CHEMQUEST1: DO GAMING STRATEGIES AFFECT STUDENT ENGAGEMENT AND MOTIVATION IN THE CHEMISTRY CLASSROOM?

by

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Carol Lee Smith

July, 2014
DEDICATION

This paper is dedicated to Stephen. It is because of his support, encouragement and steadfast belief in me that I have been able to finish it and maintain the ever so tenuous hold on my sanity. Thank you for feeding the animals too, dear.
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ABSTRACT

This paper investigates the effects of a particular set of gaming strategies on student motivation and engagement in learning chemistry. ChemQuest1 was designed to use game elements such as leaderboards, experience points, guilds and tasks to engage students in learning chemistry. The results indicate a significant increase in student confidence in their ability to be successful in chemistry when compared to students in lecture based On Level chemistry classes. Students enrolled in ChemQuest1 performed well on most teacher constructed tests, however they did not perform as well on standardized tests where they could not retake the test and improve their scores.
INTRODUCTION AND BACKGROUND

“In every job that must be done, there is an element of fun. You find the fun and snap! The job’s a game (Sherman, 1964).” Written for the movie, *Mary Poppins* and immortalized by Julie Andrews, I believe these lyrics are right on target for finding a way to engage students in learning material that requires practice. Finding the fun for my students in practicing skills to be successful in chemistry is my challenge.

I teach chemistry at Van Alstyne High School in Van Alstyne, Texas and we have 403 students enrolled in the high school. I have 100 sophomores enrolled in my chemistry classes, which includes pre-Advance Placement and On Level. Our school is rural, but Van Alstyne is close enough to Dallas to be considered a bedroom community. Many of my students’ parents work in the Dallas area and have a 20 to 30 minute commute to work. Many are longtime residents of this agriculturally based area (City-data.com). About 19% of my students are minorities most of which are Hispanic (Texas Education Agency 2012-2013 School Report Card).

Chemistry is a demanding class for most high school students. Chemical concepts are abstract and difficult to visualize. It often takes effort for students to develop confidence and proficiency in completing tasks in class. As a chemistry teacher, I am constantly looking for ways to engage and encourage my students to learn and practice chemistry.

Finding relevance in chemistry is often a struggle for the sophomore chemistry student (Osborne & Collins, 2001). With a myriad of options available to the average high school student, it is not a surprise that learning chemistry is low on their list of “must do” activities. As a result, students do not spend enough time engaged in honing
skills such as dimensional analysis and writing and balancing equations. These are methods that require practice to be proficient and attain a level of comfort and confidence in their use.

Students need to practice in order to attain a level of proficiency that will allow them to excel on timed tests. Some students have the necessary discipline to listen to lectures and follow along with practice problems during class. These are students that usually do well no matter what format the instruction is given to them. However, the majority of students are not as self-disciplined and require more prodding and occasional threats of failure to get them to pay enough attention during class and practice sufficiently to reach the required level of proficiency.

Games on the other hand, especially video games, can keep students engaged and on task for long periods of time outside of the classroom. Turning classwork into a game may be a way to find the fun in learning chemistry. Students who play video games often spend many hours performing complicated tasks for such intrinsic rewards as an achievement badge, leveling up or gaining a skill. These rewards give them advantages that allow them to win in various aspects of their games. What if a chemistry class was based around gaming strategies? In the place of grades, students could earn points for completing tasks that would give them a better chance to do well in chemistry. Those points could earn a student a place on a leaderboard or a special badge of recognition. The many aspects of games that are so riveting to students could be exploited for the good of learning. I would like to explore these gaming possibilities for the benefit of improving student proficiency in chemistry. This is also the first year that almost all of my students will have a Samsung Galaxy Tab2 provided by the school.
Area of Focus: What are the effects of gaming strategies on student motivation and engagement in learning chemistry?

Research question: What are the effects of gaming strategies on student self-concept in learning chemistry?

Sub-Question 1: What are the effects of gaming strategies on student self-efficacy in learning chemistry?

Sub-Question 2: Do gaming strategies in the chemistry classroom increase learning/test scores?

CONCEPTUAL FRAMEWORK

Motivating students to learn and continue to take chemistry courses is a challenge for chemistry teachers in high school and college alike. Student learning is affected by both motivation and engagement. It is an ongoing struggle for teachers to find ways to draw students into the more difficult topics like chemistry. In a study by Zusho, Pintrich and Coppola (2003), motivation in chemistry classes decreased for students over time, particularly the low-achieving students. These students also found the material less relevant as they progressed through the course (Zusho, Pintrich, & Coppola, 2003).

Connections have been made between success in chemistry and self-concept. Chemistry self-concept is the perception a student has of his or her ability to be successful in chemistry. Students with high chemistry self-concepts have higher overall chemistry scores than those with low chemistry self-concepts. A pilot study was undertaken to increase students’ self-concept in chemistry. The results of the study showed that students who are actively involved in learning chemistry have improved chemistry self-concepts (Lewis, Shaw & Heitz, 2009).
Student’s confidence in their ability to perform successfully in science, self-efficacy, has an effect on whether they continue to seek out science classes or even participate in required science classes. Students with high self-efficacy have higher performance at the end of the course than those with low self-efficacy. Confidence in their ability to do well was a better predictor of students’ final scores than their scores on the math portion of the SAT (Zusho, Pintrich, & Coppola, 2003). Alternatively, students who feel as though they are unable to master science content disengage from the process of learning. Engagement in a game platform called multi-user virtual environment (MUVE) can reduce the effect of low self-efficacy on accomplishments in gathering scientific information (Ketelhut, 2007). This study revealed after a point in the MUVE, there was a leveling effect and students with low and high self-efficacy had equal performance.

Students have difficulty finding reasons to continue with science courses when they do not find intrinsic value in them (Lyons, 2006). The school culture itself works against students choosing the more difficult science courses. The perception that these classes have little intrinsic value has caused students to turn away from the more difficult sciences, such as chemistry and physics. It is not that these classes do not have intrinsic value, but rather students perceive that careers in science have less importance in society and therefore less value to them. Anxiety about chemistry coursework and exams causes students to avoid chemistry classes or take only what is required in their degree plan (McCarthy, 2009). Gaming strategies in the classroom encourage students to participate (Sheldon, 2012; Foster, 2009; Shaffer, 2006; Gee, 2007). Games give people a feeling of pride known as fiero (McGonigal, 2011). This is a strong motivation factor that drives
gamers to continue to play even when the tasks required by the game are very difficult and time consuming. Games allow players to fail fearlessly. Failure is part of the game and expected (Sheldon, 2011). Games can be used to teach students about different professions and allow them to work through scenarios as if they were actually an architect or an engineer (Shaffer, 2006).

