THE EFFECTS OF GAMIFICATION USING THE 5E LEARNING CYCLE (QuIVERS) ON A SECONDARY HONORS CHEMISTRY CLASSROOM

by

Robert David Maul

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

Master of Science

in

Science Education

MONTANTA STATE UNIVERSITY
Bozeman, Montana

June 2016
TABLE OF CONTENTS

INTRODUCTION AND BACKGROUND ........................................................................... 1

CONCEPTUAL FRAMEWORK ..................................................................................... 2

METHODOLOGY ........................................................................................................... 15

DATA AND ANALYSIS ................................................................................................. 25

INTERPRETATION AND CONCLUSION ....................................................................... 36

VALUE .......................................................................................................................... 39

REFERENCES CITED ..................................................................................................... 41

APPENDICES ................................................................................................................... 45

APPENDIX A Nomenclature Unit Test ................................................................. 46
APPENDIX B Chemical Reactions Unit Test ..................................................... 52
APPENDIC C Nomenclature Unit Formative Assessment 1 ............................ 58
APPENDIX D Nomenclature Unit Formative Assessment 2 ........................... 60
APPENDIX E Nomenclature Unit Formative Assessment 3 ........................... 62
APPENDIX F Chemical Reactions Unit Formative Assessment .................... 64
APPENDIX G Attitude Survey .................................................................................... 67
APPENDIX H Post-intervention Interview Questions ........................................ 69
APPENDIX I Focused Autobiographical Sketch ................................................ 71
APPENDIX J Nomenclature Unit Challenge 1: Poly Ions ................................. 73
APPENDIX K Nomenclature Unit Chem-Guild Challenge 1: Acid ............... 81
APPENDIX L Chemical Reactions Unit Challenge 1: Reaction Types .......... 85
LIST OF TABLES

1. Data Triangulation Matrix ...........................................................................................................25

2. Treatment and Non-Treatment Assessment Analysis (n=?) .....................................................27

3. Attitude Survey Including Categories, Survey Questions, and Percentage of Students in Agreement or Disagreement.................................................................32

4. Patterns in Scientific Identity Open-Ended Question ..................................................................34
LIST OF FIGURES

1. Learning Objectives for Units of Study ................................................................. 19
ABSTRACT

Many honors chemistry students lack the motivation and confidence needed to succeed academically in science classes. This may be a result of past science classes that are not engaging, motivating, or that punish students for failure. To improve student success and scientific literacy, I utilized gamification and the 5E learning cycle (QuIVERS) with high school honors chemistry students. The goal of this project was to use a variety of compelling aspects of video games and incorporate them into my classroom to improve my student’s success at learning chemistry and to foster their identities as scientists.

The intervention was inspired by Paul Andersen, who developed the QuIVERS method for his AP Biology classes. Within this cycle students engage in a question, explore an investigation, watch a video, read an elaborative reading, review, and take a summary quiz. In my intervention, I incorporated the following characteristics of gamification: self-paced advancement, failure normalization, badges for completing challenges, and levelling.

The study began with a non-treatment control group from the previous year. Class averages, formative assessment scores, and summative assessment scores were recorded for comparing with the treatment group. Two units of the study, nomenclature and chemical reactions were used at the treatment units. The assessments included three nomenclature quizzes and a multiple choice test for the nomenclature unit, and a balancing equations quiz and multiple choice test for the chemical reaction unit.

Overall, the impact on student learning and student identity as a scientist was inconclusive and it appeared that the intervention had no significant impact on either. Changes were small in many of the measured standards. Students seemed to be most impacted in their confidence and willingness to learn in environments where failure was encouraged. The majority of students found the intervention positive and helpful. My results matched the research that demonstrated that student engagement, achievement, and motivation all can be affected positively by high-quality games and holistic classroom game environments. Because of the importance of careful design, the time needed to incorporate a successful gamification intervention may, for some, outweigh the possible benefits.

An increase in the duration of the intervention could be used to see if there is a stronger impact on student learning and to help foster identities in science content could be incorporated in ways that involve more science practices and inquiry.
INTRODUCTION AND BACKGROUND

I have taught high school science for five years, and this was my third year teaching at Notre Dame Preparatory Academy in Pontiac, MI. It is a Catholic School that has around 700 students in the high school and the class selected for the intervention was the single Honors Chemistry section I taught in the second semester of the 2014/2015 school year. These honors students have an above average academic ability (as a class, and as a school). The students at NDP are very motivated, driven, and have strong family support. The school is not very diverse, drawing upon mostly white middle/upper-class families as its primary source of students. Every student was equipped with a Windows 8 Tablet PC this past year as part of the school’s new 1:1 technology program.

Family, faith, and excellence are among the top priorities in this district that draws students from a very wide geographical area. Parents expect a lot from the students and most students expect a lot from themselves. Nearly all students are college-bound, but they are stretched very thin as the demands for success are very high. Students have eight classes a day and many are involved with after-school sports, clubs, and activities. Many students go on to take (or are currently enrolled in) multiple Advanced Placement courses and IB classes if they are part of the International Baccalaureate program. With so much pressure on achieving academic success, students do not get enough sleep each night and report stress to be a significant problem for them. In my experience, students do not handle failure well and need lots of encouragement if they do not succeed right away.

Project Focus

I have observed that students at Notre Dame Prep have a tremendous amount of gaming fluency and potential that I believed could be tapped for effective teaching and
learning. Many honors chemistry students lack the motivation and confidence needed to succeed academically in science classes. This may be a result of past science classes that are not engaging, motivating, or that punish students for failure. To improve student success and scientific literacy, I developed an engaging and pedagogically-sound intervention to determine the impact of utilizing gamification and the 5E learning cycle (QuIVERS) with high school honors chemistry students. The 5E learning cycle is a science curriculum deployment model that consists of five phases that each start with the letter “e”: engagement, exploration, explanation, elaboration, and evaluation (Bybee, Taylor, Gardner, Van Scotter, Carson Powell, Westbrook & Landes, 2006). QuIVERs is an acronym that was developed by Paul Anderson (2012) that takes the key components of the 5E learning cycle and package them into a form that works well for computer-based delivery methods. The name QuIVERs (like the tool used to hold arrows for a bow) is something that can easily be thought of as being found in a fantasy video game. In the QuIVERs cycle, students engage in a question (Qui), explore an investigation (I), watch a video (V), read an elaborative reading (E), review (R), and take a summary quiz (S). The following question and sub-question was addressed: 1) Will implementing elements of gamification and the 5E learning cycle into a classroom environment improve student performance? 2) Will implementing elements of gamification and the 5E learning cycle into a classroom foster student identities as scientists?

CONCEPTUAL FRAMEWORK

People love to play video games; including many of my students and myself. Many people devote hours to video games and despite a game’s difficulty or a person’s frequent encounters with failure, people persist at learning the skills needed to be
successful at those games. A recent study by Pew Internet & American Life Project (as cited in Schaffhauser, 2013) found that 97% of kids age 12-17 play some kind of digital game every week. In fact people are encountering more game-like activities in all aspects of life (Schaffhauser, 2013).

I grew up a gamer and have been playing video games since elementary school. I have a passion for engaging and high-quality video games. My experience with my students suggests that a tremendous amount of gaming fluency and potential can be tapped for effective teaching and learning. The goal of this literature review is to inform the development of an engaging and pedagogically-sound intervention to help students succeed in science and in growing as scientists.

There has been a great deal of current research on the effective use of videogames to improve learning in the past few years (Morris, Croker, Zimmerman, Gill, Romig, Ford, & Sharman, 2013; Schaffhauser, 2013; Barata, Gama, Jorge, & Goncalves, 2013; Clark, Tanner-Smith, & Killingsworth, 2013; Rouse, 2013). These studies identify many best practices as well as the potential to improve learning experiences and outcomes, understanding, motivation, engagement, diligence, and satisfaction. Video games are designed to keep players engaged (Morris et al., 2013). Games are especially good at promoting behavioral persistence, increased time devoted to a task, gaining levels, achieving mastery and developing expertise, and suppressing the fear of failure. Video games also can encourage inquiry, and provide a contextual bridge between concepts learned and their applications. Engagement through videogame play to promote successful learning is consistent with various theories of motivation, positive psychology, and with educational research theory.
According to a report by the Federation of American Scientists (as cited in Morris et al., 2013) video games can contain many features found in excellent learning environments such as: clear learning goals, opportunities for practice and reinforcing expertise, monitoring of progress, and adaptation to the level of mastery of the learner. Games are ongoing assessments of player’s abilities or knowledge (McClarty, Orr, Frey, Dolan, Vassilev, & McVay, 2012). Salen (as cited in Schaffhauser, 2013) says that video games are incredibly data rich. They can reveal how players are doing, where they need to go, and how they need to improve. As opposed to most standardized tests, games can simulate an authentic context in which players can demonstrate their learning (Morris et al., 2013).

In this literature review, I will attempt to look at what gamification is, how it can be used as a basis for science education reform, how it can be used to foster intrinsic motivation, and how it can be implemented. Intrinsic motivation occurs when behaviors are caused by internal factors rather than external rewards (Coon & Mitterer, 2010). Engaging in an activity provides its own enjoyment and incentive to continue.

I will then review current research that supports the use of educational games and gamification. Finally, I will address an approach at melding gamification with successful science pedagogy through a focus on using the 5E learning cycle.

Gamification

Suits (1978) defines playing a game as “the voluntary attempt to overcome unnecessary obstacles” (p. 2). Kapp (as cited in Morris et al, 2013) defines gamification “as a term used to describe using game elements in other environments to enhance user experience” (p. 2). Playing a game and gamification are actually two different things,
both of which however, can be used effectively in a learning environment. In the educational world Schaffhauser (2013) makes the distinction when he says that “gaming” refers to digital games that have learning objectives. Gamification, on the other hand involves introducing the mechanics of games—such as experience points; badges, achievements, or rewards; and leaderboards—into activities that can be non-digital and can involve no actual gameplay. These game mechanics are intended to inspire similar engagement as playing a real game does.

For gamification to be truly effective, Schaffhauser (2013) contends that there must be elements present that make real commercial games compelling. If there is no fun factor, it can’t really be considered a game. Gillispie (as cited in Schaffhauser, 2013) notes that gamification can easily become just another “gold star on the chart,” (p. 33) which is nothing but a new form of extrinsic motivation. To really engage the player, true gamification also needs novelty; unexpected things; hard, difficult choices; narrative and story that can draw players in; continuous feedback; and challenge on the right level that is tough but not frustrating. DiCerbo, (as cited in Schaffhauser, 2013) says that the game reward structures (points, levels, badges, leaderboards, etc.) found in many games and game platforms is really behaviorism in disguise. He argues that the problem with using games in this way is that if learners are already intrinsically motivated, the rewards associated with a gamified environment may actually decrease motivation. DiCerbo believes that aspects of games and “gaming” are in the long run are more likely to succeed in the classroom than gamification based just on game-reward structures.

A middle ground then, seems to be classroom environments that have both the rewards-based aspect of gamification and the play and compelling aspects of games
themselves. McClarty et al., (2012) states games would work best when coupled with other pedagogy, and “will not replace teachers and classrooms, but they might replace some text books and laboratories” (p.12). There is no ‘magic bullet’ in education and gamification is just one tool that has potential to be used to improve particular elements of modern education, most notably in teaching science-specific skills (Morris et al., 2013).

There are some problems that educators face as they try to add various elements of games to their classrooms. Squire (2008) argues that games and game environments that are used in classrooms are not as sophisticated as commercial games, require less time on task, and are more likely to mimic typical instruction with gameplay tacked on as an extrinsic motivator. DiCerbo (as cited in Schaffhauser, 2013) says that the major factor that many games lack is adaptivity. Choice becomes limited to mechanistic responses and experiences are too linear. The game or game environment should look at behavior and underlying skill of each player. Educational games need to adapt the skills to games that they need for learning and present opportunities for players to apply the content in its proper context.

To avoid the use of gameplay as purely an extrinsic motivator, Habgood and Ainsworth (2011) argue that learning activities should be closely integrated with gameplay and presented when the game is most engaging. Thus, a player’s flow-state generated by the game, their optimal state of awareness, can be exploited and used. If learning isn’t integrated intrinsically, there can be difficulty transferring learning to different contexts. Morris, et al., (2013) contends that gaming contexts are often very
different from normal classroom experiences like lab experiments and therefore may be even less likely to promote transfer of learning.

A review of gaming in education by McClarty et al. (2012) concludes that despite the many reasons that games should be effective (forced mastery, engagement, feedback, planning, fun failure, choice, agency, etc.) there is not yet much evidence from research for the effectiveness of games in science instruction or learning. There is little evidence that games or gamification promote developing scientific skills, understanding of science content, or understanding of the nature of science. Schaffhauser (2013) adds that most public schools are not past the experimentation stage of using games or gamification and much implementation is poor at improving, and not distracting learning.

