VSEPR theory, the shape of a molecule whose central atom has 3 bonds and no lone pairs is
- | | |
|---------------------|------------|
| a. trigonal-planar. | c. linear. |
| b. tetrahedral. | d. bent. |
- _____ 4. Which shape has the highest bond angle?
- | | |
|---------------------|------------|
| a. trigonal-planar. | c. linear. |
| b. tetrahedral. | d. bent. |
- _____ 5. According to VSEPR theory, the shape of a molecule whose central atom has three bonds and one lone pair is
- | | |
|---------------------|------------------------|
| a. trigonal-planar. | c. trigonal pyramidal. |
| b. tetrahedral. | d. square pyramidal |
- _____ 6. According to VSEPR theory, the compound whose electron arrangement shape is different than its molecular shape is
- | | |
|----------------------------------------|-------------------------------------|
| a. carbon dioxide, CO_2 . | c. sulfur trioxide, SO_3 . |
| b. boron trichloride, BCl_3 . | d. ammonia, NH_3 . |
- _____ 7. Use VSEPR theory to predict the shape of the hydrogen chloride molecule, HCl .
- | | |
|----------------|--------------------|
| a. tetrahedral | c. bent |
| b. linear | d. trigonal-planar |
- _____ 8. Use VSEPR theory to predict the shape of the carbon tetrabromide molecule, CBr_4 .
- | | |
|----------------|--------------------|
| a. tetrahedral | c. bent |
| b. linear | d. trigonal-planar |

- _____ 9. According to VSEPR theory, why can a compound have an electron arrangement shape that is different than its molecular shape?
- the central atom has one or more lone pairs of electrons
 - the molecule has resonance structures
 - the arrangement of atoms cannot be represented by one shape.
 - this is not allowed under VESPR theory
- _____ 10. Use VSEPR theory to predict the shape of carbon dioxide, CO₂.
- | | |
|----------------|---------------|
| a. tetrahedral | c. bent |
| b. linear | d. octahedral |

Open Answers. *Be sure to include all drawings, names and explanations that each problem asks for. Remember to use the appropriate conventions to show objects projecting in front of and behind your piece of paper.*

- Sulfur dioxide (SO₂) and water (H₂O) both have bent molecular shapes. Explain why they do not have exactly the same bond angles.
- Draw the Lewis dot structure, draw the molecular shape, and name the molecular shape for the polyatomic ion ammonium, NH₄⁺.
- Draw the Lewis dot structure, draw and name the electron arrangement, and draw and name the molecular shape for phosphorous tribromide, PBr₃.

Chemistry: Intermolecular Forces Quiz

Multiple Choice. *Identify the choice that best completes the statement or answers the question.*

- _____ 1. The forces of attraction between molecules in a molecular (aka covalent) compound are
- stronger than the forces of ionic bonding.
 - weaker than the forces of ionic bonding.
 - approximately equal to the forces of ionic bonding.
 - zero.
- _____ 2. A compound that vaporizes readily at room temperature is most likely to be a(n)
- molecular compound.
 - ionic compound.
 - metal.
 - brittle compound.
- _____ 3. A compound that remains in the solid state under intense heat is most likely to be a(n)
- molecular compound.
 - ionic compound.
 - metal.
 - brittle compound.
- _____ 4. Physical properties, such as boiling point, melting point and surface tension, of both ionic and molecular compounds are related to the
- lattice energies of the compounds.
 - strengths of attraction between the particles.
 - number of covalent bonds each contains.
 - mobile electrons that they contain.
- _____ 5. Dipole-dipole forces are considered the most important forces in polar substances because the London dispersion forces
- act only in nonpolar substances.
 - are usually much weaker than the dipole-dipole forces.
 - are too unpredictable.
 - act only in solids.
- _____ 6. The intermolecular attraction between a hydrogen atom bonded to a strongly electronegative atom and the unshared pair of electrons on a nitrogen, oxygen or fluorine atom is called
- electron affinity.
 - covalent bonding.
 - hydrogen bonding.
 - electronegativity.