Games like *Quest Atlantis* encourage students to create an avatar, collaborate, and allow them to choose how to become socially involved (Barab, Dodge, Carteaux, & Tuzun, 2005). According to Gee (2007), empowered learners have a say in how they learn and what they produce when they learn and they identify with the content. All of these conditions are met with a game like *Quest Atlantis*. The question remains as to how much content students are learning, and is it transferrable to standardized testing.

Gamers are problem solvers. Games often require players to complete complex tasks with other players, making task completion a collaborative effort. They are also expected to transfer skills and information to new situations (Gee, 2007). The challenge of gaming often creates communities of learners. They collaborate on wiki pages and game forums to improve their play and help other gamers. Research indicates that collaborative learning improves student self-efficacy in the sciences (Driscoll, 2010).

A good game encourages players to try to see the world through someone else’s eyes, often challenging them to think in new and innovative ways. Taking on new roles, players discover things about themselves and the world and as Gee (2007) says “a good science class should do the same” (p.117). Good games allow players to control many aspects of their play. This gives them a level of self-determination and agency that increases the intrinsic value of the game (Asgari & Kaufman, 2009).
However exciting it may be to use gaming strategies to encourage and teach students chemistry, it needs to be tempered with the fact that there is research showing a possible problem with students misunderstanding what the important concepts are in a topic. Instructors and students did not agree on what the important topics were in a game about emergency care (Wouters, van der Spek, & van Oostendorp, 2011).

It may be important what type of game is chosen for both classroom activities and homework practice. In Foster’s (2009) research, he recommends that teachers play games to become familiar with the genre of games their students are playing. This will also help them better determine which types of games might be appropriate to incorporate into their teaching to engage their students. The study also indicates that assignments that do more than drill and kill is a lofty pursuit which will require a new type of education for the teacher as well as the student (Foster, 2009).

Clearly, more research is needed in the area of content knowledge attainment from gaming strategies used in education and whether the transfer of that knowledge is possible ((Barab et al., 2005). Additional research is also needed in what kinds of games work best in the school environment (Foster, 2009).

Games, if they are to be successful in changing student learning, need to go beyond being ‘chocolate covered broccoli,’ but rather move towards approaches that develop creative and powerful ways for learners to engage with the essential qualities of subject matter. (Foster & Mishra, 2009, p. 46)
METHODOLOGY

The purpose of this study was to determine if gaming strategies have an effect on student attitudes and confidence in learning chemistry. This study was conducted on five classes of on-level chemistry at Van Alstyne High School. First and eighth periods were the treatment classes called ChemQuest1, and second, third, and fifth periods were untreated classes. The on-level chemistry course is a survey course that has a list of Texas Essential Knowledge and Skills (TEKS) attached to it (Appendix A). These are the same for any first year chemistry course taught in Texas. The research methodology for this project received an exemption by Montana State University’s Institutional Review Board and compliance for working with human subjects was maintained (Appendix B).

The treatment consisted of the same basic materials used in the on-level chemistry course, such as worksheets, websites, videos and notes over significant figures, scientific notation, dimensional analysis, matter and its changes, etc. The main difference was they were presented using a program that flowed like a video game in the treated classes. Olotolo.org, written and maintained by Erik Nickerson, was the program that was used to set up the flow of the game (Appendix C). Some assignments were also set up on the school’s website, edlinesites.net and all assignments were available to all classes on that website. Assignments for ChemQuest1 were set up in the olotolo.org program as Lore of Chemistry (notes), Tasks, Craftings (labs), Battles (quizzes) or Boss Fights (tests). Tasks consisted of videos or text to be read and practice worksheets which were known as Pushing the Bar. Occasionally, a task completed would unlock the next Task, Battle or Boss Fight in the program, but often the students had access to a group of assignments
and had the freedom to choose which assignments they completed and in what order. Some *Craftings* and all *Boss Fights* were hard stops that students were required to complete to be able to gain access to subsequent assignments. Students gained points called *XP* (known as experience points in games) for completed *Tasks, Battles, Craftings,* and *Boss Fights.* In ChemQuest1, the students began the game with no points which was effectively an F, and worked their way up to the grade they wanted by gaining points as they completed the assignments. Ranks were set up so that students could *Level Up* (move up in rank) as they gained enough *XP* (Appendix D). A leaderboard was presented at the start of each class period where students could identify their XP level and rank by their avatar name (Appendix E). The *XP* were translated into grades by dividing the student’s *XP* by the total possible *XP* at that point in time and multiplying by 100. This gave each student a grade for the grade book and met the eligibility requirements for extra-curricular activities.

Anonymous Pre, Mid and Post Attitude Surveys were administered to 73, 61, and 50 students, respectively, (Appendix C, D and E). Most of the students in the chemistry courses chose to fill out the surveys and the numbers also included students who left or arrived during the year. The Attitude Surveys (AS) were modified from the original Chemistry Attitudes and Experiences Questionnaire developed by Coll, Dalgety and Salter, (2002). The AS had two sections; one utilized the scale 1-5 with 1 being *not confident* and 5 being *totally confident.* Students were asked to rate each task according to how they currently felt. The next section used the Likert scale rating of *strongly agree* (SA), *agree* (A), *neutral* (N), *disagree* (D), and *strongly disagree* (SD). The questions were related to student experiences during their first year of chemistry. The Likert scale
was then converted into a numerical scale with 5-1 representing SA-SD, respectively. A chi-squared test was calculated on both the Pre and Post AS ChemQuest1 data sets and on the Post AS of the ChemQuest1 and On Level classes (Appendix F). The Post AS percentage data of the treated and untreated classes was then compared. The lengths of the Mid and Post Attitude Surveys were reduced by eliminating the questions that did not pertain to high school chemistry classes and then only compared the results of the questions that were the same in all surveys.

All students were also asked to complete the Chemistry Concept Inventory (CCI) at the beginning of the semester and then again at the end of the semester (Appendix G). The CCI was developed by Doug Mulford for his M.S. thesis at Purdue University (1996). A total of nine students from the treated and untreated groups were interviewed by me using the Student Interview (Appendix H) three weeks into the treatment phase, and then ChemQuest1 students were asked to fill out an anonymous Reflections on ChemQuest1 Survey (Appendix I) close to the end of the semester. In addition, open-ended questions were added to most assessments during the semester to monitor student attitudes and confidence during the year to allow for adjustments (Appendix J). The AS, however, were anonymous and could not be directly correlated to the students who were interviewed or grades they earned for the course. Students who were dropped or added to the course were not able to be excluded from the data because of the anonymity of the surveys.

Journal entries were made into the online lesson plans each week, reflecting on the progress of students and the treatment. Observations were recorded each week in the same way to keep all the data together for easy access.
Formative Assessments were administered several times throughout the treatment period (Appendix K). Some Formative Assessments were given using the online quiz program on my school webpage; others were one question Exit Tickets on note cards students handed in on their way out the door. The results from these assessments were compared to the teacher observational data.