**Gamification as a Basis for Science Education Reform**

Modern psychology and educational research theory has contributed to how gamification could specifically be used to improve science education. Due to the difficulty of creating and developing a high-quality game environment, I focused my intervention more on the incorporation of game mechanics (gamification) rather than designing a full-scale game to correspond with content instruction (gaming). Since I believe that true gamification of a classroom should incorporate the compelling aspects associated with playing a game and not just reward-structures, I will use the terms gaming and gamification interchangeably from this point forward to discuss the aspects of games that I focused on for my intervention.

Morris et al. (2013) define scientific thinking as the “set of reasoning and problem-solving skills involved in generating, testing, and revising hypotheses or theories.” (p. 2) However, scientific thinking does not develop spontaneously and is therefore highly
dependent on individuals who are motivated to learn about science. Motivation they argue is the critical link in achieving short term (content) and long term (science literacy) goals. Video games can provide a method for achieving this motivation.

The National Research Council’s (2012) Framework for K-12 Science Education sees the goals of science education to create scientifically-literate members of society who can consume and produce scientific information through their experiences of doing science and engineering rather than just learning a multitude of facts. Students need to appreciate that science is the product of collaborative human activity driven by societal needs. Gee (2008) argues that video games can mirror scientist’s approach to a problem when they have the opportunity to construct a hypotheses, design an experiment, evaluate their results, and revise their hypothesis. Gamification efforts ultimately must situate students in the context of a scientific investigation. This means undergoing inquiry investigations where science practices and values are taught and students work together with many other users to collaborate and argue their way to understanding (Morris et al., 2013).

Morris et al. (2013) define scientific literacy which “describes the skills that are required by citizens in a scientifically advanced democracy” (p. 1). What this means is that people need to be able to “investigate, evaluate, and comprehend science content, processes, and products, as well as possess positive attitudes toward science.” (p.1)

Morris et al. (2013) state that gamification can be used as a basis for science education reform through the use of motivational, cognitive, and metacognitive scaffolds. Gamification should evoke a natural curiosity to explore which can improve motivation.
This aspect will be an important part of engage stage of the 5E learning cycle which I will mention later in this review. Games also allow players participate in leveling. Leveling in games means that early levels are easy to obtain, but complexity is added as higher levels are sought as gamers monitor their knowledge and what they yet need to learn.

As they move at their own pace they must be given sufficient, specific, and prompt feedback about their progress toward learning outcomes (Morris et al., 2013). When performance is compared to a standard, it can naturally increases intrinsic motivation (Baumeister, Hutton, & Cairns, 1990). Praising effort, which is something students have control over, means they are more likely to liken their success or failure to their own effort, rather than personal characteristics. Gamification can incorporate optimal types and frequency of praise to increase motivation and persistence (Morris et al., 2013).

Schaffhauser (2013) describes that play is the way that human beings learn about the world and discover how things work. Science and play have much in common and one of these commonalities is failure; an essential aspect of both science and play. Games can structure problem solving in a way that helps a player, as Salen (as cited in Schaffhauser, 2013) puts it, “fail up.” If problems presented to players are sufficiently difficult and fun, students will likely learn the skills to persist to solve them.

Games can also produce in players a phenomenon known as flow. Flow has been described by Nakamura and Csikszentmihalyi (2002) as an optimal state of being in which a person is able to focus intensely and concentrate more than normal as they experience improved awareness, a high sense of agency, and an improved ability to
perform various actions. Flow can be especially useful in helping students stay focused on a task for an extended period of time; a skill that is needed in science, which often demands much practice to achieve mastery.

**Cognitive Scaffolds**

Cognitive scaffolds are another aspect that can be incorporated into games to improve science education (Morris et al., 2013). Cognitive scaffolds, as defined by Zimmerman (2007), include identifying problems, generating hypotheses, designing experiments, collecting data, evaluating evidence, and making inferences. Computer simulations are one such scaffold that I will use to allow students to identify problems, make predictions, manipulate variables, collect and evaluate data, observe effects, and draw conclusions to try to understand the rules of complex systems. Players also can draw upon distributed knowledge to assist in their cognition. Players’ goals can be made meaningful through cooperating with other characters or players who can act as mentors that possess knowledge and skills that they lack (Wood, Bruner, & Ross, 1976; Chi, 2009). Mastery is not necessary to play. Players act as team members, each which can contribute the knowledge needed to engage in scientific activities, while they simultaneously can internalize the values of scientists, who solve problems in the real world as a team, rather than in isolation.

The last type of scaffolds that gamification can foster are metacognitive scaffolds, which involve thorough self-monitoring of assumptions, knowledge, skills, and progress towards a goal (Morris et al., 2013). A player’s beliefs can be changed based on evidence they encounter in a game. Another aspect of games that make learning science especially helpful is that in the context of the game, players are more likely to evaluate evidence
objectively for their theories without prejudice. If players can create their own characters they have the opportunity to behave as that character would and at the same time, adopt the beliefs and values the character would adopt.

**Impact of Using Gamification in the Classroom**

In the following paragraphs, I will explore three studies that highlight the use and effectiveness of gamification and using classroom games. Their impact on classroom engagement, motivation, and achievement will be discussed.

One study looked at the effects on student performance and satisfaction of adding game-like elements to a master’s-level Multimedia Content Production engineering college course (Barata et al., 2013). A gamified version of the course was used which contained the following game elements: experience points, levels, leaderboards, challenges, and badges. To measure performance, they collected quantitative and qualitative data on attendance, participation in forum posts, satisfaction, and usage of reference materials. The intervention focused on providing gaming elements that were aimed at increasing intrinsic motivation through competence, autonomy, and relatedness. Results were very positive as lecture attendance improved, students accessed course materials more frequently, online participation increased, students demonstrated more proactive behaviors, and students reported that the gamified course was more motivating, interesting, and easier to learn compared to other courses. Despite the positive effects on motivation and engagement, there was no observable correlation between student grades and the added game elements.

The intervention of this study used an extrinsic rewards-systems of points and badges which the designers were worried may crowd out intrinsic motivation. To combat
this, they attempted to align the goals of the course with those of the student (to learn and pass the course) and introduce gaming aspects that share or foster forms of intrinsic motivation (Barata et al., 2013). Competence was promoted through positive feedback and displaying student progress via points, levels, and badges. Autonomy was fostered by allowing students to choose challenges to pursue and which achievements to level up. Relatedness and competition was fostered as students were encouraged to cooperate and share opinions on forum and compete via the leaderboard. (Barata et al., 2013)

“Digital Games for Learning: A Systematic Review and Meta-Analysis” looked at a compilation of all studies in the literature published between 2000 and 2012 and analyzed the effectiveness of games across all of them (Clark et al., 2013). The preliminary findings from the study suggest that relative to traditional approaches, games can enhance student learning as measured by cognitive competencies, primarily for knowledge outcome measures rather than cognitive processes/strategies. When compared to a control group, students’ achievement could have been raised 12% in cognitive learning outcomes if they had received a digital game. The study suggests however that this evidence was only valid for games that had quality and advanced designs. The positive effects of games on learning was highly dependent on the design of the game rather than just the fact that students were playing a game.

Another recent study looked to determine if the use of educational games in a community college microbiology classroom increases motivation and achievement (Rouse, 2013). The participants of this study were pre-nursing students enrolled in a southern community college microbiology class who were given class time to play the games and complete the questionnaires. Students in the experimental group demonstrated
significant difference in motivation levels in attention, relevance, confidence, and satisfaction. Also there was a statistically significant increase in the flow (antecedent, experience, and intrinsic motivation.) totals of all four units. However, there appeared to be no difference in flow of extrinsic motivation between the groups. Students who participated in educational games had higher post-test scores than students who did not. The control and experiment pre-test means were 57.35% and 57.21% respectively, while post-test means were 82.95% vs. 94.27%. Students who participated in educational games scored significantly higher for all four units. Overall, gamification did improve both motivation and achievement.

These three studies highlight that there has been success with both using educational games and gamification in the science classroom. Student engagement, achievement, and motivation all can be affected positively by high-quality games and holistic classroom game environments. However, the research for using gamification for improving science practices and processes specifically is still limited and more research is needed.

Gamification with the 5E Learning cycle

The 5E learning cycle is an effective science-specific learning pedagogy that Bybee & Landis, Bybee et al., Stamp and O’Brien (as cited in Tzu-Chien, Hsinyi, Wen-Hsuan, & Ming-Sheng, 2009) consider a hands-on, minds-on, and inquiry-based learning method that can enhance understanding.

The 5E learning cycle starts with the engagement phase where opportunities are provided to engage students, assess prior knowledge, make connections, and organize thoughts about learning outcomes. Students then enter the exploration phase where
teachers provide activity opportunities to explore concept processes and skills. New ideas are generated as students reflect on questions and possibilities. The experiences in the exploration phase provide a foundation of common experience that are drawn upon as students investigate this primary investigation. Students then enter the explanation phase where teachers can intervene and explain the concept being learned through direct instruction in a way the students wouldn’t be able to do on their own. The elaboration phase also allows students to draw upon their experiences in the first two stages to demonstrate how their understanding or skills can contribute to understanding what they have experienced. Teachers then challenge and extend the student’s learning in a way that draws upon the first three stages. Students use what they learned and apply it to different contexts and situations to deepen their understanding and skill level. Lastly, a student’s progress is measured in the evaluation phase. Teachers and students are involved in the assessment of the progress and understanding of the instructional goals.

Martin-Hauser, and Windschitl (as cited in Tzu-Chien, et al., 2009) consider the cycle a guided-inquiry where teachers provide guidance, materials, and problems that allow students explore and develop procedures to solve those problems. Balci, Cakiroglu, and Tekkaya (as cited in Tzu-Chien, et al., 2009) studied the effectiveness of the 5E learning cycle compared to direct instruction for a genetics class for 8th graders and found that students who participated in the 5E learning cycle were able to better activate prior knowledge to overcome misconceptions. They also had a better opportunity to explain, argue, and debate their ideas.

A study on fourth grade students in Taiwan incorporated the 5E learning cycle with mobile, tablet-based, learning environments, and found that the 5E learning model
was effective at increasing content knowledge and learning motivation (Tzu-Chien, et al., 2009). Students scored significantly higher in tests for understanding after they completed the learning activities. This is attributed to the depth of content coverage provided through the 5E learning cycle, the ease of misconception identification through adequate support of mobile devices, the degree of hands-on inquiry experiences, and the prolonged engagement that the activities provided.

Paul Anderson, Montana’s 2011 teacher of the year, has successfully incorporated game mechanics and a 5E-learning-cycle-based approach to gamify his AP biology class (Brunsell & Horejsi, 2013). Anderson’s approach to game design used a unique learning cycle approach (QuIVERS) in which students used a Moodle-based delivery method to allow students to engage in a question, explore an investigation, watch a video, read an elaborative reading, review, and take a summary quiz. He used game elements involving a leveling system, class leaderboards, avatars, and computer applications to engage students in learning science. Anecdotal evidence suggests that there is more time available for individualized attention for students who need help and students are highly motivated by the self-paced learning.

**METHODOLOGY**

To improve student success and scientific literacy, I investigated the impact of utilizing gamification and the 5E learning cycle (QuIVERS) with high school honors chemistry students in a classroom environment to improve student performance and foster student identities as scientists. My control group was my chemistry students from last year and their averages from the previous year’s tests, quiz scores for the same units
covered, and final exam scores at the end of the semester. The intervention lasted around 4.5 weeks.

Participants

I teach at Notre Dame Preparatory Academy in Pontiac, MI. It is a Catholic School that has around 800 students in the high school and the class selected was a class of 21 sophomores: 11 girls and 10 boys. These students were honors students with an above average academic ability (as a class, and as a school) and therefore don’t have any special learning needs. The students at NDP are very motivated, driven, and have strong family support. The school is not very diverse, drawing upon mostly white middle-upper class families as its primary source of students.

Intervention

I used a gamified learning environment with a modification of the 5E learning cycle (QuIVERS) to deliver content to my Honors Chemistry students. The intervention was inspired by Paul Andersen, who developed the QuIVERS method for his biology classes. In my intervention, I incorporated the following characteristics of gamification: self-paced advancement, failure normalization, badges for completing challenges, and levelling. Participants had limited opportunities to move at their own pace to complete challenges and earn badges linked to specific learning objectives to demonstrate mastery. As they choose to complete required and additional challenges, they earned badges and progressed through each unit’s learning objectives. Originally, I had planned on students gaining levels every time they earned a set number of badges, but the process became overwhelming and I abandoned it early on. If I had done levelling, the higher level a student progressed to, the higher rank research scientist they would became. Unit
modules were set up so that students became research scientists in a game with game avatars that they themselves drew and designed.