- _____ 7. The weak intermolecular forces resulting from temporary and transient dipoles are called
- London dispersion forces.
 - dipole-dipole forces.
 - hydrogen forces.
 - polar covalent bonding.
- _____ 8. Compared with molecular bonds, the strength of London dispersion forces, dipole-dipole attractions and hydrogen bonding is
- weaker.
 - stronger.
 - about the same.
 - too variable to compare.
- _____ 9. That the boiling point of water (H_2O) is higher than the boiling point of hydrogen sulfide (H_2S) is partially explained by
- London forces.
 - covalent bonding.
 - ionic bonding.
 - hydrogen bonding.
- _____ 10. A polar molecule contains
- ions.
 - a region of positive charge and a region of negative charge.
 - only London forces.
 - no bonds.
- _____ 11. Iodine monochloride (ICl) has a higher boiling point than bromine (Br_2) partly because iodine monochloride is a(n)
- nonpolar molecule.
 - ion.
 - crystal.
 - polar molecule.

Open Answer. *Provide all the information asked for in each problem below.*

12. How can a compound with polar bonds be a non-polar molecule?
13. Rank the following compounds from highest boiling point to lowest boiling point and explain why you made these choices: H_2O , LiO_2 , and H_2S .
14. Draw the molecular shape, bond dipoles and molecular dipole for BCl_3 . Then identify the partial or full charges, and all intermolecular forces that exist. Clearly indicate if one or more of these quantities do not exist.
15. Draw the molecular shape, bond dipoles and molecular dipole for NF_3 . Then identify the partial or full charges, and all intermolecular forces that exist. Clearly indicate if one or more of these quantities do not exist.
16. Draw the molecular shape, bond dipoles and molecular dipole for NH_3 . Then identify the partial or full charges, and all intermolecular forces that exist.

APPENDIX C

STUDENT LEARNING DATA SELECTED FORMATIVE ASSESSMENTS

Chemistry: Molecules & Compounds Quick Quiz

1. Why are molecules called the building blocks of compounds?
2. List at least three characteristics of compounds?
3. Draw the structural formula for water, it has a bent shape.
4. Draw the ball and stick model for carbon dioxide, it has a linear shape with two double bonds.
5. The compound methane has the chemical formula CH_4 . List the types of atoms that make up methane and how many atoms of each type are in a molecule of methane.

Valence Electrons, Lewis Dot Structures and the Octet Rule Quick Quiz

1. How many valence electrons does phosphorous have?
2. How many valence electrons does rubidium have?
3. Draw the Lewis dot structure for phosphorous.
4. Draw the Lewis dot structure for rubidium.
5. How many electrons does phosphorous have to gain to satisfy the octet rule?
6. How many electrons does rubidium need to lose to satisfy the octet rule?

Chemical Bonds Quick Quiz

1. In one sentence contrast ionic and covalent bonds?
2. In one sentence explain what a chemical bond is?
3. What is the ΔEN of the H – S bond and would we classify this as a non-polar covalent, polar covalent or ionic bond?
4. What is the ΔEN of the Ca – O bond and would we classify this as a non-polar covalent, polar covalent or ionic bond?
5. What is it about the metallic bond that makes metals good conductors of heat and electricity?

Lewis Dot Structures & Covalent Compounds Quick Quiz

1. Draw the Lewis dot structure for carbon disulfide (CS_2). Show any resonance structures if they exist.

Lewis Dot Structures & Ionic Compounds Quick Quiz

1. Draw the Lewis dot structures for strontium chloride (SrCl_2). You need to show the Lewis dot structures for the neutral atoms before the electron transfer and the Lewis dot structures for the ions that were created after the electron transfer. This is just like the ionic compound problems we've been doing in class.

Bond Polarity Quick Quiz

1. Draw the bond between silicon and oxygen, show the charges and draw the dipole arrow.
2. Draw the bond between chlorine and boron, show the charges and draw the dipole arrow.
3. Draw the bond between fluorine and lithium, show the charges and draw the dipole arrow.

Molecular Polarity Quick Quiz

For the molecule carbon dibromide difluoride, CBr_2F_2 ...

1. Draw the molecular shape, show the bond dipoles, label the partial positive and negative ends of each bond, and draw the molecular dipole.