Table 1
Data Triangulation Matrix

<table>
<thead>
<tr>
<th>Focus Questions</th>
<th>Data Source 1</th>
<th>Data Source 2</th>
<th>Data Source 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. What are the effects of gaming strategies on student self-concept in learning chemistry?</td>
<td>Instructor observations and journaling</td>
<td>Student pre and post treatment attitude surveys</td>
<td>Student interviews</td>
</tr>
<tr>
<td>2. What are the effects of gaming strategies on student self-efficacy in learning chemistry?</td>
<td>Teacher constructed formative assessments</td>
<td>Student pre and post treatment attitude surveys</td>
<td>Teacher observations and journaling</td>
</tr>
<tr>
<td>3. Do gaming strategies in the chemistry classroom increase learning/test scores?</td>
<td>Chemical Concept Inventory</td>
<td></td>
<td>Teacher constructed summative assessments</td>
</tr>
</tbody>
</table>

DATA AND ANALYSIS

The results of the Post Attitude Survey (AS) indicated that 64% of the ChemQuest1 students *agreed* or *strongly agreed* that the instructor has made them feel that they can continue in science as opposed to only 36% of the On Level chemistry students (*N* = 50) (Figure 1). Both groups were within one percentage point of each other on the Pre Attitude Survey (*N* = 73) (Figure 2). When asked how confident they were in being able to pass this chemistry course, 60% of the ChemQuest1 students felt confident compared to 56% of the On Level students on the Pre AS (Figure 3). Eighty-six percent
of ChemQuest1 students responded in the open-ended interview by saying *confident* or *very confident* when asked the same question (*n*=7). One student did respond with “I feel positive about it. I think I’ll make a 71,” however, none of the students expressed a lack of confidence in passing the course in any of the interviews.

*Figure 1*. Post Attitude Survey Classroom Experience Results, (*N*=50).

*Figure 2*. Pre Attitude Survey Classroom Experience Results, (*N*=73).
Confidence in their ability to pass the course dropped to 55% on the Mid AS for the ChemQuest1 students and rose to 65% for the On Level students (Figure 4). This trend is supported by the Mid AS student response to the question of confidence in learning chemistry where 46% of the ChemQuest1 students felt confident in their learning ability; however 50% of On Level students felt confident.

Eighty-two percent of the ChemQuest1 students responded favorably on the Mid AS to the questions about video lectures and the instructor explanations being clear. The On Level students responded less favorably in both instances with percentages of 58% and 62% respectively. “I like the videos. The little video clips,” was a comment made during one of the ChemQuest1 student interviews. An On Level student said that she was “more of a visual learner.”

Additional results from one of the ChemQuest1 tests indicated a high confidence level in the gaming strategies in the classroom. Many comments were similar to this student’s: “I love working at my own pace and the videos have helped me so much. I like everything. It’s a really fun way to learn.”
“I like how class is like a game. I don’t like how we have Saplings.” Several students said positive things about the ChemQuest1 program, but were unhappy using the
tablets or Sapling, which was the other software program they were required to access for some of their assignments. “I like how everything we do is on your own time and you can pace yourself. Our tablets are really the only thing I don’t like about it, but other than that I really like it!”

By the Post AS, both the ChemQuest1 and the On Level student confidence in learning chemistry had risen to 73% and 59%, respectively (Figure 5). The gap lessened in Post AS in student confidence in passing chemistry, with ChemQuest1 students maintaining their level from the slight drop at the Mid AS. ChemQuest1 students also felt more confident in explaining something learned in chemistry to another person with a 55% confidence level as opposed to On Level confidence level of 36%.

\[\begin{array}{c|c|c}
\text{Confidence in achieving a passing grade in a chemistry course.} & \text{Confidence in tutoring another student in a first year chemistry course.} & \text{Confidence in determining what answer is required from a written description of a chemistry problem.} & \text{Confidence in learning chemistry.} \\
\hline
55 & 27 & 27 & 73 \\
59 & 23 & 26 & 59 \\
\end{array}\]

Figure 5. Post Attitude Survey Self-efficacy Results, (N=50).

On the teacher constructed tests, ChemQuest1 test averages were compared to the On Level test averages (Figure 6). While the average was slightly lower for ChemQuest1 students on the Fall Final Exam, a two tailed t-test indicated a null hypothesis with no
statistical significant difference between this year’s scores and the Final Exam from the
fall of 2012.

Figure 6. Teacher Constructed Test Scores, \((N=78)\).

A normalized gain was calculated on the pre and post CCI for both ChemQuest1
and On Level students. ChemQuest1 had a normalized gain of five percent in contrast
with the On Level students showing an eleven percent gain by the end of the semester
(Figure 7).
In the Reflections on ChemQuest1 Survey, 55% of the students said that the most helpful part of the course was “wall time,” which was when I lectured to the class or small groups at the whiteboard. Eighteen percent said they learned the least from the videos, while 27% said they learned the most from the videos. When asked how well they felt they had learned the chemical concepts so far, 73% gave a positive response.

**INTERPRETATION AND CONCLUSION**

The ChemQuest1 students performed better on tests requiring calculations than on tests that were mostly conceptual or vocabulary terms. I was able to spend more time in class working individually and with small groups in the ChemQuest1 classes. These students practiced more in class than at home. The intention was for self-study at home, but students showed little motivation in this area.
The difference in the standardized scores for ChemQuest1 and On Level students may be the ChemQuest1 students were constantly repeating tasks, battles and boss fights. They also had more tasks with instant feedback. At the beginning of the semester students were using Sapling assignments with immediate feedback. This was short lived as the software assignments became too difficult to use with their tablets. I had to change to the online quiz application on our school’s webpage in an effort to continue the instant feedback. Ultimately though, I think reliance on retesting lead to ChemQuest1 students having performance issues with tests that they couldn’t retake.

ChemQuest1 students were able to access their tasks through a webpage that kept track of their progress with a progress bar. I was able to check on their progress and use the website to create a leaderboard which was posted at the start of class each day. I had several students who did not regularly access the website and complete tasks even though all sophomores were provided a Wi-Fi enabled tablet by the school. Multiple excuses were given, most of which involved inability to recall usernames and/or passwords or tablets not being available (left at home) or not operational (not charged).

Students were excited at the beginning of the semester about the gaming strategies, as the semester continued on the excitement waned for some and completely died for others. Only the students who were at the top of the leaderboard were able to keep their excitement and interest the entire semester. Students often clustered in friend groups rather than their guilds and spent time chatting rather than working.

It is interesting that the confidence level for ChemQuest1 students was higher in many areas than the On Level students. Many students did say they were having fun learning with the game, but it became very stressful at the end of the semester when they
had so much ground to cover after not getting enough done earlier. They did take responsibility for that, but didn’t think that they were ready for it. However, their self-efficacy in science dropped only slightly as opposed to the On Level students whose interest dropped dramatically, which is in line with previous research (Zusho, Pintrich, & Coppola, 2003).