In my class, my students do homework when I assign it, they work on it that night, and the following day I stamp the homework for completion when it is due. The homework is corrected as a class and students are required to make additions and corrections with red ink. Students can earn full points for their homework if it is complete on time and they have made sufficient corrections to incorrect problems. For this intervention, students will initially be given strict deadlines for challenges so that practice worksheets are completed before relevant assessments. Eventually, students could be given more freedom on when they could complete the challenges leading up to an assessment, but deadlines will be set for all challenges for this intervention. The self-directed progress piece came from bonus challenges they could choose to pursue. Rather than use class time to go over the homework answers with everyone, I gave hard copies of answer keys accessible only when I had reviewed with them and their group their completed assignments and then on their own they checked the answer key, asked me the questions that they needed to, and made the changes as they needed to.

Collaborative learning was a focus as each student was not only a research scientist, but they also were an elite member of a Chem-Guild-- a small, heterogeneous, group of students who will work together to solve various challenges for themselves and for the benefit of the entire class. In addition to having students earn badges individually, each Chem-Guild was able to earn Guild-specific badges which showed up on their guild avatar and their individual avatars. Chem-Guilds were an aspect of the intervention that I used to attempt to meld the self-paced aspect of the QuIVERs method into a more
collaborative endeavour. In-class challenges were an opportunity for guilds to earn these guild-specific badges. I used the badge system incorporated into Haiku, which is similar to Blackboard.

Because students needed to work together in-class to accomplish various tasks, some of the QuIVERS learning cycle was required for them to do at home. The question, explore, and video phase were something students needed to do at home for homework. The elaboration and review phase took place primarily in the classroom where students applied what they learned with help from their peers and guidance from me.

**Context**

Two and a half weeks were spent on nomenclature, hydrates, empirical formulas, and molecular formulas. The following two weeks were spent on writing and balancing chemical equations, reaction types, predicting products, and net ionic equations. Located in Figure 1 are my objectives for the units of the intervention. For example, objective (a.) for nomenclature was broken down into seven challenges based on the different type of skill students were to learn: name to formula for ionic, name to formula for molecular, formula to name for ionic, formula to name for molecular, name to formula for acids, formula to name for acids, hydrates. QuIVERS modules and videos were used for the other content topics. Since I incorporated the 5E learning cycle, I presented the modules to the students in a way that gave them a meaningful question to investigate in the context of my storyline (see following paragraph). For example: “On a mission to investigate some ruins, one of your team members stumbles upon a hidden stockpile of chemicals. Only one problem, you don’t know what the names and formulas on the containers mean. Using your skills of scientific observation and SMR Robbie, it is your task to figure out
how the names and formulas are related to the compounds you want to bring back to your outpost.”

1. **Nomenclature** (2.5 weeks to complete)
   a. I can turn a chemical formula to name and name to formula for the following:
      i. Ionic, multivalent, polyatomic ionic, hydrates, molecular (covalent)
   b. I can calculate the percent composition of elements in a compound
   c. I can find the empirical Formula from the masses of different elements that make up a compound.
   d. I can use a compounds molar mass and its empirical formula to determine its molecular formula.

2. **Chemical Reactions** (2 weeks to complete)
   a. I can apply the law conservation of matter through balancing reactions
   b. I can predict a reactions reactants or products by applying common reaction patterns for common reaction types:
   c. I can recognize the following reaction types
      i. Synthesis
      ii. Decomposition
      iii. Single replacement reactions
      1. I can an activity series to determine if a reaction occurs.
      iv. Double Replacement reaction
         1. I can recognize what is necessary for a double replacement reaction to occur.
         2. I can use a Solubility table to determine if a reactions occurs and a precipitate forms
      v. Combustion
   d. I can write complete ionic equations for single and double replacement reactions
   e. I can write net ionic equations for single and double replacement reactions

---

**Figure 1. Learning Objectives for Units of Study.**

**Fictional Storyline of Gamified Environment**

The following storyline will be read to students at the start of the unit before students are instructed to draw their avatars and Chem-guilds are formed.

Suddenly you are aware that you are awake. The last thing you remember, but it seems like so long ago, was that it was the year 1999 and a giant asteroid was on a direct collision-course towards Earth! You shudder as you remember the fear of that day. As you sit up the feeling begins to return to your stiff limbs. You open your eyes and look around you realize that you
and those you find yourself with now were the ones lucky enough to be randomly chosen among a group of everyday-people to be cryogenically frozen. With the future of the world as it was known a mystery, the goal was to try to preserve a representative sample of the population in case the catastrophic event unfolding at the dawn of the new millennium destroyed civilization! But what happened?

Little did you know, that when the asteroid collided directly with Earth, everything changed. Originally, you were supposed to be frozen for only 50 years, but the computer malfunctioned and you stayed frozen in an underground bunker for 1000 years! Now, as you slowly rise from your deep sleep and crawl through seemingly endless piles of rubble on your way to the Earth’s surface in the year 3000, you encounter a world that has lost all knowledge of science! You find planet Earth overrun with monsters, countless perils, and a world that is in a desperate need of research scientists to undo the confusion caused by hundreds of years of people who have forgotten everything about science. You now must use your own wits and your trusty Science Mentor Robot (SMR Robbie), who was programmed by the greatest scientists of the 20th century, to learn about and to teach this new era of humans about the nature of the world that you now find yourselves in. Who would have known just an everyday person like you would become the Revolutionary Scientist that just might be the world’s only hope! You suddenly realize that this is a big job and the only way you have a chance is if you work together with those around you. As you start
to ponder how good at science you think you are or aren’t, the fact slams into your consciousness all at once: you are infinitely better at science than the rest of humanity is right now and… there is something about this place. You feel smarter. Soon you will realize that the people here will look up to you as a scientist, a name from legends! You don’t quite know what it is, but you feel like despite the hard work to come, you really are a research scientist now and whatever you need to do, you can and will do it!

**Badging**

To incorporate prompt feedback and a rewards system I used badges that students earned upon the completion of various challenges. My school uses a cloud-based content creation and sharing tool called Haiku Learning. Assignments, feedback, and grades are all in one place for students. Haiku includes a badges system to give students unique feedback, which I implemented. The intervention applied to the two units of study mentioned above. I broke each unit into badges earnable through mastering content from homework worksheets and in-class challenges. Completion of each worksheet unlocked a summary quiz that was worth a badge. Depending on how students performed on the quiz, the badge they earned was gold (~A-range grade), silver (~B-range grade), or bronze (~ C-range grade or below). The in-class challenges were content-specific and the entire group could earn a badge for successfully completing them. Students were also able to receive badges if they created their own avatars. I did not have a class leaderboard to display who has the most badges or the highest levels, but if students looked at each other’s Haiku profiles, they could see their avatar and the badges each had earned. I wanted the environment to be cooperative rather than competitive.
Curriculum content was broken down into a series of challenges that each Chem-Guild or individual students had to face. These challenges were delivered via the complete QuIVERS approach as much as possible. They started with a question; students then explored an investigation, watched a video, read an elaborative reading, reviewed by self-correcting their homework, and took a summary quiz. Because much of the content was primarily based on direct instruction, rather than scientific inquiry, most of the questions were re-written forms of the objectives the students were expected to learn at the end of the specific challenge. Each challenge started with a small bit of storyline, which put students in a position where they would have to master certain content if they were to help the village of the fictional story. Each challenge had various components of QuIVERS, while some components were left out if they didn’t fit. For example, the first challenge of the nomenclature unit found in Appendix J had no video component. The first challenge of chemical reactions unit found in Appendix L had no investigation or elaborative reading, but included the question, the video, the password-protected review answer key, and the password-protected summary quiz. Student would get their worksheets stamped for completion at the start of class and I would give them the passwords for the review and summary quiz so they could spend some time in-class making corrections and attempting to earn a badge. See also Appendix K for ChemGuild Challenge 1: Acid and Appendix L for Challenge 1: Reaction Types. These appendices include screenshots of the challenge viewable from the Haiku interface, worksheets, keys, summary quizzes, badges, and any relevant component that made up the challenge. To add an element of fun each worksheet had a small video game character or popular-culture icon which also became the basis for the passwords chosen as well as the image
for the badge. Examples of these badges can be found in Appendices J-K. Summary quizzes also included feedback for wrong questions that highlighted either what they did right, or gave them hints to see why they were wrong and what they needed to correctly answer a problem. Examples of the feedback given in multiple choice questions can be found in Appendix L. Students would get partial credit for a question if it didn’t get answered correctly and each incorrect answer would make the question worth 25% less point value for a maximum of four attempts. Gold, silver, or bronze badges were awarded based on how well they were able to do on quizzing over the challenge’s objectives. These questions were written for each challenge based on the objectives, the worksheet questions, and on test questions over relevant content covered in the challenge. I wrote many of the questions to be similar to questions they would need to be able to answer later on the test.

The nomenclature unit had seven total challenges that incorporated content from six worksheets and one in-class Chem-Guild challenge: Challenge 1: Poly Ions, Challenge 2: Nomenclature, Challenge 3: Nomenclature Review, Challenge 4: Percent Composition, Challenge 5: Empirical Formulas, Challenge 6: Empirical Formulas & Percent Composition Revisited, and ChemGuild Challenge 1: Acid. Challenge 1 and all its accompanying components can be found in Appendix J while the ChemGuild Challenge can be found in Appendix K. The chemical reactions unit had a total of six challenges: Challenge 1: Reaction Types, Challenge 2: Balancing Equations, Challenge 3: Predicting Products or Reactants, Challenge 4: Net Ionic Equations, Challenge 5: Exciting Reactions, and ChemGuild Challenge: Battle for Middle Earth. Challenge 1: Reaction Types and its components can be found in Appendix L.
Data Collection

Student-generated artifacts included unit tests, quizzes, and student self-assessments. Quiz scores and test scores were compared to average scores from the previous year when no intervention was applied. A Self-assessment questionnaire was used during the intervention to measure student progress towards learning objectives as well as provide an opportunity for me to make changes as necessary during the intervention. I used a modified version of classroom assessment technique Focused Autobiographical Sketch (Angelo & Cross 1993). The self-assessment can be found in appendix I. My control group was class averages from the previous year’s test and quiz scores for the same units covered. Summative assessments can be found in Appendices A-B, while formative assessments can be found in Appendices C-F.

Surveys were given before and after the intervention. I made clear to students that honesty and accuracy were critical, and that honest feedback would help me create and improve teaching activities to increase student learning and growth. The survey focused on student’s scientific identity and included attitude scales as well as an open-ended question. The student survey can be found in Appendix G. This survey was modified from the Conceptual Science PoR Student Survey (Morris, 2013).

I kept a journal of my own feelings and observations throughout the study. I focused on how the implementation was going, analyse and reflect on participant responses, and any discussed any surprising events that occurred.

At the end of the intervention, student interviews were administered to five students; one student who was high-achieving, two who were average-achieving, and two who were low-achieving based on their grade during the semester. The interviews
focused on student perceptions about the effectiveness of the QuIVERS learning modules and whether the modules affected student identities as a scientists. Students were also asked during the interview the ways in which they thought QuIVERS could be improved and the positive and negative aspects of the intervention. The interview was semi-structured, which included specific and open-ended questions based on the participant’s responses. The interview questions can be found in APPENDIX H. Table 1 summarizes my data collection techniques.

Table 1

<table>
<thead>
<tr>
<th>Data Triangulation Matrix</th>
</tr>
</thead>
<tbody>
<tr>
<td>Focus Question:</td>
</tr>
<tr>
<td>Primary Question:</td>
</tr>
<tr>
<td>1. Will Implementing Elements of Gamification and the 5E Learning Cycle Into a Classroom Improve Student Performance?</td>
</tr>
<tr>
<td>Sub Question:</td>
</tr>
<tr>
<td>2. Will Implementing Elements of Gamification and the 5E Learning Cycle into a Classroom Foster Student Identities as Scientists?</td>
</tr>
</tbody>
</table>

DATA AND ANALYSIS

As previously stated, this study took place during the start of the second semester and was aimed at addressing is whether or not implementing elements of gamification and the 5E learning cycle into a classroom improved student performance and fostered scientific identities. Some of my students decided not to participate in the pre- and post-intervention surveys, so there were an uneven number of data points for comparison.
There were a total of two classes (47 students) in the control group from last year and only one class of students (22 students) in the treatment group that contributed to the assessment scores to gauge student performance. I used assessment scores, self-assessment surveys, interviews, and field notes to report results for my first research question. I used pre- and post-intervention attitude surveys, interviews, and field notes to report my results for my second research question.