Intermolecular Forces Quick Quiz

1. For the molecule ammonium, NH_3 ...
2. Draw and name the molecular shape.
3. Draw the bond dipoles on your molecular shape drawing.
4. Identify the partial charges on your molecular shape drawing.
5. Beside the molecular shape draw the molecule dipole (indicate if there is no molecular dipole).
6. List all the intermolecular forces that this compound has.
7. Is this compound polar or non-polar?
8. Which is the strongest IMF?

Nomenclature & Formula Writing for Ionic Compounds Quick Quiz

1. Write the formula for ammonium phosphate.
2. What is the name of $\text{Pb}(\text{CO}_3)_2$?

Nomenclature & Formula Writing for Inorganic Molecular Compounds Quick Quiz

1. Write the formula for diphosphorous pentoxide.
2. What is the name of C_3S_2 ?

Organic Compounds Nomenclature & Formula Writing Quick Quiz

1. Write the formula for butane.
2. What is the name of C_2H_6 ?
3. Write the formula for propyne?
4. What is the name of C_7H_{14} ?

APPENDIX D
SAMPLE OF VIDEO LESSON

Bond Polarity Remediation Video Lesson

A video lesson begins with a video, and then questions are inserted at key points in the video in order to keep students engaged and help them process the information. My videos use voice, text, images, hand written notes and hand drawn sketches to explain the topic. I give examples and practice problems to reinforce the concept. Students must go through the entire video the first time. They cannot fast forward from one question to the next. After answering a question students receive feedback on whether they got the question correct or not. They are given the correct answer if they answered the question incorrectly. On the questions they get wrong, students have the chance to explain why their choice is wrong and the correct choice is the right answer.

The print screen below shows the video lesson at the point a question is being asked. The entire list of questions for this video lesson is provided below. The time when each question is asked in the video is shown in parentheses. Several different question formats can be used such as multiple choice, fill in the blank and open response.

The screenshot shows a video player interface. At the top, the title is 'Bond Polarity' with a subtitle 'Understanding polarity and how to determine the positive and negative ends of bonds.' There are 'SHARE' and 'DOWNLOAD LESSON' buttons. The main content area displays a question: 'Which of the following statements are true? Please check all answer choices that apply.' Below the question are five checkboxes, each with a statement. To the right, a sidebar titled 'Previously Learned Concepts' lists four key concepts: Electronegativity, Non-polar covalent bond, Polar covalent bond, and Ionic bond, each with a brief definition.

1. (00:59) Which of the following statements are true?
 - Atoms with high electronegativity have a stronger pull on valence electrons than atoms with low electronegativity.
 - Atoms with low electronegativity have a strong hold on their own valence electrons.
 - When two identical atoms are bonded to each other the bond will always be a non-polar covalent bond.
 - An ionic bond occurs if one or more electrons are transferred from one atom to another.
 - Polar covalent bonds and non-polar covalent bonds are formed when two atoms share electrons.

2. (03:15) When two atoms bonded to each other have different electronegativities positive and negative _____ are created.
3. (05:31) Unequal sharing of bonding electrons creates _____ charges, and the transfer of valence electrons creates _____ charges.
4. (06:18) If a bond has polarity then it must have
 - a positive pole.
 - a negative pole.
 - a dipole.
 - all of the above.
5. (08:09) Which of the following statements are true?
 - Ionic bonds use a different dipole arrow than polar covalent bonds.
 - A bond with no poles means the two atoms share the bonding electrons equally.
 - The partial negative charge in a polar bond will always be located at the atom with the higher electronegativity.
 - The full positive charge in an ionic bond will always be located at the atom with the lower electronegativity.
 - The tip of the dipole arrow will always point toward the more electronegative atom.
6. (10:28) Why does the non-polar bond between carbon and hydrogen have a dipole?
7. (10:48) The partial _____ charge exists at the carbon end of the bond because it has the _____ electronegativity.
8. (11:11) The tail of the dipole arrow will be at the _____ end of the bond.
9. (11:32) Why is the bond between sodium and chlorine an ionic bond?
10. (12:09) The chlorine end of the bond will have a
 - partial negative charge.
 - partial positive charge.
 - 1- charge.
 - 1+ charge.
11. (14:40) Explain how you determine: 1) if a bond has a dipole, 2) if it has partial or full charges, and 3) which end of the bond has the negative pole.