ChemQuest1 in its current format requires students to be self-directed and take responsibility for their learning. Most of my sophomores did not have the maturity for this much responsibility and a few of their parents were unhappy with the lectures by video aspect as they perceived this form of instruction was not suitable for their struggling student. One of the leaders on the ChemQuest1 leaderboard felt that “having the kind of freedom we have with ChemQuest should only be rewarded to those who deserve it, like Pre-AP, or hardworking students.” This student was upset with her classmates for “taking advantage of the course,” and felt they weren’t “mature enough to handle a course like this.”

Due to the difference in standardized testing scores between the ChemQuest1 students and On Level students and the negative feedback from a few students and parents, I returned to teaching both classes with the same method of lecture, lab and homework. I believe there is a lot of potential with the use of game elements in the chemistry classroom. Students enjoyed the competition of Guild Wars and got very excited when they moved up the leaderboard. As one student put it, “this class is awesome!”
Value

ChemQuest1 has potential to help students gain confidence in learning chemistry, but it needs a lot of work to make it a viable alternative to regular chemistry classes. There needs to be a schedule that is very clear for students to measure their progress against. Many sophomores are not ready for the responsibility for self-direction and need more daily guidance. Not all students felt as this one: “It makes me feel mature that you are trusting us to get all this work done.” However, it was very encouraging that a few students did understand the trust and responsibility that was given to them.

The implementation of ChemQuest1 was extremely labor and time intensive before and during the semester. The leaderboard data was not easily transferred to a format that could be presented anonymously to the class, and the feedback for student work needed to be turned around each day. I spent two to three hours every night just on ChemQuest1, so there needs to be a more automated way to administer the leaderboard.

There were also constant issues with the tablets, software, and the school Wi-Fi which kept shutting down during online activities. But even with all of the difficulties of implementing my research project, it was inspiring to see some students really understand that learning is a personal responsibility and take on the challenges of chemistry with enthusiasm and confidence.

A very valuable outcome of designing the classroom as a game was the time I was able to spend with individual students during class. I was able to build relationships with even my quietest students. I also learned that frequent, small wins really helped students gain and keep their confidence in chemistry. A simple homework assignment could gain
a student enough points to level up which would create excitement and cause and increase in engagement in order to level up again.

This research really brought home to me that students need more opportunities and encouragement to take ownership of their learning. Given the right circumstances, they get very excited about learning. It also made me really reflect on whether I am relying too much on the fear of failure environment to achieve student success in my classroom. It was very difficult for me to let students repeat work until they became proficient. I constantly wanted to move forward and work on the next unit before many of the students had mastered the current material. My instinct was to give them an assessment that they were not prepared for when they were dragging their feet on getting work completed. I need to find better ways to motivate students to move through material than threats of failure.

There are some significant points to keep in mind when deciding to design a class as a video game using an online program. First, be sure to make it very clear how many XP students need to have by the end of the year and remind them frequently. Set deadlines for *Craftings* and *Boss Fights*. This will prevent lab supplies from having to be set out for excessively long periods of time and encourage students who are lagging behind to get their assignments completed before they are tested over them. Also, have all videos and programs preloaded onto any devices that the students are using, particularly if they are taking them home. This will help eliminate internet access issues. Keep a list of student usernames and passwords and use only one website if possible. Lastly, be sure that the school WiFi can handle the load of having all of your students engaged in internet activities at the same time.
More research is needed to determine if motivation to study outside of class can be improved using game elements. It might be possible to include a check-in outside of class time award of XP in the next iteration of ChemQuest1. There also needs to be a way of keeping students accountable for material without taking the self-direction away from them.

I feel ChemQuest1 will work best if it is offered as a choice for students taking chemistry, an alternative method of learning rather than a mandated one. Games must be voluntary to remain a game.
REFERENCES CITED


APPENDICES
APPENDIX A

CHEMISTRY TEXAS ESSENTIAL KNOWLEDGE AND SKILLS
§112.35. Chemistry, Beginning with School Year 2010-2011 (One Credit).

(a) General requirements. Students shall be awarded one credit for successful completion of this course. Required prerequisites: one unit of high school science and Algebra I. Suggested prerequisite: completion of or concurrent enrollment in a second year of math. This course is recommended for students in Grade 10, 11, or 12.

(b) Introduction.

(1) Chemistry. In Chemistry, students conduct laboratory and field investigations, use scientific methods during investigations, and make informed decisions using critical thinking and scientific problem solving. Students study a variety of topics that include characteristics of matter, use of the Periodic Table, development of atomic theory and chemical bonding, chemical stoichiometry, gas laws, solution chemistry, thermochemistry, and nuclear chemistry. Students will investigate how chemistry is an integral part of our daily lives.

(2) Nature of Science. Science, as defined by the National Academy of Sciences, is the "use of evidence to construct testable explanations and predictions of natural phenomena, as well as the knowledge generated through this process." This vast body of changing and increasing knowledge is described by physical, mathematical, and conceptual models. Students should know that some questions are outside the realm of science because they deal with phenomena that are not scientifically testable.

(3) Scientific inquiry. Scientific inquiry is the planned and deliberate investigation of the natural world. Scientific methods of investigation can be experimental, descriptive, or comparative. The method chosen should be appropriate to the question being asked.

(4) Science and social ethics. Scientific decision making is a way of answering questions about the natural world. Students should be able to distinguish between scientific decision-making methods and ethical and social decisions that involve the application of scientific information.

(5) Scientific systems. A system is a collection of cycles, structures, and processes that interact. All systems have basic properties that can be described in terms of space, time, energy, and matter. Change and constancy occur in systems as patterns and can be observed, measured, and modeled. These patterns help to make predictions that can be scientifically tested. Students should analyze a system in terms of its components and how these components relate to each other, to the whole, and to the external environment.

(c) Knowledge and skills.
(1) Scientific processes. The student, for at least 40% of instructional time, conducts laboratory and field investigations using safe, environmentally appropriate, and ethical practices. The student is expected to:

(A) demonstrate safe practices during laboratory and field investigations, including the appropriate use of safety showers, eyewash fountains, safety goggles, and fire extinguishers;

(B) know specific hazards of chemical substances such as flammability, corrosiveness, and radioactivity as summarized on the Material Safety Data Sheets (MSDS); and

(C) demonstrate an understanding of the use and conservation of resources and the proper disposal or recycling of materials.