**Effect on Student Learning**

In the following paragraphs, I will examine student learning by comparing test and quiz scores, analyzing observations and field notes, and analyzing student perceptions of their learning.

Overall, the impact on student learning is inconclusive. Based on the results from looking at the mean scores for quizzes and tests for the control group from last year compared to the test group, it appears that the intervention had no significant impact on student learning. After comparing the scores for four quizzes and two tests, some were slightly higher, some were slightly lower, and some remained the same. The largest gain was noticed on the Chapter 8 test, where the average increased by 3.86% as compared to the control group. All other assessments resulted in fluctuations that were less than 3.00% either higher or lower. These results are displayed in Table 2 on the following page.
In analysing my first research question, I also used my teacher journal and field notes observations to help me evaluate student performance, which included how students were responding to the intervention on a daily basis. Having taught the material in a different way before and seeing how my students responded to the intervention as a whole, I am making the claim that student engagement in class improved. After looking over my field journal and reflecting, I noticed that students were more engaged, were having more fun, were more on-task, and worked better independently as well as in groups. On January 8th, 2015, when I first introduced the intervention and read through the fictional background story and gave them their first challenge, I recorded in my field journal: “After reading the story students clapped and were excited. The level of excitement was high today.” Later in that entry, I noted a certain student who when he did poorly on the first summary quiz was asking if he had another chance to learn the badge or get more points. This excitement and desire to do well continued throughout the intervention. On Jan 30th, I recorded: “I noticed that today, I gave students a lot of time to work independently, but they were all on task the entire time. Students didn’t seem
especially confused and they worked well with each other.” On Feb 3rd, I noted “Students engage, stay on task, work together at their own pace and I can come and help when needed. Students seem more confident and seem to be enjoying themselves.”

Student Perception

The majority of students perceived the intervention as helpful. Before the interviews were conducted, I administered a survey to help me see how students were responding to the intervention and to see what changes I could make. I was about halfway through the intervention when I administered the questionnaire. This questionnaire can be found in Appendix I. I focused on what specifically they found helpful or not helpful for their learning and what has improved their confidence as a scientist. Eleven students returned this questionnaire. From this assessment alone, the majority of comments supported that the intervention was helping students learn the content better. Seven out of eleven respondents mentioned the helpfulness of the summary quizzes. Some comments about them included that they helped students know what they could improve on, test themselves, and build confidence. Also mentioned was that they helped ensure a student would not forget lesson from night before. The quizzes themselves were thought by one student as: not too difficult or too easy and a good length. Seven of the eleven respondents also mentioned the videos as being especially helpful in their learning. Student comments included that it helped them learn better, that it was convenient, and that it gave them time to stop and process and fully understand.

Other notable responses from the questionnaire included that the class was more fun and less boring, that the classroom had a better atmosphere, and that with the combination of in-class teaching and videos students felt they could actually do the
homework. In addition to students feeling more capable of doing the homework, it was appreciated that they had an opportunity in class to help other students and that they were allowed to ask questions. One student said: “I actually understood most of the questions,” in regards to success on homework assignments.

Based on the student interviews, the self-perception of improved performance was also inconclusive, even though students gave more positive feedback about the experience than negative feedback. The student interview questions can be found in Appendix H. There was significant evidence from the student interviews that showed that students felt certain aspects of the intervention helped them learn better. Four of the five interviewees found that the summary quizzes to be especially helpful in them learning the content. One student commented that they thought it helped their learning the most because it brought all ideas together and that it forced them to keep studying after they had originally learned the information. Another student likened them to a “mini-test” at the end that helped you “know if you got it” and it was helpful that it was similar to the test. Another student said they liked the hints provided when they got a question wrong. Three students mentioned fun as a contributor to their learning. Two students commented about the helpfulness of the videos and their availability and one student said it helped them to be able to go back if they didn’t understand. Other notable things students mentioned that helped their learning was that it was something different and new, that it was self-paced and they could ask questions if they needed to or move on. One student said that Chem-guilds could be helpful if he was in a good group. This supported the importance of well-scaffolded groups. One student said the intervention helped them understand better and another said it helped them go more in-depth to the topic.
A small number of students did have a negative experience with the intervention. Despite the majority of positive comments in the mid-unit questionnaire about the videos, there were still a number of students who thought the videos were not helpful. Three of eleven students disliked the videos and their comments included that they preferred in-class teaching, that videos were too fast or confusing, hard to learn from, and that they made them upset. One said that they felt overwhelmed, it took a long time to watch videos and do worksheets, and that there were not enough concrete examples that showed enough to effectively solve problems. There was also some evidence from the interview that suggested that the intervention hindered students from feeling they were performing as well as they could have. Many of these critiques were ones that I was expecting due to the flipped-classroom nature of some of the content. One student didn’t feel as comfortable because the teaching style was “not like normal.” Another student complained that it wasn’t clear to them what they needed to know. One of the students commented that it was harder to study. Another said it was harder not being able to ask questions while watching the videos. One student said technology issues with the quizzing system caused some concern, and the student who said that the Chem-guilds could be helpful, also said that the Chem-guilds were not as helpful when he was in a different group. The same student also complained that the videos were too simple and that the examples didn’t really adequately prepare students to solve the homework problems.
Impact of Gamification on Student Identities as Scientists

For the second research question, I used my results to assess was whether or not implementing elements of gamification and the 5E learning cycle into a classroom fostered student identities as scientists.

Based on the attitude survey given to students before and after the intervention, students did not feel more or less confident in their ability to do some of key practices of science that were included in the survey. While there were some science practices where student competence decreased, there were nearly just as many questions that students answered in a way that showed their competence increased. I grouped each question into categories based on five of the eight scientific practices determined by The National Research Council’s Framework for K-12 Science Education (2012). I then took each question and calculated the percentage of response in each of five possible responses: strongly agree, agree, neutral, disagree, and strongly disagree. I looked at data before and after to see if there was a percentage gain in statements in agreement or disagreement with the questions related to each science practice. Based on each question I made note of percentage changes toward or away from a “science- positive” response; one that a student who identified with a scientist would likely make. I summarized the results in Table 3 on the following page.
<table>
<thead>
<tr>
<th>General Competence and Relevance</th>
<th>Pre-SA or A %</th>
<th>Post-SA or A %</th>
<th>Pre-D or SD %</th>
<th>Post-D or SD %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. I enjoy taking part in activities that most people would consider “doing science.”</td>
<td>65</td>
<td>68.75</td>
<td>10</td>
<td>6.25</td>
</tr>
<tr>
<td>2. When I think about it, science is something I use frequently in my everyday life.</td>
<td>80</td>
<td>72.22</td>
<td>5</td>
<td>12.5</td>
</tr>
<tr>
<td>Asking Questions</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. I feel confident asking questions that are “testable”</td>
<td>65</td>
<td>62.5</td>
<td>5</td>
<td>6.25</td>
</tr>
<tr>
<td>Developing and Using Models</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. I can make and use models to represent complicated phenomenon</td>
<td>33.33</td>
<td>31.25</td>
<td>33.33</td>
<td>31.25</td>
</tr>
<tr>
<td>Planning and Carrying Out Investigations</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. I believe that failure is an important part of success</td>
<td>100</td>
<td>87.5</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Analyzing and Interpreting Data</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. I am good at making sense of data</td>
<td>54.55</td>
<td>56.25</td>
<td>18.18</td>
<td>12.5</td>
</tr>
<tr>
<td>Engaging In Argument From Evidence</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. I am likely to modify my thinking if I am confronted a better explanation</td>
<td>78.95</td>
<td>76.47</td>
<td>16.67</td>
<td>0</td>
</tr>
<tr>
<td>8. I will usually accept or believe something without needing evidence to back it up</td>
<td>15</td>
<td>12.5</td>
<td>50</td>
<td>56.25</td>
</tr>
<tr>
<td>9. Collecting evidence is an important part of making a decision</td>
<td>85</td>
<td>100</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>10. I can make a claim and back it up with evidence when I am trying to make a point</td>
<td>75</td>
<td>100</td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td>11. I can critique the claims of others as a “reflective friend”</td>
<td>70</td>
<td>87.5</td>
<td>5</td>
<td>6.25</td>
</tr>
<tr>
<td>Obtaining, Evaluating, and Communicating Information</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12. Science is mostly in individual effort, rather than a collaborative one</td>
<td>5</td>
<td>18.75</td>
<td>65</td>
<td>56.25</td>
</tr>
<tr>
<td>13. I am open to listening to alternative explanations or the viewpoints of others</td>
<td>100</td>
<td>87.5</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>14. I feel confident contributing to group efforts to solve science-related problems</td>
<td>80</td>
<td>62.5</td>
<td>5</td>
<td>12.5</td>
</tr>
<tr>
<td>15. I can explain my thoughts well to others</td>
<td>80</td>
<td>81.25</td>
<td>10</td>
<td>6.25</td>
</tr>
</tbody>
</table>
Overall, changes were small in many categories. Statements related to using evidence became more positive, while those relating to obtaining, evaluating and communicating shifted negative or more towards neutral.

In evaluating students’ general competence and relevance in science, more students enjoyed “doing science,” but less students found science as relevant in their everyday life. In terms of asking questions, students felt less confident asking testable questions after the intervention. Slightly less students felt comfortable making and using models even though there were slightly more neutral responses as well. As part of carrying out and planning investigations, there was a 12.5% decrease in students who thought failure was an important part of success.

Students did feel more confident in analysing and interpreting data. There was positive evidence to suggest that students felt better in engaging in argument from evidence as well. Even though students felt less likely to modify their thinking based on better explanations, there were significant gains noted in four of the responses related to engage in good argument from evidence. Despite feeling more confident explaining their thoughts well to others, students felt less confident in three of the four questions relating to obtaining, evaluating, and communicating information.

The final question in the survey asked students: “In what ways do you consider yourself a scientist?” This open-ended question had many varied responses both before and after. One problem with these results was that students seemed to put more effort into the responses the first time. Also, fewer students responded the second time. There were more detailed responses the first time so based on the number and variety of more detailed responses, it would seem students felt more like scientists before the
intervention. However, there was some evidence that supported a slight increase or at least no change in scientific identities among the respondents. I looked at comments that appeared both before and after and noted their frequencies. The results are summarized in Table 4. Seven of the 16 students after commented on their ability to make claims based on evidence, whereas only six of the 19 respondents mentioned it the first time. Four respondents after as compared to only two before mentioned that they enjoyed learning. Two students said they were good at collecting data where only one student mentioned it before. One student mentioned afterwards that he could make a model where no students mentioned it before. Three students before and after mentioned their ability to do experiments and perform tests. Three respondents of 16 who took the post survey responded that they were good at solving problems, whereas only two of 19 students mentioned problem solving as one of the ways they considered themselves a scientist. Four of the 19 before and three of the 16 after noted their ability to ask researchable questions.

Table 4
Patterns in Scientific Identity Open-Ended Question

<table>
<thead>
<tr>
<th>Comment</th>
<th>Percentage Before (19 respondents)</th>
<th>Percentage After (16 respondents)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Make Claims and support with evidence</td>
<td>32%</td>
<td>44%</td>
</tr>
<tr>
<td>Enjoy learning</td>
<td>11%</td>
<td>25%</td>
</tr>
<tr>
<td>Collecting data</td>
<td>5%</td>
<td>13%</td>
</tr>
<tr>
<td>Making models</td>
<td>0%</td>
<td>6%</td>
</tr>
<tr>
<td>Experiment and test</td>
<td>16%</td>
<td>19%</td>
</tr>
<tr>
<td>Solving problems</td>
<td>11%</td>
<td>19%</td>
</tr>
<tr>
<td>Asking researchable questions</td>
<td>21%</td>
<td>19%</td>
</tr>
<tr>
<td>Wonder and curiosity</td>
<td>16%</td>
<td>6%</td>
</tr>
<tr>
<td>Explore</td>
<td>11%</td>
<td>6%</td>
</tr>
<tr>
<td>Be observant</td>
<td>5%</td>
<td>6%</td>
</tr>
</tbody>
</table>
The results from the interview strongly support that there was no change to the scientific identities of students after the intervention. Four out of the five students interviewed mentioned that the way they feel about science hasn’t changed or that their ability to “do science” is the same after the intervention as it was before. One student noted how the intervention actually caused more of a lack of human interaction. On a positive note, two students commented on their improved ability to look at problems with different approaches; in “more than one way, not just one set way.” One student commented that it was more hands-on vs. lecture. He was “not just listening to talking.” Another student commented that he was better able to look at data after the intervention. Other positive comments included that students were more interested and knew better how to do problems because of the intervention.