(2) Scientific processes. The student uses scientific methods to solve investigative questions. The student is expected to:

(A) know the definition of science and understand that it has limitations, as specified in subsection (b)(2) of this section;

(B) know that scientific hypotheses are tentative and testable statements that must be capable of being supported or not supported by observational evidence. Hypotheses of durable explanatory power which have been tested over a wide variety of conditions are incorporated into theories;

(C) know that scientific theories are based on natural and physical phenomena and are capable of being tested by multiple independent researchers. Unlike hypotheses, scientific theories are well-established and highly-reliable explanations, but may be subject to change as new areas of science and new technologies are developed;

(D) distinguish between scientific hypotheses and scientific theories;

(E) plan and implement investigative procedures, including asking questions, formulating testable hypotheses, and selecting equipment and technology, including graphing calculators, computers and probes, sufficient scientific glassware such as beakers, Erlenmeyer flasks, pipettes, graduated cylinders, volumetric flasks, safety goggles, and burettes, electronic balances, and an adequate supply of consumable chemicals;

(F) collect data and make measurements with accuracy and precision;
(G) express and manipulate chemical quantities using scientific conventions and mathematical procedures, including dimensional analysis, scientific notation, and significant figures;

(H) organize, analyze, evaluate, make inferences, and predict trends from data; and

(I) communicate valid conclusions supported by the data through methods such as lab reports, labeled drawings, graphs, journals, summaries, oral reports, and technology-based reports.

(3) Scientific processes. The student uses critical thinking, scientific reasoning, and problem solving to make informed decisions within and outside the classroom. The student is expected to:

(A) in all fields of science, analyze, evaluate, and critique scientific explanations by using empirical evidence, logical reasoning, and experimental and observational testing, including examining all sides of scientific evidence of those scientific explanations, so as to encourage critical thinking by the student;

(B) communicate and apply scientific information extracted from various sources such as current events, news reports, published journal articles, and marketing materials;

(C) draw inferences based on data related to promotional materials for products and services;

(D) evaluate the impact of research on scientific thought, society, and the environment;

(E) describe the connection between chemistry and future careers; and

(F) research and describe the history of chemistry and contributions of scientists.

(4) Science concepts. The student knows the characteristics of matter and can analyze the relationships between chemical and physical changes and properties. The student is expected to:

(A) differentiate between physical and chemical changes and properties;

(B) identify extensive and intensive properties;
(C) compare solids, liquids, and gases in terms of compressibility, structure, shape, and volume; and

(D) classify matter as pure substances or mixtures through investigation of their properties.

(5) Science concepts. The student understands the historical development of the Periodic Table and can apply its predictive power. The student is expected to:

(A) explain the use of chemical and physical properties in the historical development of the Periodic Table;

(B) use the Periodic Table to identify and explain the properties of chemical families, including alkali metals, alkaline earth metals, halogens, noble gases, and transition metals; and

(C) use the Periodic Table to identify and explain periodic trends, including atomic and ionic radii, electronegativity, and ionization energy.

(6) Science concepts. The student knows and understands the historical development of atomic theory. The student is expected to:

(A) understand the experimental design and conclusions used in the development of modern atomic theory, including Dalton's Postulates, Thomson's discovery of electron properties, Rutherford's nuclear atom, and Bohr's nuclear atom;

(B) understand the electromagnetic spectrum and the mathematical relationships between energy, frequency, and wavelength of light;

(C) calculate the wavelength, frequency, and energy of light using Planck's constant and the speed of light;

(D) use isotopic composition to calculate average atomic mass of an element; and

(E) express the arrangement of electrons in atoms through electron configurations and Lewis valence electron dot structures.

(7) Science concepts. The student knows how atoms form ionic, metallic, and covalent bonds. The student is expected to:

(A) name ionic compounds containing main group or transition metals, covalent compounds, acids, and bases, using International Union of Pure and Applied Chemistry (IUPAC) nomenclature rules;
(B) write the chemical formulas of common polyatomic ions, ionic compounds containing main group or transition metals, covalent compounds, acids, and bases;

(C) construct electron dot formulas to illustrate ionic and covalent bonds;

(D) describe the nature of metallic bonding and apply the theory to explain metallic properties such as thermal and electrical conductivity, malleability, and ductility; and

(E) predict molecular structure for molecules with linear, trigonal planar, or tetrahedral electron pair geometries using Valence Shell Electron Pair Repulsion (VSEPR) theory.

(8) Science concepts. The student can quantify the changes that occur during chemical reactions. The student is expected to:

(A) define and use the concept of a mole;

(B) use the mole concept to calculate the number of atoms, ions, or molecules in a sample of material;

(C) calculate percent composition and empirical and molecular formulas;

(D) use the law of conservation of mass to write and balance chemical equations; and

(E) perform stoichiometric calculations, including determination of mass relationships between reactants and products, calculation of limiting reagents, and percent yield.

(9) Science concepts. The student understands the principles of ideal gas behavior, kinetic molecular theory, and the conditions that influence the behavior of gases. The student is expected to:

(A) describe and calculate the relations between volume, pressure, number of moles, and temperature for an ideal gas as described by Boyle's law, Charles' law, Avogadro's law, Dalton's law of partial pressure, and the ideal gas law;

(B) perform stoichiometric calculations, including determination of mass and volume relationships between reactants and products for reactions involving gases; and

(C) describe the postulates of kinetic molecular theory.
(10) Science concepts. The student understands and can apply the factors that influence the behavior of solutions. The student is expected to:

(A) describe the unique role of water in chemical and biological systems;

(B) develop and use general rules regarding solubility through investigations with aqueous solutions;

(C) calculate the concentration of solutions in units of molarity;

(D) use molarity to calculate the dilutions of solutions;

(E) distinguish between types of solutions such as electrolytes and nonelectrolytes and unsaturated, saturated, and supersaturated solutions;

(F) investigate factors that influence solubilities and rates of dissolution such as temperature, agitation, and surface area;

(G) define acids and bases and distinguish between Arrhenius and Bronsted-Lowry definitions and predict products in acid base reactions that form water;

(H) understand and differentiate among acid-base reactions, precipitation reactions, and oxidation-reduction reactions;

(I) define pH and use the hydrogen or hydroxide ion concentrations to calculate the pH of a solution; and

(J) distinguish between degrees of dissociation for strong and weak acids and bases.

(11) Science concepts. The student understands the energy changes that occur in chemical reactions. The student is expected to:

(A) understand energy and its forms, including kinetic, potential, chemical, and thermal energies;

(B) understand the law of conservation of energy and the processes of heat transfer;

(C) use thermochemical equations to calculate energy changes that occur in chemical reactions and classify reactions as exothermic or endothermic;

(D) perform calculations involving heat, mass, temperature change, and specific heat; and
(E) use calorimetry to calculate the heat of a chemical process.

(12) Science concepts. The student understands the basic processes of nuclear chemistry. The student is expected to:

(A) describe the characteristics of alpha, beta, and gamma radiation;

(B) describe radioactive decay process in terms of balanced nuclear equations; and

(C) compare fission and fusion reactions.