Based on my field notes and teacher observations, I felt my student’s growth in their scientific identity the most on their ability to ask questions and work together. On February 6th, 2014, I recorded in my journal: “Students ask me questions and when I see that they are struggling I can help them and give them a little bit of personal one on one feedback which is nice.” I also noticed that through the intervention students were growing in their awareness of the importance of failure as a part of the learning process. As part of the summary quizzes, I began to incorporate immediate feedback and hints into each wrong response. In my journal, I recounted a time where I forget to do this: “On the last summary quiz, I accidentally made the quiz an exam type and when I did so, students didn’t have a chance to get feedback on what they did wrong.” Students pointed out to me that day that they didn’t have a chance to go back and get hints and learn how to do it right so just accepted whatever result they had and moved on. After looking at
student scores for other quizzes, I noticed that nearly all non-perfect scores throughout the intervention had decimal values rather than whole numbers. That meant that students went back after they got a problem wrong initially and learned the right way to do it before submitting the quiz. Students were quick to catch when they had made a mistake and sought how to fix it and if there were mistakes on my end with a poorly-worded question or answer, students were quick to help me realize I needed to fix the problem. They saw that failure, even on my end was perfectly okay, acceptable, and part of the process. However, I also realized very early into the intervention that the content and labs that I was planning on covering during the intervention did not include enough inquiry to really help my students become as much as scientific thinkers as I had originally hoped they would become. On January 8th I noted, “After looking at my survey, I am not going to be effective unless I come up with some activities to allow students to do some actual inquiry. Looks like I might have to modify my labs a bit.” I felt that the amount of content that was direct-instruction heavy was too much to really effectively engage my students in practices of science to truly have a significant impact on their scientific identities. After the project, I still feel like the growth in my students in all of the areas of science I wanted them to improve upon was rather limited because of the relatively few chances for students to engage in the practices I wanted them to foster.

INTERPRETATION AND CONCLUSION

Through the use of gamification and the 5E learning cycle (QuiVERs) students seem to be most impacted in their confidence and willingness to learn in environments where failure is not heavily penalized but rather encouraged and understood to be part of the learning process. The majority of students found the intervention positive and helpful.
The research shows that games can help students succeed when failure becomes a productive part of play and is naturalized through repetition and discovery (Schaffhauser, 2013). With the possible exception of notable gains in achievement, my results matched the research that demonstrated that student engagement, achievement, and motivation all can be affected positively by high-quality games and holistic classroom game environments (Barata et al., 2013; Clark et al., 2013; Rouse, 2013).

Students built confidence by watching and re-watching videos to work on mastering the content at their own pace. Their confidence was also improved by having the opportunity to make, fix, and learn from their mistakes on the homework. They appreciated being encouraged to ask questions and being able to receive prompt and constructive feedback on the multiple-choice problems. By normalizing failure my students used their energy to learn rather than to focus on fear of not being able to understand. I remember saying to one of my students: “It’s good that you got it wrong. That’s good. Now you won’t get it wrong next time.” The student initially laughed, but it was because they realized that it was true.

The next steps for further implementation of this approach is to incorporate more ‘doing science’; into the curriculum or try to adapt it to a course better fitted to take advantage of it. I could further develop my current curriculum to cater my lessons and challenges to give students an opportunity to more fully engage in authentic science practices. I can focus more on setting up challenges that take advantage of the 5E learning cycle for what it is. This means starting a challenge with a truly compelling question and not just re-stating an objective in question form. The objectives were important, but there was less wonder and less exploration involved; both aspects I feel are
a part of what this intervention is really made for. I underutilized many of the QuIVERs components that might be a better fit with a different course or perhaps for only specific content. I specifically would like to incorporate this into my AP Physics 1 class where I feel the nature of how I run my class fits more appropriately with the QuIVERS approach. Since my Chemistry class is very teacher-directed, linear, and structured, it was difficult for me to really take full advantage of the possibilities of the gamification intervention. In my AP Physics class, I usually start every day with a question that could be investigated. I also do many open-ended inquiry labs whereas most labs in Chemistry were “cook-book” labs rather than true investigations. I could really incorporate the elaborative readings section of QuIVERS better by using the textbook more to provide supplemental instruction and clarification like I do in my AP Physics class. I would like to incorporate more podcasts of lecture notes so I have more time in-class to do example problems. This may entail introducing basics like equations, definitions, and general ideas into a video student could watch that goes along with the reading. Students would see it in the videos, in the reading, take it in the summary quiz, and see it in class when I worked on example problems. The review could be a chance for students to look at an outline of a chapter instead of just an answer key to a worksheet.

I also want to further develop making prompt and helpful feedback on my multiple-choice questions so I can spend less time explaining questions in class and more time on doing example problems. The better the feedback, the more likely students will figure it out without giving up or getting discouraged. I feel that the badge system was too bulky and time consuming to use as frequently as I originally did. If the technology improves, I would like to keep using badges. There was a great demand with the amount
of time necessary to give badges with the system that I had in place and might like the idea of using experience points instead, which could be earned from the summary quizzes. Students would be able to gain levels rather than gain badges. I liked the idea of experience points and would like to experiment with making a leader board where student can see their standing in comparison to their peers and I could see how adding the elements of competition helps or hinders the learning process.

I could increase the duration of the intervention and see if it had a stronger impact on student learning. Perhaps next year I can incorporate aspects the QuIVERs method into my content from 1st semester as well. To help foster identities in science I can try to incorporate content in ways that involve more science practices and inquiry.

VALUE

The use of gamification can be beneficial for both improving student achievement as well as helping students develop sound scientific practices. However, careful planning and design is needed that can incorporate authentic experiences that engage students in the practices of science. Although there isn’t a wealth of current research on effective uses of gamification to teach science, the potential benefit is still apparent as students were more engaged, confident, and willing to learn. Students who could relate to video games might have been more willing to learn in the familiar context of playing a game than in a traditional science classroom. Adding various components of games can be used to teach not only content, but also science practices. Many aspects of good video games can easily be incorporated into providing students opportunities to investigate phenomenon and engage in science. Because of the importance of careful design, the
time needed to incorporate a successful gamification intervention may, for some, outweigh the possible benefits. Also, gamification elements can easily become gimmicks or forms of extrinsic motivation if they are not properly incorporated into instruction. It is important to remember that teaching and learning can take many forms and that if students can be as engaged and devoted to being successful in their learning as they are to playing a videogame, there is much opportunity for improved learning. Finding what students are interested in and what works to get them excited about learning, not necessarily what has worked in the past, is an important realization for a successful educator.

The process of action research has helped me to listen to my students and realize that I must adapt as a teacher to what works best for my students in my school. While there is no one way to be a successful teacher, there is definitely a uniformly bad way, and that is by becoming stagnant and complacent. Trying new things and reflecting on what does and doesn’t work is a process that must be taking place as long as I am an educator. I have learned that there is balance between learning about good teaching practices and finding will actually work with my students. What works well for someone else, may not necessarily work for me and that is perfectly fine. As the semester went on, I continued to use the format of challenges and summary quizzes to help my students prepare for tests and quizzes. The amount of time necessary to start using technology was initially high, but I can see that having a predictable and effective system in place will help me to be more efficient in the classroom and help me better meet the needs of my students in the future.
REFERENCES CITED


APPENDIX A

NOMENCLATURE UNIT TEST
CHEMISTRY TEST Version A

CHAPTER 7

NAME: __________________

PERIOD: ______________

Directions: For each of the following questions, choose the letter that best answers the question and place it on your answer sheet.

1. Molecular compounds are usually ____.
   a. composed of two or more transition elements
   b. composed of positive and negative ions
   c. composed of two or more nonmetallic elements
   d. exceptions to the law of definite proportions

2. Which of the following formulas represents the correct name and formula for a molecular compound?
   a. N\textsubscript{2}O nitrogen dioxide
   b. ZnO zinc oxide
   c. Si\textsubscript{2}O disilicon monoxide
   d. BeF\textsubscript{2} Beryllium difluoride

3. What type of ions have names ending in -ide?
   a. only cations
   b. only anions
   c. only metal ions
   d. only monoatomic gaseous ions

4. Which of the following compounds contains the Mn\textsuperscript{3+} ion?
   a. MnS
   b. MnBr\textsubscript{2}
   c. Mn\textsubscript{2}O\textsubscript{3}
   d. MnO

5. Which of the following shows correctly an ion pair and the ionic compound the two ions form?
   a. Sn\textsuperscript{4+}, N\textsuperscript{3−}; Sn\textsubscript{4}N\textsubscript{3}
   b. Cu\textsuperscript{2+}, O\textsuperscript{2−}; Cu\textsubscript{2}O\textsubscript{2}
   c. Cr\textsuperscript{3+}, I\textsuperscript{−}; CrI
   d. Fe\textsuperscript{3+}, O\textsuperscript{2−}; Fe\textsubscript{2}O\textsubscript{3}

6. Which set of chemical name and chemical formula for the same compound is correct?
   a. iron(II) oxide, Fe\textsubscript{2}O\textsubscript{3}
   b. aluminum fluorate, AlF\textsubscript{3}
   c. Tin (IV) selenide, SnSe\textsubscript{2}
   d. potassium chloride, K\textsubscript{2}Cl\textsubscript{2}

7. In writing the name (not formula) for a molecular or covalent compound, the number of atoms of each element present in the molecule is indicated by ____.
   a. Roman numerals
   b. superscripts
   c. prefixes
   d. suffixes

8. When naming acids, the prefix hydro- is used when:
   a. Oxygen is present
   b. Hydrogen paired with –ite anion
   c. Hydrogen paired with –ate anion
   d. None of these
9. Which of the following shows both the correct formula and correct name of an acid?
   a. HClO₂, chloric acid  
   b. HNO₂, hydronitrous acid  
   c. H₃PO₄, phosphoric acid  
   d. HI, iodic acid

10. What is the formula for sulfurous acid?
   a. H₂SO₄  
   b. H₂SO₃  
   c. H₂SO₂  
   d. H₂S

11. What is the formula for hydrosulfuric acid?
   a. H₂S₂  
   b. H₂SO₄  
   c. HSO₂  
   d. H₂S

12. The formula for magnesium nitrate is
   a) Mg(NO₃)₂;  
   b. Mg₂NO₃;  
   c. MgNO₃;  
   d. Mg₂(NO₃)₃.

13. The formula of the oxide of titanium is TiO₂. The formula of the corresponding fluoride is
   a) TiF;  
   b) TiF₂;  
   c) TiF₃;  
   d) TiF₄;  
   e) TiF₄.

14. The correct formula for magnesium hydroxide is
   a) MgOH;  
   b) MgOH₂;  
   c) Mg₂OH;  
   d) 2MgOH;  
   e) Mg(OH)₂.

15. What is the formula for tetraphosphorus hexoxide?
   a. ₄P₂O  
   b. P₄O₇  
   c. P₃O₆  
   d. (P)₄(O)₇  
   e. None of these are correct.

16. What is the formula of chromium (III) sulfide?
   a) CrS₃  
   b) Cr₂S₃  
   c) Cr₃S₂  
   d) Cr₃S  
   e) Cr₃S₃

17. What is the formula for the compound aluminum phosphate?
   a. AlPO₄  
   b. AlP  
   c. A1₃PO₄  
   d. Al(PO₄)₃  
   e. A1₃(PO₄)₃

18. “M” represents a metallic element, the oxide of which has the formula M₂O.
   The formula of the chloride of M is
   a. MCl;  
   b. MCl₂;  
   c. MCl₃;  
   d. MCl₄.

19. Acetylene, C₂H₂, and benzene, C₆H₆, have the same empirical formula, CH. The molecular formulas could be found from comparing the molar mass of the empirical formula with which of the following:
   a. the mole ratios;  
   b. the combining ratios;  
   c. the molecular molar masses;  
   d. the heats of formation.
20. Which is the correct name for Fe$_2$(SO$_4$)$_3$?
   a. Iron (II) sulfate  b. iron (III) sulfate  c. iron (IV) sulfate
d. iron(II) sulfite  e. iron(III) sulfite

21. Silver hydrogen phosphate has the formula Ag$_2$HPO$_4$. What is the formula for iron (III) hydrogen phosphate?
   a. Fe$_2$HPO$_4$  c. Fe$_2$(HPO$_4$)$_3$
b. Fe$_3$(HPO$_4$)$_2$  d. Fe(HPO$_4$)$_3$  e. Fe(HPO$_4$)$_2$

22. Which formula is not correct?
   a. Al$_2$(SO$_4$)$_3$  b. BaHCO$_3$  c. Ca(OH)$_2$  d. NH$_4$HSO$_4$  e. LiCl

23. Which of the following is true of empirical formulas:
   a. They represent the most-reduced whole number ratio of atoms in a compound
   b. They show the simplest mole ratio possible among elements in a compound
c. Molecular formulas are always multiples of the empirical formula
d. All of the above are true
e. None of the above are true

24. Which of the following represents what chemists use in a compound’s name to distinguish metals that can lose a different number of electrons when bonding ionically (multivalence)?
   a) Subscripts  b) Roman Numerals  c) prefixes  d) Suffixes

25. N$_2$S$_3$ is properly named:
   a) nitrogen sulfide  b) nitrogen (III) sulfide  c) nitrogen (II) sulfide
d) none of these

26. Which of the following is a polyatomic ion?
   a) CaSO$_4$  b) NH$_3$  c) Mg$^{2+}$  d) SO$_3^{2-}$  e) none of these

27. The chemical name for FeO is:
   a) iron (I) oxide  b) iron (II) oxide  c) iron (III) oxide  d) iron (VI) oxide

28. When naming a ionic compound, the name of the component that has a positive charge is always written:
   a. first  b. last  c. with parenthesis  d. with no subscript
29. A compound contains 6.0 g of carbon and 1.0 g of hydrogen. The percent composition of the compound is:
   a. 14 % hydrogen and 86 % carbon
   b. 86 % hydrogen and 14 % carbon
   c. 17 % hydrogen and 83 % carbon
   d. 83 % hydrogen and 17 % carbon
   e. None of these answers are correct.

30. The empirical formula for the above reaction would be:
   a. CH₂   b. C₂H   c. C₆H   d. C₂H₅   e. None of These

31. Which of the following could be an empirical formula?
   a. N₂O₄
   b. N₂H₆
   c. N₂O₅
   d. More than one could be an empirical formula.
   e. None of these are empirical formulas.

32. If the empirical formula of a compound is CH₂ what is a possible molecular formula for the compound?
   a. CH₂
   b. C₂H₆
   c. C₄H₈
   d. More than one could be a molecular formula for CH₂.
   e. None of these could be a molecular formula for CH₂.

33. If the empirical formula of a compound is P₂O₃, what could be a possible molar mass of the compound?
   a. 55 g/mol
   b. 165. g/mol
   c. 275. g/mol
   d. More than one could be a molar mass for P₂O₃.
   e. None of these could be a molar mass for P₂O₃.

34. A compound is 40.0 % carbon, 53.3 % oxygen, and 6.66 % hydrogen. What is its empirical formula?
   a. C₄O₅H₇
   b. CO₂H₃
   c. COH₂
   d. More than one could be the correct empirical formula.
   e. None of these is the correct empirical formula.
35. If the compound in the previous problem has a molecular weight equal to 60.0 g/mol, what is the molecular formula?
   a. C₃OH₆
   b. CO₂H₁₆
   c. C₂O₂H₄
   d. More than one could be the correct molecular formula.
   e. None of these is the correct molecular formula.

36. How many total atoms are in one molecule of ammonium dichromate?
   a. 14                   b. 15                   c. 19                   d. 23                    e. none of these

37. The total number of atoms of oxygen represented in Na₂B₄O₇ • 10 H₂O is
   a) 7; b. 10; c. 17; d. 20; e. 27.

38. A formula representing a hydrate is
   a. H₂O₂; b. BaCl₂ • 2H₂O; c. NaOH; d. H₂SO₄

39. A 6.3 gram sample of a blue hydrate was heated until the water of hydration was driven off.
   The anhydrous compound had a mass of 4.8 grams. What was the percent of water (by mass) in the hydrate?
   a. 23.8% b. 31.3% c. 39.4% d. 76.2% e. 107.1%

40. The percent composition of aluminum in aluminum hydroxide is:
   a) 50% b) 25% c) 14% d) none of these answers is correct.
APPENDIX B

CHEMICAL REACTIONS UNIT TEST
Directions: For each of the following questions, choose the number that best answers the question and place it on your answer sheet.

1. In a balanced chemical equation:
   a. all coefficients are the same;
   b. there is the same number of atoms on each side;
   c. there is the same number of molecules on each side;
   d. energy is always produced;
   e. none of these.

2. To satisfy the law of conservation of matter, an equation
   a. must be written in words;
   b. should show the molar mass of both reactants and products;
   c. must be balanced;
   d. must indicate the physical state of each of the reactants and products.

3. The correct formula for three molecules of oxygen is
   a. O₃    b. O₂    c. 3 O₂    d. 3 O    e. 2 O₃

4. The substances to the left of the arrow in a chemical equation are called
   a. coefficients;    b. products;    c. subscripts;    d. reactants.

5. A gas whose molecule is monatomic is
   a. oxygen;    b. helium;    c. nitrogen;    d. chlorine;    e. hydrogen.

6. A hypothetical metallic element, Z, forms a chloride with the formula ZCl₅. What is the most probable formula for its oxide?
   a. ZO₂    b. ZO₅    c. Z₂O₅    d. Z₅O₂

7. The reaction type whereby a chemist produces a new material by combining elements is called
   a. hydrolysis;    b. electrolysis;    c. analysis;    d. synthesis.

8. The chemical reaction represented by the equation: 2 NaOH + H₂SO₄ → _____+ _____,
   is an example of
   a. double replacement;    b. single replacement;
   c. decomposition;    d. direct combination.

9. The reaction type for a reaction between zinc and hydrochloric acid is:
   a. synthesis;    b. single replacement;    c. neutralization;    d. double replacement.
10. The type of reaction represented by the expression, AB $\rightarrow$ _____ + _____ is a
   a. composition reaction.        c. single replacement reaction.
   b. decomposition reaction.    d. double replacement reaction.   e. condensation reaction.

11. The balanced equation for the synthesis of ammonia is
   a. 2 N + 3 H₂ $\rightarrow$ 2 NH₃         c. N₂ + 3 H₂ $\rightarrow$ 2 NH₃
   b. N₂O + 3 H₂O $\rightarrow$ 2 NH₃ + 2 O₂      d. 4 NO + 6 H₂O $\rightarrow$ 4 NH₃ + 5 O₂

12. When correctly balanced, the coefficient X which should appear in front of oxygen
    when the following reactants,
    C₂H₆ + X O₂ $\rightarrow$ CO₂ + H₂O is:
   a. 7;       b. 2;       c. 8;       d. 6;       e. none of these.

13. In a double replacement reaction, a reaction will occur only if:
   a. The metal or non-metal is higher on the activity series than the one it wants to
      replace
   b. A precipitate, a liquid, or a gas is formed
   c. The reaction forms all aqueous products
   d. All double replacement reactions are assumed to occur.

14. When the equation SbCl₃ + H₂S $\rightarrow$ Sb₂S₃ + ________ (must determine this
    product) is balanced, the coefficient of H₂S is:
   a. 2;               b. 4 ;               c. 6;               d. 8;               e. none of these.

15. Which of the following sets of coefficients correctly balances the equation:
    Ca₃(PO₄)₂ + H₂SO₄ $\rightarrow$ Ca(H₂PO₄)₂ + CaSO₄?
   a. 1, 1, 1, 1       b. 1, 2, 1, 2  c. 1, 3, 1, 2  d. 1, 1, 3, 2  e. none of these

16. The term X in the correctly balanced equation of the non-metal oxide reaction of
    SO₃ + H₂O $\rightarrow$ X is:
   a. H₂SO₄;               b. SO + H₂O₃;               c. SO₄ + H₂;               d. S + 2O₂ + H₂;               e. 2 SO₂.

17. The term X in the correctly balanced equation of the metal oxide reaction of
    K₂O + H₂O $\rightarrow$ X is:
   a. K₂ + O₂ + H₂;  b. 2K + 2O + 2H;  c. 2 KOH;  d. (KOH)₂;  e. K₂(OH)₂

18. The balanced molecular equation for the single replacement reaction between copper
    and silver nitrate is:
   a. Cu + AgNO₃ $\rightarrow$ AgCuNO₃.  c. Cu + 2 AgNO₃ $\rightarrow$ Cu(NO₃)₂ + 2 Ag.
   b. Cu + AgNO₃ $\rightarrow$ no reaction.  d. Cu + AgNO₃ $\rightarrow$ Ag⁺ + Cu⁺ + NO₃⁻.
19. In the thermite reaction iron is produced from iron ore, Fe₃O₄. Which expression for this reaction is balanced?
   a. Fe₃O₄ + 2 Al \rightarrow A1₂O₃ + 3 Fe  
   b. 2 Fe₃O₄ + 2 Al \rightarrow 2 A1₂O₃ + 6 Fe  
   c. 3 Fe₃O₄ + 4 Al \rightarrow .4 Al₂O₃ + 9 Fe  
   d. 3 Fe₃O₄ + 8 Al \rightarrow 4 Al₂O₃ + 9 Fe

20. The coefficient X which should appear when the molecular equation
   Al + X HC1 \rightarrow \underline{\text{____________}}, is correctly balanced is
   a. 8; 
   b. 4; 
   c. 3; 
   d. 6; 
   e. 5.

21. Which expression for the complete burning of pentane, C₅H₁₂ is properly balanced?
   a. 2 C₅H₁₂ + 8 O₂ \rightarrow 10 CO₂ + 12 H₂O  
   b. 2 C₅H₁₂ + 5 O₂ \rightarrow 10 CO₂ + 6 H₂O  
   c. C₅H₁₂ + 8 O₂ \rightarrow 5 CO₂ + 6 H₂O  
   d. C₅H₁₂ + 8 O₂ \rightarrow 5 CO₂ + 12 H₂O

22. In a single replacement reaction, a reaction will occur only if:
   a. The metal or non-metal is higher on the activity series than the one it wants to replace
   b. A precipitate, a liquid, or a gas is formed
   c. The reaction forms all aqueous products
   d. All single replacement reactions are assumed to occur.

23. Among the following equations the one which is correctly balanced is:
   a. S + O₂ \rightarrow SO₂ .  
   b. 2 HgO \rightarrow Hg + O₂ .  
   c. H₂ + O₂ \rightarrow H₂O.  
   d. Zn + HC1 \rightarrow ZnCl₂ + H₂.

24. Iodine gas is bubbled through a solution of potassium chloride. In the balanced equation, the coefficient in front of the potassium chloride is:
   a. 1  
   b. 2  
   c. 3  
   d. 4  
   e. NO RXN OCCURS

25. In the balanced equation or a reaction between Al₂(SO₄)₃ + Ca(OH)₂ \rightarrow \underline{\text{____________}}, the Ca(OH)₂ has the coefficient of
   a. 1; 
   b. 2; 
   c. 3; 
   d. 4; 
   e. NO RXN OCCURS

26. What is the coefficient of hydrogen sulfide when this equation is balanced?
   H₂S + SO₂ \rightarrow S + H₂O
   a. 1  
   b. 2  
   c. 3  
   d. 4  
   e. NO RXN OCCURS

27. The balanced equation for the commercial production of iron (III) chloride is:
   a. 2 Fe + 3 Cl₂ \rightarrow 2 FeCl₃  
   b. 3 Fe + 3 Cl₂ \rightarrow 2 FeCl₃  
   c. 3 Fe + 2 Cl₂ \rightarrow 2 FeCl₃  
   d. Fe + Cl₂ \rightarrow FeCl₃.

28. Complete the following reaction: Sodium chlorate + zinc \rightarrow \underline{\text{____________}}.
    When the reaction is correctly balanced, what is the coefficient in front of sodium chlorate? 
    a. 1  
    b. 2  
    c. 3  
    d. 4  
    e. NO RXN OCCURS
29. All of the following reactions belong to one type except:
   a. 2 NaCl → 2 Na + Cl₂.  
   b. Ca(OH)₂ → CaO + H₂O.  
   c. CaCO₃ → CaO + CO₂.  
   d. Zn + H₂SO₄ → ZnSO₄ + H₂.  

30. What does X stand for in the following balanced chemical reaction?
   Zinc + ___X___ → zinc sulfate + hydrogen.  
   a. H₂  
   b. H₂O  
   c. SO₂  
   d. H₂SO₄  
   e. none of these

31. Complete the reaction: sodium chloride + magnesium nitrate → ________.  
   When this reaction is properly balanced, what is the coefficient in front of sodium chloride?  
   a. 1  
   b. 2  
   c. 3  
   d. 4  
   e. NO RXN OCCURS

32. Balance the equation: Zn₃As₂ reacts with hydrochloric acid to produce AsH₃ and zinc chloride. What is the coefficient in front of hydrochloric acid?  
   a. 7  
   b. 6  
   c. 5  
   d. 4  
   e. 3

33. Complete combustion of any hydrocarbon in air produces  
   a. CO and H₂;  
   b. CO and H₂O;  
   c. CO₂ and H₂;  
   d. CO₂ and H₂O.