Source: The provisions of this §112.35 adopted to be effective August 4, 2009, 34 TexReg 5063.
APPENDIX B

INSTITUTIONAL REVIEW BOARD APPROVAL
INSTITUTIONAL REVIEW BOARD
For the Protection of Human Subjects
FWA 00000165

MEMORANDUM

TO: Carol Smith and John Graves
FROM: Mark Quinn, Chair
DATE: September 9, 2013
RE: "ChemQuest": Using Gaming Strategies in the High School Chemistry Classroom to Motivate and Engage Students in Learning Chemistry” [CS090913-EX]

The above research, described in your submission of September 9, 2013, is exempt from the requirement of review by the Institutional Review Board in accordance with the Code of Federal regulations, Part 46, section 101. The specific paragraph which applies to your research is:

X (b) (1) Research conducted in established or commonly accepted educational settings, involving normal educational practices such as (i) research on regular and special education instructional strategies, or (ii) research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.

X (b) (2) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior, unless: (i) information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects; and (ii) any disclosure of the human subjects' responses outside the research could reasonably place the subjects at risk of criminal or civil liability, or be damaging to the subjects' financial standing, employability, or reputation.

(b) (3) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior that is not exempt under paragraph (b)(2) of this section, if: (i) the human subjects are elected or appointed public officials or candidates for public office; or (ii) federal statute(s) without exception that the confidentiality of the personally identifiable information will be maintained throughout the research and thereafter.

(b) (4) Research involving the collection or study of existing data, documents, records, pathological specimens, or diagnostic specimens, if those sources are publicly available, or if the information is recorded by the investigator in such a manner that the subjects cannot be identified, directly or through identifiers linked to the subjects.

(b) (5) Research and demonstration projects, which are conducted by or subject to the approval of department or agency heads, and which are designed to study, evaluate, or otherwise examine: (i) public benefit or service programs; (ii) procedures for obtaining benefits or services under those programs; (iii) possible changes in or alternatives to those programs or procedures; or (iv) possible changes in methods or levels of payment for benefits or services under those programs.

(b) (6) Taste and food quality evaluation and consumer acceptance studies, (i) if wholesome foods without additives are consumed, or (ii) if a food is consumed that contains a food ingredient at or below the level and for a use found to be safe, or agricultural chemical or environmental contaminant at or below the level found to be safe, by the FDA, or approved by the EPA, or the Food Safety and Inspection Service of the USDA.

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

SCREENSHOTS OF OLOTOLO.ORG
ChemQuest1 on olotolo.org

Assignments - Teacher view
Task 1-Teacher view

Main Text:
You will play this game using an avatar. Choose a name that will represent your player in the game. You must keep this name SECRET at all times as it will be posted along with your scores on the Leaderboard.

Add a link:
https://docs.google.com/a/vanastyneiied.org/forms/d/1QmG1-ANkfabcfOp3A30J7a6VnQOqIftWhJYkI6SWWAI/viewform

Details:
Lesson title: Task 1: Choose your avatar name!
Possible points: 10
Who determines the score?: Student

Task 1-Student view

TASK 1: CHOOSE YOUR AVATAR NAME!

You will play this game using an avatar. Choose a name that will represent your player in the game. You must keep this name SECRET at all times as it will be posted along with your scores on the Leaderboard.

Inappropriate names will be rejected.

Use this Google form to choose your avatar name:
https://docs.google.com/a/vanastyneiied.org/forms/d/1QmG1-ANkfabcfOp3A30J7a6VnQOqIftWhJYkI6SWWAI/viewform
APPENDIX D

RANKS
Ranks that allowed students to level up as they gained sufficient points.

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<td>Chemistry PhD candidate</td>
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<td>Post doc chemist</td>
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<td>Master chemist</td>
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<td>Principal Investigator</td>
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<td>Chemist Extraordinaire</td>
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APPENDIX E

EXAMPLE LEADERBOARD
ChemQuest1 8th Period Leaderboard

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<td>3866</td>
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<tr>
<td>Jaty4Lyfe</td>
<td>Junior chemist</td>
<td>3794</td>
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<tr>
<td>theprincess</td>
<td>Accepted</td>
<td>3474</td>
</tr>
<tr>
<td>Dogcat1228</td>
<td>Accepted</td>
<td>3127</td>
</tr>
<tr>
<td>sparkles</td>
<td>Accepted</td>
<td>3069</td>
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<tr>
<td>forensicpuppy19</td>
<td>Senior apprentice chemist</td>
<td>2524</td>
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<tr>
<td>GEORGIA ROSE</td>
<td>Senior apprentice chemist</td>
<td>2492</td>
</tr>
<tr>
<td>Volleyball Chick</td>
<td>Senior apprentice chemist</td>
<td>2282</td>
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<tr>
<td>Mrs. Bieber</td>
<td>Senior apprentice chemist</td>
<td>2230</td>
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<td>QueenBee</td>
<td>Senior apprentice chemist</td>
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<tr>
<td>BLACK BEAUTY</td>
<td>Senior apprentice chemist</td>
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<td>Animi</td>
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<td>RollyM</td>
<td>Junior apprentice chemist</td>
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Class total XP 33024
APPENDIX F

ANONYMOUS PRE ATTITUDE SURVEY
Anonymous Pre Attitude Survey

Note: The information provided will remain anonymous.
Survey: Anonymous Pre Attitude Survey
User: SMITH, CAROL
Status: Draft
Participation in this research is voluntary and participation or non-participation will not affect a student’s grades or class standing in any way.

This questionnaire is optional, but filling it out will help me understand what helps students learn chemistry. Your participation is greatly appreciated.

This part of the questionnaire investigates the confidence you have in undertaking different tasks.

Using the scale 1-5 with 1 being not confident and 5 being totally confident, rate each task according to how you currently feel.