34. Ammonia combines with oxygen gas to produce nitrogen gas and water. Which set of coefficients correctly balances this reaction?  
   a. 2, 3, 1, 7  
   b. 1, 3, 7, 2  
   c. 4, 1, 1, 1  
   d. 3, 2, 3  
   e. none of these

35. Which of the answers below is a complete ionic representation of the reaction:  
   Calcium nitrate and sodium sulfide solutions react to form solid calcium sulfide and sodium nitrate solution.  
   a. Ca²⁺ (aq) + NO₃⁻ (aq) + Na⁺ (aq) + S²⁻ (aq) → CaS (s) + NaNO₃ (s)  
   b. Ca²⁺ (aq) + NO₃⁻ (aq) + Na⁺ (aq) + S²⁻ (aq) → CaS (s) + Na⁺ (aq) + NO₃⁻ (aq)  
   c. Ca²⁺ (aq) + 2 NO₃⁻ (aq) + Na⁺ (aq) + S²⁻ (aq) → CaS (s) + Na⁺ (aq) + NO₃⁻ (aq)  
   d. Ca²⁺ (aq) + 2 NO₃⁻ (aq) + 2 Na⁺ (aq) + 2 S²⁻ (aq) → CaS (s) + 2 Na⁺ (aq) + 2 NO₃⁻ (aq)  
   e. Ca²⁺ (aq) + 2 NO₃⁻ (aq) + 2 Na⁺ (aq) + S²⁻ (aq) → CaS (s) + 2 Na⁺ (aq) + 2 NO₃⁻ (aq)

36. The spectator ions in the previous problem are:  
   a. Ca²⁺ and NO₃⁻.  
   b. Na⁺ and S²⁻.  
   c. Ca²⁺ and S²⁻.  
   d. Na⁺ and NO₃⁻.  
   e. Ca²⁺ and Na⁺
37. What would be the complete ionic equation if aqueous solutions of potassium sulfate and barium acetate were mixed?
   a. \[ 2 \text{K}^+ (aq) + \text{SO}_4^{2-} (aq) + \text{Ba}^{2+} (aq) + 2 \text{C}_2\text{H}_3\text{O}_2^- (aq) \rightarrow \text{BaSO}_4 (s) + 2 \text{K}^+ (aq) + 2 \text{C}_2\text{H}_3\text{O}_2^- (aq) \]
   b. \[ \text{K}_2^+ (aq) + \text{SO}_4^{2-} (aq) + \text{Ba}^{2+} (aq) + 2 \text{C}_2\text{H}_3\text{O}_2^- (aq) \rightarrow \text{BaSO}_4 (s) + \text{K}_2^+ (aq) + 2 \text{C}_2\text{H}_3\text{O}_2^- (aq) \]
   c. \[ \text{K}_2^{+2} (aq) + \text{SO}_4^{2-} (aq) + \text{Ba}^{2+} (aq) + (\text{C}_2\text{H}_3\text{O}_2)_2^{2-} (aq) \rightarrow \text{BaSO}_4 (s) + \text{K}_2^{+2} (aq) + (\text{C}_2\text{H}_3\text{O}_2)_2^{2-} (aq) \]
   d. \[ 2 \text{K}^+ (aq) + \text{SO}_4^{2-} (aq) + \text{Ba}^{2+} (aq) + 2 \text{C}_2\text{H}_3\text{O}_2^- (aq) \rightarrow 2 \text{K}_2\text{C}_2\text{H}_3\text{O}_2 (s) + \text{Ba}^{2+} (aq) + \text{SO}_4^{2-} (aq) \]
   e. \[ \text{K}_2^{+2} (aq) + \text{SO}_4^{2-} (aq) + \text{Ba}^{2+} (aq) + (\text{C}_2\text{H}_3\text{O}_2)_2^{2-} (aq) \rightarrow 2 \text{K}_2\text{C}_2\text{H}_3\text{O}_2 (s) + \text{Ba}^{2+} (aq) + \text{SO}_4^{2-} (aq) \]

38. What would be the net ionic reaction in the previous problem?
   a. \[ \text{K}_2^+ (aq) + (\text{C}_2\text{H}_3\text{O}_2)_2^{2-} (aq) \rightarrow 2 \text{K}_2\text{C}_2\text{H}_3\text{O}_2 (s) \]
   b. \[ 2 \text{K}^+ (aq) + 2 \text{C}_2\text{H}_3\text{O}_2^- (aq) \rightarrow 2 \text{K}_2\text{C}_2\text{H}_3\text{O}_2 (s) \]
   c. \[ \text{Ba}^{2+} (aq) + \text{SO}_4^{2-} (aq) \rightarrow \text{BaSO}_4 (s) \]
   d. More than one of these are correct.
   e. None of these are correct.

39. Will a precipitate form when 0.1 M aqueous solutions of AgNO₃ and NaCl are mixed? If a precipitate does form, identify the precipitate and give the net ionic equation for the reaction.
   a. No precipitate forms.
   b. AgCl precipitates. \[ \text{Ag}^+(aq) + \text{Cl}^-(aq) \rightarrow \text{AgCl}(s) \]
   c. Ag₃N precipitates. \[ 6\text{Ag}^+(aq) + 2\text{NO}_3^-(aq) \rightarrow 2\text{Ag}_3\text{N}(s) + 3\text{O}_2(g) \]
   d. AgCl precipitates. \[ \text{Ag}^+(aq) + \text{NaCl}(aq) \rightarrow \text{AgCl}(s) + \text{Na}^+(aq) \]
   e. NaNO₃ precipitates. \[ \text{NO}_3^-(aq) + \text{Na}^+(aq) \rightarrow \text{NaNO}_3(s) \]

40. What would happen if aqueous solutions of sodium nitrate and ammonium chloride were mixed?
   a. A precipitate of sodium chloride would form.
   b. A precipitate of ammonium chloride would form.
   c. Precipitates of sodium chloride and ammonium chloride would form.
   d. Neither sodium nitrate nor ammonium chloride would dissolve.
   e. Nothing would happen, all products would be aqueous.
APPENDIX C

NOMENCLATURE UNIT FORMATIVE ASSESSMENT 1
NAME TO FORMULA QUIZ 1A

Please convert the following chemical names into formulas:

1. Strontium phosphide ___________________________

2. Nitrous acid ___________________________

3. Dinitrogen tetraoxide ___________________________

4. Lead (IV) selenide ___________________________

5. Zinc nitride ___________________________

6. Cobalt (III) Phosphite ___________________________

7. Tin (II) sulfate ___________________________

8. Sulfur trichloride ___________________________

9. Hydrosulfuric acid ___________________________

10. Ammonium bicarbonate ___________________________
APPENDIX D

NOMENCLATURE UNIT FORMATIVE ASSESSMENT 2
FORMULA TO NAME TO QUIZ A
Please convert the following chemical formulas into names:

1. Fe$_3$P$_2$ ________________________

2. N$_2$O ________________________

3. AlN ________________________

4. NH$_4$MnO$_4$ ________________________

5. H$_3$N ________________________

6. HClO$_3$ ________________________

7. SeBr$_6$ ________________________

8. Sn(CO$_3$)$_2$ ________________________

9. ZnCl$_2$ ________________________

10. Cu(ClO)$_2$ ________________________

Extra Credit: Determine the oxidation numbers on all of the following atoms in their respective polyatomic ion. (Hint: the additive charges equal the total charge on the ion and you assign a charge based on an individual atom and oxygen will always be -2)

SO$_4^{2-}$  MnO$_4^-$  CO$_3^{2-}$

S =  ____  Mn =  ____  C =  ____
APPENDIX E

NOMENCLATURE UNIT FORMATIVE ASSESSMENT 3
Please convert the following chemical names into formulas, or vice versa:

1. MgI₂ ____________________________
2. Aluminum Selenide ____________________________
3. Cadmium Phosphate decahydrate___________________________
4. (NH₄)₂SO₃ ____________________________
5. Manganese (III) acetate ____________________________
6. H₂SO₄ ____________________________
7. Tetraphosphorus decaoxide___________________________
8. CS₂ ____________________________
9. Hydrophosphoric acid ____________________________
10. CuO • 5 H₂O ____________________________
11. HCl ____________________________
12. permanganic acid ____________________________
13. N₂O₄ ____________________________
14. Copper (II) bisulfide ____________________________
15. SnO₂ ____________________________
APPENDIX F

CHEMICAL REACTIONS UNIT FORMATIVE ASSESSMENT
CHEMICAL REACTIONS QUIZ A

Name __________________ Pd _______

For the following chemical reactions, please write the balanced chemical equation and reaction type for the following (SYN, DEC, SR, DR, COMB). Assume all reactions occur.

1. Nitrogen and hydrogen gases combine to form nitrogen trihydride gas (ammonia).

   Reaction Type: ______________

2. Aqueous magnesium phosphate and aqueous ammonium nitride react to form one aqueous and one solid product.

   Reaction Type: ______________

3. Pentane C\(_5\)H\(_{12}\) combusts.

   Reaction Type: ______________

4. Aqueous copper (II) sulfate reacts with iron metal to form two products.

   Reaction Type: ______________

5. Mercury (II) oxide powder decomposes into its constituent elements.

   Reaction Type: ______________
For the following chemical reactions, please balance and write the corresponding reaction type.

6. _____ HCH₃COO + _____ NaOH → _____ NaCH₃COO + _____ H₂O

Reaction Type: ______________

7. _____ CO + _____ O₂ → _____ CO₂

Reaction Type: ______________

8. _____ Mg + _____ HCl → _____ MgCl₂ + _____ H₂

Reaction Type: ______________

9. _____ C₄H₁₀ + _____ O₂ → _____ CO₂ + _____ H₂O

Reaction Type: ______________

10. _____ KClO₃ → _____ KCl + _____ O₂

Reaction Type: ______________
APPENDIX G

ATTITUDE SURVEY
<table>
<thead>
<tr>
<th>Attitude Survey</th>
<th>SA</th>
<th>A</th>
<th>N</th>
<th>D</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Participation in this research is voluntary and participation or non-</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>participation will not affect your grade or class standing in any way. Please</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>take a few moments to respond to the following questions thoughtfully and</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>honestly. Thank you for your time. Please respond to the questions 1-15 by</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>indicating whether you agree or disagree with the statement and to what extent.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SA= Strongly Agree, A=Agree, N= Neutral (neither agree nor disagree), D</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>disagree, SD= Strongly disagree.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. I enjoy taking part in activities that most people would consider</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>“doing science.”</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. When I think about it, science is something I use frequently in my</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>everyday life.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. I feel confident asking questions that are “testable”</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. I am likely to modify my thinking if I am confronted a better</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>explanation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. I can make and use models to represent complicated phenomenon</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. I believe that failure is an important part of success</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. I am good at making sense of data</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. I will usually accept or believe something without needing evidence to</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>back it up</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. Collecting evidence is an important part of making a decision</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. I can make a claim and back it up with evidence when I am trying to</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>make a point</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11. Science is mostly in individual effort, rather than a collaborative</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>one</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12. I am open to listening to alternative explanations or the viewpoints of</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>others</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13. I feel confident contributing to group efforts to solve science-related</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>problems</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14. I can explain my thoughts well to others</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15. I can critique the claims of others as a “reflective friend”</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16. In what ways do you consider yourself a scientist?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
APPENDIX H

POST INTERVENTION INTERVIEW QUESTIONS
Post Intervention Interview Questions: Participation in this research is voluntary and participation or non-participation will not affect your grade or class standing in any way. Modified from: Student survey on literature circles (Hendricks, 2013).

1. In what ways have the QuIVERS modules and gamified classroom learning environment helped or hindered you from learning the content you were studying?

2. What have you learned about “doing science” as a result of participating in the QuIVERS modules and a gamified classroom learning environment?

3. After participating in the QuIVERS modules and a gamified classroom learning environment, do you feel you are a better at doing science, worse at doing science, or the same at doing science before you participated?

4. How has your participation in the QuIVERS modules and gamified classroom learning environment changed the way you feel about science?

5. How could I change the QuIVERS modules and gamified classroom learning environment to make it more effective for someone like yourself?

6. Is there anything else you would like to say about the QuIVERS modules and gamified classroom learning environments.
APPENDIX I

FOCUSED AUTOBIOGRAPHICAL SKETCH
Participation in this research is voluntary and participation or non-participation will not affect your grade or class standing in any way.