1. Please indicate how confident you feel about talking to a scientist about chemistry.
   1 2 3 4 5

2. Please indicate how confident you feel about achieving a passing grade in a chemical hazards course.
   1 2 3 4 5

3. Please indicate how confident you feel about reading the procedures for an experiment and conducting the experiment without help.
   1 2 3 4 5

4. Please indicate how confident you feel about designing and conducting a chemistry experiment.
   1 2 3 4 5

5. Please indicate how confident you feel about tutoring another student in a first year chemistry course.
   1 2 3 4 5

6. Please indicate how confident you feel about determining what answer is required from a written description of a chemistry problem.
   1 2 3 4 5

7. Please indicate how confident you feel about ensuring that data obtained from an experiment is accurate.
   1 2 3 4 5
8. Please indicate how confident you feel about proposing a meaningful question that could be answered experimentally.
   1 2 3 4 5

9. Please indicate how confident you feel about explaining something that you learned in this chemistry course to another person.
   1 2 3 4 5

10. Please indicate how confident you feel about choosing an appropriate formula to solve a chemistry problem.
    1 2 3 4 5

11. Please indicate how confident you feel about learning chemistry.
    1 2 3 4 5

12. Please indicate how confident you feel about determining the appropriate units for a result found by using a formula.
    1 2 3 4 5

13. Please indicate how confident you feel about after watching a television documentary dealing with some aspect of chemistry, discussing the main points with another person.
    1 2 3 4 5

14. Please indicate how confident you feel about achieving a passing grade in a second year chemistry course.
    1 2 3 4 5

15. Please indicate how confident you feel about writing up the conclusion section in a lab write up.
    1 2 3 4 5

16. Please indicate how confident you feel about after listening to a public lecture regarding some chemistry topic, explaining its main ideas to another person.
    1 2 3 4 5

This part of the questionnaire looks at your experiences during your first year chemistry class.
Using:
   SA - Strongly Agree
   A - Agree
   N - Neither
   D - Disagree
   SD - Strongly Disagree
Please answer these questions considering all of your experiences during your first year chemistry class. For example if you thought three out of four of your lectures were relevant to the objectives of the course, you would answer the following question:

The lecture material was relevant to the objectives of the course.

You would choose N for Neither.
17. The lecture material was relevant to the objectives of the course.
   SA   A   N   D   SD

18. The video lecture material was relevant to the objectives of the course.
   SA   A   N   D   SD

19. The instructor was interested in my progress in chemistry.
   SA   A   N   D   SD

20. The concepts introduced in the lecture material were explained clearly.
   SA   A   N   D   SD

21. The concepts introduced in the video lecture material were explained clearly.
   SA   A   N   D   SD

22. The lectures were interesting.
   SA   A   N   D   SD

23. The video lectures were interesting.
   SA   A   N   D   SD

24. The chemistry instructor has made me feel that I have the ability to continue in science.
   SA   A   N   D   SD

25. The lecture notes were clearly presented.
   SA   A   N   D   SD

26. It was easy to find the instructor to discuss a problem with.
   SA   A   N   D   SD

27. The lectures were presented in an interesting manner.
   SA   A   N   D   SD

28. The video lectures were presented in an interesting manner.
   SA   A   N   D   SD

29. The instructor explained problems clearly to me.
   SA   A   N   D   SD
30. The tutors explained problems clearly to me.
   SA  A  N  D  SD

31. When writing-up experiments, the relationship between the data and the results was clear.
   SA  A  N  D  SD

32. The experiments were interesting.
   SA  A  N  D  SD

33. The amount of work required when writing up the lab report was appropriate for the amount of the assessment.
   SA  A  N  D  SD

34. I find science fiction movies exciting.
   SA  A  N  D  SD

35. I find science documentaries enjoyable.
   SA  A  N  D  SD

36. I enjoy playing video games.
   SA  A  N  D  SD
APPENDIX G

ANONYMOUS MID ATTITUDE SURVEY
Mid Attitude Survey

Note: The information provided will remain anonymous.
Survey: Anonymous Pre Attitude Survey
User: SMITH, CAROL
Status: Draft
Participation in this research is voluntary and participation or non-participation will not affect a student’s grades or class standing in any way.

This questionnaire is optional, but filling it out will help me understand what helps students learn chemistry. Your participation is greatly appreciated.

This part of the questionnaire investigates the confidence you have in undertaking different tasks.

Using the scale 1-5 with 1 being not confident and 5 being totally confident, rate each task according to how you currently feel.

1. Please indicate how confident you feel about talking to a scientist about chemistry.
   1  2  3  4  5

2. Please indicate how confident you feel about achieving a passing grade in a chemistry course.
   1  2  3  4  5  2

3. Please indicate how confident you feel about reading the procedures for an experiment and conducting the experiment without help.
   1  2  3  4  5

4. Please indicate how confident you feel about designing and conducting a chemistry experiment.
   1  2  3  4  5

5. Please indicate how confident you feel about tutoring another student in a first year chemistry course.
   1  2  3  4  5

6. Please indicate how confident you feel about determining what answer is required from a written description of a chemistry problem.
   1  2  3  4  5

7. Please indicate how confident you feel about ensuring that data obtained from an experiment is accurate.
   1  2  3  4  5
8. Please indicate how confident you feel about explaining something that you learned in this chemistry course to another person.

1  2  3  4  5

9. Please indicate how confident you feel about learning chemistry.

1  2  3  4  5

10. Please indicate how confident you feel about determining the appropriate units for a result found by using a formula.

1  2  3  4  5

11. Please indicate how confident you feel about writing up the conclusion section in a lab write up.

1  2  3  4  5

This part of the questionnaire looks at your experiences during your first year chemistry class.
Using:

SA - Strongly Agree
A - Agree
N - Neither
D - Disagree
SD - Strongly Disagree

Please answer these questions considering all of your experiences during your first year chemistry class. For example if you thought three out of four of your lectures were relevant to the objectives of the course, you would answer the following question:

The lecture material was relevant to the objectives of the course.

You would choose N for Neither.

12. The lecture material was relevant to the objectives of the course.

SA  A  N  D  SD

13. The video lecture material was relevant to the objectives of the course.

SA  A  N  D  SD

14. The instructor was interested in my progress in chemistry.

SA  A  N  D  SD

15. The concepts introduced in the lecture material were explained clearly.

SA  A  N  D  SD

16. The concepts introduced in the video lecture material were explained clearly.

SA  A  N  D  SD

17. The lectures were interesting.

SA  A  N  D  SD
18. The video lectures were interesting.
   SA  A  N  D  SD

19. The chemistry instructor has made me feel that I have the ability to continue in science.
   SA  A  N  D  SD

20. The lecture notes were clearly presented.
   SA  A  N  D  SD

21. It was easy to find the instructor to discuss a problem with.
   SA  A  N  D  SD

22. The instructor explained problems clearly to me.
   SA  A  N  D  SD

23. When writing-up experiments, the relationship between the data and the results was clear.
   SA  A  N  D  SD

24. The experiments were interesting.
   SA  A  N  D  SD

25. The amount of work required when writing up the lab report was appropriate for the mount of the assessment.
   SA  A  N  D  SD

26. I find science fiction movies exciting.
   SA  A  N  D  SD

27. I find science documentaries enjoyable.
   SA  A  N  D  SD

28. I enjoy playing video games.
   SA  A  N  D  SD
APPENDIX H

ANONYMOUS POST ATTITUDE SURVEY
Post Attitude Survey

Note: The information provided will remain anonymous.
Survey: Anonymous Pre Attitude Survey
User: SMITH, CAROL
Status: Draft

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

This questionnaire is optional, but filling it out will help me understand what helps students learn chemistry. Your participation is greatly appreciated.