In one page or less (not more), and in less than 15 minutes, describe what learning experiences have been helpful or not helpful in your learning of chemistry and in improving your confidence in solving problems as a scientist thus far. In relating and discussion how your recent experiences have influenced your learning or confidence, focus not only on what you learned but also on how and why you judged the experiences to be successful or meaningful in improving your learning and/or your confidence as a scientist.
APPENDIX J

NOMENCLATURE UNIT CHALLENGE 1: POLY IONS
Challenge 1: Poly Ions

Question

SMR Robbie Says:
If you want to be able to name all these compounds so you can bring back the right chemicals to the outpost, you will need to start with the basics. Science always begins with a good question, so I will start by giving you this one to investigate.

What are the formulas with charges for some common polyatomic ions and what are some patterns among their names, charges, and the types of atoms involved?

Investigation

With your neighbor,
Open the link below to obtain a copy of the worksheet answer key you will use to self-correct in RED INK the Poly Ion Identification Practice and share with each other your answers to the patterns you noticed on the back side.
Click the link below to preview this practice.

[Practice: Investigation]

Password is required to start this Practice
Password for Review

Assessment Passwords

<table>
<thead>
<tr>
<th>Password</th>
<th>Active</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOOM</td>
<td>✔️</td>
<td>anytime</td>
</tr>
</tbody>
</table>
I have corrected my worksheet and made additions and corrections in red.
Elaborative Reading

You notice that on many of the compounds you find that they have formulas that have similar "chunks" or "groupings" of elements. For example you see the compounds NH₄NO₃, NaNO₃, (NH₄)₂SO₄, and Na₂SO₄. You notice that these groupings of atoms such as NO₃ and NH₄ and SO₄ come bundled together in the compound. These are called polyatomic ions. They are "chunks with a charge" or groups of atoms that are bonded together that have an overall charge due to added or missing electrons among the atoms involved.

Review

Agree on one pattern you both noticed, write it on the board (unless the pattern you identified has already been addressed, in which case you need to pick a different one), and return to your seat. If there are any new patterns you noticed, add those to your list. Call over your instructor to share what you have learned and acquire the password needed to self check the worksheet and complete the summary quiz.

Summary QUIZ

Click the link below to preview this practice.

Practice: Summary QUIZ

Password is required to start this Practice
Summary Quiz

Section 1

The prefix bi- means that an H⁺ (an H and a positive 1 charge) is added to a formula.

True

If the suffix -ite or -ate is in a name, there are no oxygens present.

False

Each polyatomic ion with suffix -ite in the name has the same number of oxygen atoms present.

False

In order of increasing number of oxygen atoms present, the prefix/suffix order is as follows: per-____-, ate-, ite-, hypo-____-, ox

False

Which of the following is a polyoxo that does NOT have -ite or -ite in the name?

N

OH⁻

\( \text{O}_2^\text{2⁺} \)

✓ All of these
### POLYATOMIC ION IDENTIFICATION

Give the formulas (including charges) for the following commonly used polyatomic ions.

<table>
<thead>
<tr>
<th>Sulfate</th>
<th>Sulfite</th>
<th>Bisulfide</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bisulfate</td>
<td>Bisulfite</td>
<td>Hydrogen sulfide</td>
</tr>
<tr>
<td>Nitrate</td>
<td>Nitrite</td>
<td>Chlorate</td>
</tr>
<tr>
<td>Phosphate</td>
<td>Chromate</td>
<td>Dichromate</td>
</tr>
<tr>
<td>Peroxide</td>
<td>Bicarbonate</td>
<td>Carbonate</td>
</tr>
<tr>
<td>Binoxalate</td>
<td>Hydroxide</td>
<td>Cyanide</td>
</tr>
<tr>
<td>Hypochlorite</td>
<td>Chlorite</td>
<td>Permanganate</td>
</tr>
<tr>
<td>Ammonium</td>
<td>Oxalate</td>
<td>Acetate</td>
</tr>
</tbody>
</table>

List 5 patterns you notice about the names and formulas that may help you remember which names belong with which formulas.

1. 
2. 
3. 
4. 
5. 
Badge

View Badge

Nomenclature Challenge 1:
Poly Ion Expert

Credit Description
You can identify polyatomic ions

Credit Criteria
You completed challenge 1
APPENDIX K

NOMENCLATURE UNIT CHEMGUILD CHALLENGE: ACID
ChemGuild Challenge 1: Acid

Question

SMR ROBBIE: "HELP! The town is under attack. At the east wall, there is a hoard of fierce spiders that have been spotted approaching the village. If they get here before we can figure out which acid we can spray them with, they will climb over the wall and who knows what might happen to the village. We need your help. Please, we are having trouble sorting out acids with nitrogen and phosphorus and if we can tell the difference between them, we can use the acid in the database that is most lethal to the approaching spiders. CAN YOU SAVE THE VILLAGE?"

Acid Nomenclature Challenge

Click the link below to preview this practice.

Practice: Acid Nomenclature Challenge

Password is required to start this Practice
Summary Quiz

**Acid Nomenclature Challenge**

- I successfully completed the Acid Nomenclature Challenge and showed the correct answers to my instructor to earn a ChemGuld Badge!

<table>
<thead>
<tr>
<th>Formula to Name</th>
<th>Name to Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. HNO₂</td>
<td>a. Phosphoric Acid</td>
</tr>
<tr>
<td>b. H₃N</td>
<td>b. Phosphorus Acid</td>
</tr>
<tr>
<td>c. HNO₃</td>
<td>c. Hydrophosphoric Acid</td>
</tr>
</tbody>
</table>

True
Badge

View Badge

ChemGuild Challenge: Acid Defender

Credit Description
You saved the village through your ability to distinguish among the names of different types of acids.

Credit Criteria
You crushed an army of deadly spiders!
APPENDIX L

CHEMICAL REACTION UNIT CHALLENGE 1: REACTION TYPES
Challenge 1: Reaction Types

**Question**

SMR Robbie Says:
If you want to be able to make the chemicals you will need to save this world, you will first have to learn a little bit about reactions.

How can I recognize the common types of reactions, turn a sentence in words into a chemical equation, and balance a chemical equation?

---

**Video: Balancing Equations**

Honors Chemistry - Balancing Equations

2. \[ \text{H}_2\text{O}_2 \rightarrow \text{O}_2 \text{ (g)} + \text{HEAT} \]
Review: Self Check Reaction Types Practice 1
Click the link below to preview this practice.
Practice: Review: Self Check Reaction Types Practice 1
Password is required to start this Practice

Summary Quiz: Challenge 1-Chemical reactions
Click the link below to preview this practice.
Practice: Summary Quiz: Challenge 1-Chemical reactions
Password is required to start this Practice

Page Comments 0
Worksheet

Direct Combination or Synthesis Reactions

1. Calcium oxide and water produce calcium hydroxide.
2. Manganese combines with sulfur to form manganese (I) sulfide.
3. Carbon monoxide burns in oxygen to form carbon dioxide.
4. Hydrogen and oxygen combine to produce water.
5. Ammonia and hydrochloric acid produce ammonium chloride.

Decomposition Reactions

6. Ammonium hydroxide decomposes to form water and ammonia.
9. When heated, mercury II oxide forms mercury and oxygen.

Single Replacement (or Single Displacement) Reactions

10. Lithium bromide and chlorine form bromine and lithium chloride.
11. Chromium and lead (II) nitrate produce lead and chromium (III) nitrate.
13. Iron (III) fluoride and zinc metal will form zinc fluoride and iron metal.
14. Mercury (II) chloride and calcium will form ? and ?

Double Replacement (or Double Displacement) Reactions

15. Phosphoric acid and potassium hydroxide form water and potassium phosphate.
16. Calcium hydroxide and hydrochloric acid form calcium chloride and water.
17. Manganese (II) sulfide and lead (IV) bromide produce lead (IV) sulfide and manganese (II) bromide.

Metal/Nonmetal Oxides reacting with water

18. Sodium oxide (a strong base) reacts exothermically with water to form a sodium hydroxide solution.
19. Magnesium oxide (a weaker base than sodium oxide) reacts with water (slightly exothermic) to form some magnesium hydroxide.
20. Tetraphosphorus decaoxide reacts violently with water to form phosphoric acid.
21. Sulfur trioxide reacts violently with water to produce a fog of concentrated sulfuric acid droplets.

Combustion of a hydrocarbon reactions

22. Octane (C8H18) is combusted (in the presence of oxygen) to form carbon dioxide and water.
23. Propane (C3H8) combusts to form the usual products (carbon dioxide and water).
24. Ethane (C2H6) is burned.
Passwords for Review: Self Check and Summary Quiz

Assessment Passwords

<table>
<thead>
<tr>
<th>Password</th>
<th>Active</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>THEONE</td>
<td>✓</td>
<td>anytime</td>
</tr>
</tbody>
</table>

Assessment Passwords

<table>
<thead>
<tr>
<th>Password</th>
<th>Active</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>THEONERING</td>
<td>✓</td>
<td>anytime</td>
</tr>
</tbody>
</table>
**Review: Self-Check**

### Review: Self Check Reaction Types Practice 1

**Section 1**

1. I have self corrected practice 1.
   - Practice 1 key pg 2.pdf
   - Practice 1 key pg 3.pdf
   - Practice 1 key pg 1.pdf
   - True
   - False

[OK]  [I'll come back later]
## Summary Quiz

### Challenge 1: Chemical Reactions

#### Section 1

<table>
<thead>
<tr>
<th>Question</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Which of the following elements is monatomic?</td>
<td></td>
</tr>
<tr>
<td>- Bromine</td>
<td></td>
</tr>
<tr>
<td>- Neon</td>
<td>□</td>
</tr>
<tr>
<td>- Hydrogen</td>
<td>□</td>
</tr>
<tr>
<td>- Nitrogen</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>What is a type of chemical reaction where a single compound is broken down into a greater number of compounds or constituent elements?</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>- Synthesis</td>
<td></td>
</tr>
<tr>
<td>- Decomposition</td>
<td>□</td>
</tr>
<tr>
<td>- Single Replacement</td>
<td></td>
</tr>
<tr>
<td>- Double Replacement</td>
<td></td>
</tr>
</tbody>
</table>

What would be the other reactants and products for a reaction of the burning of pentane (C\textsubscript{5}H\textsubscript{12}? (This is a hydrocarbon, of which the general form is usually C\textsubscript{n}H\textsubscript{2n+2}.)
| Reactants: CO\textsubscript{2} and O\textsubscript{2}, Products: H\textsubscript{2}O |        |
| Reactants: O\textsubscript{2}, Products: CO\textsubscript{2} and H\textsubscript{2}O |        |
| Reactants: C\textsubscript{5}H\textsubscript{12}, Products: C\textsubscript{5}H\textsubscript{10}O\textsubscript{2}, Products: O\textsubscript{2} |        |

What is the correct way of saying there are three molecules of hydrogen?
| There isn’t, hydrogen doesn’t form a molecule.                          |        |
| 2 H\textsubscript{2}                                                    |        |
| 3 (2H)                                                                  |        |
| Name of these are correct.                                              | □      |
| H\textsubscript{2}                                                     | □      |

A balanced chemical equation accomplishes which of the following?
| It makes it so that the law of conservation of matter is valid.         |        |
| It makes it so the same number of atoms are accounted for before and after a reaction |        |
| It ensures that each product and reactant has the same coefficients.    |        |
| It ensures that there are the same number of molecules on each side of an equation. |        |
| All of these are correct.                                               | □      |
| Only two of these are correct.                                          | □      |

The SYNTHESIS of a metal oxide and water would likely produce... while a non-metal oxide with water would produce...
| oxides like H\textsubscript{2}SO\textsubscript{4}, strong base like KOH |        |
| strong base like KOH, oxides like H\textsubscript{2}SO\textsubscript{4} |        |
| a metal and hydrogen and oxygen gases; a non-metal and hydrogen and oxygen gases |        |
| a non-metal and hydrogen and oxygen gases; a metal and hydrogen and oxygen gases |        |
Example of Multiple Choice Question Feedback

Edit Multiple Choice Question

The following hint will be displayed to your students if they answer the question:

Hydrogen

BriNCHOF

elements are all Diatomic.

Monatomic means that they exist

Save  Cancel

Edit Multiple Choice Question

The following kudos will be displayed to your students if they answer the question:

Neon

Perfect! Neon isn’t one of the seven diatomic elements (BriNCHOF), which the rest of the answer choices are. Neon is

Save  Cancel
Challenge 1: Reaction types

Challenge 1: Reaction types completed!

Credit Description
You can recognize various reaction types and are all-around awesome!

Credit Criteria
You completed challenge 1: Reaction types