This part of the questionnaire investigates the confidence you have in undertaking different tasks.

Using the scale 1-5 with 1 being not confident and 5 being totally confident, rate each task according to how you currently feel.

1. Please indicate how confident you feel about talking to a scientist about chemistry.
   1 2 3 4 5

2. Please indicate how confident you feel about achieving a passing grade in a chemistry course.
   1 2 3 4 5

3. Please indicate how confident you feel about reading the procedures for an experiment and conducting the experiment without help.
   1 2 3 4 5

4. Please indicate how confident you feel about designing and conducting a chemistry experiment.
   1 2 3 4 5

5. Please indicate how confident you feel about tutoring another student in a first year chemistry course.
   1 2 3 4 5

6. Please indicate how confident you feel about determining what answer is required from a written description of a chemistry problem.
   1 2 3 4 5

7. Please indicate how confident you feel about ensuring that data obtained from an experiment is accurate.
   1 2 3 4 5
8. Please indicate how confident you feel about explaining something that you learned in this chemistry course to another person.
   1 2 3 4 5

9. Please indicate how confident you feel about learning chemistry.
   1 2 3 4 5

10. Please indicate how confident you feel about determining the appropriate units for a result found by using a formula.
   1 2 3 4 5

11. Please indicate how confident you feel about writing up the conclusion section in a lab write up.
   1 2 3 4 5

This part of the questionnaire looks at your experiences during your first year chemistry class.
Using:
   SA - Strongly Agree
   A - Agree
   N - Neither
   D - Disagree
   SD - Strongly Disagree

Please answer these questions considering all of your experiences during your first year chemistry class. For example if you thought three out of four of your lectures were relevant to the objectives of the course, you would answer the following question:
   The lecture material was relevant to the objectives of the course.
You would choose N for Neither.

12. The lecture material was relevant to the objectives of the course.
   SA A N D SD

13. The video lecture material was relevant to the objectives of the course.
   SA A N D SD

14. The instructor was interested in my progress in chemistry.
   SA A N D SD

15. The concepts introduced in the lecture material were explained clearly.
   SA A N D SD

16. The concepts introduced in the video lecture material were explained clearly.
   SA A N D SD

17. The lectures were interesting.
   SA A N D SD
18. The video lectures were interesting.
   SA A N D SD

19. The chemistry instructor has made me feel that I have the ability to continue in science.
   SA A N D SD

20. The lecture notes were clearly presented.
   SA A N D SD

21. It was easy to find the instructor to discuss a problem with.
   SA A N D SD

22. The instructor explained problems clearly to me.
   SA A N D SD

23. When writing-up experiments, the relationship between the data and the results was clear.
   SA A N D SD

24. The experiments were interesting.
   SA A N D SD

25. The amount of work required when writing up the lab report was appropriate for the mount of the assessment.
   SA A N D SD

26. I find science fiction movies exciting.
   SA A N D SD

27. I find science documentaries enjoyable.
   SA A N D SD

28. I enjoy playing video games.
   SA A N D SD
APPENDIX I

CHI SQUARED TEST RESULTS
Chi squared test over pre and post attitude surveys ChemQuest1

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<td>1</td>
<td>10</td>
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**P value and statistical significance:**
Chi squared equals 10.888 with 4 degrees of freedom.
The two-tailed P value equals 0.0279.
By conventional criteria, this difference is considered to be statistically significant.
The P value answers this question: If the theory that generated the expected values were correct, what is the probability of observing such a large discrepancy (or larger) between observed and expected values? A small P value is evidence that the data are not sampled from the distribution you expected.

Chi squared test over post attitude surveys of On Level (expected) and ChemQuest1 (observed)

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</table>

**P value and statistical significance:**
Chi squared equals 16.704 with 4 degrees of freedom.
The two-tailed P value equals 0.0022.
By conventional criteria, this difference is considered to be very statistically significant.
The P value answers this question: If the theory that generated the expected values were correct, what is the probability of observing such a large discrepancy (or larger) between observed and expected values? A small P value is evidence that the data are not sampled from the distribution you expected.

http://graphpad.com/quickcalcs/chisquared2/
APPENDIX J

CHEMICAL CONCEPT INVENTORY
Please do not put your name on this form. Participation in this research is voluntary and participation or non-participation will not affect a student’s grades or class standing in any way.

Conceptual Questions (CQs): Chemical Concepts Inventory

This inventory consists of 22 multiple choice questions. Carefully consider each question and indicate the one best answer for each. Several of the questions are paired. In these cases, the first question asks about a chemical or physical effect. The second question then asks for the reason for the observed effect.

1. Which of the following must be the same before and after a chemical reaction?

   a. The sum of the masses of all substances involved.
   b. The number of molecules of all substances involved.
   c. The number of atoms of each type involved.
   d. Both (a) and (c) must be the same.
   e. (e) Each of the answers (a), (b), and (c) must be the same.

2. Assume a beaker of pure water has been boiling for 30 minutes. What is in the bubbles in the boiling water?

   a. Air.
   b. Oxygen gas and hydrogen gas.
   c. Oxygen.
   d. Water vapor.
   e. Heat.

3. A glass of cold milk sometimes forms a coat of water on the outside of the glass (Often referred to as 'sweat'). How does most of the water get there?

   a. Water evaporates from the milk and condenses on the outside of the glass.
   b. The glass acts like a semi-permeable membrane and allows the water to pass, but not the milk.
   c. Water vapor condenses from the air.
   d. The coldness causes oxygen and hydrogen from the air combine on the glass forming water.
4. What is the mass of the solution when 1 pound of salt is dissolved in 20 pounds of water?
   a. 19 Pounds.
   b. 20 Pounds.
   c. Between 20 and 21 pounds.
   d. 21 pounds.
   e. More than 21 pounds.

5. The diagram represents a mixture of S atoms and O₂ molecules in a closed container.

Which diagram shows the results after the mixture reacts as completely as possible according to the equation:

\[ 2S + 3O₂ \rightarrow 2SO₃ \]

6. The circle on the left shows a magnified view of a very small portion of liquid water in a closed container.
7. True or False? When a match burns, some matter is destroyed.
   a. True
   b. False

8. What is the reason for your answer to question 7?
   a. This chemical reaction destroys matter.
   b. Matter is consumed by the flame.
   c. The mass of ash is less than the match it came from.
   d. The atoms are not destroyed, they are only rearranged.
   e. The match weighs less after burning.

9. Heat is given off when hydrogen burns in air according to the equation

   \[ 2H_2 + O_2 \rightarrow 2H_2O \]

Which of the following is responsible for the heat?
a. Breaking hydrogen bonds gives off energy.
b. Breaking oxygen bonds gives off energy.
c. Forming hydrogen-oxygen bonds gives off energy.
d. Both (a) and (b) are responsible.
e. (a), (b), and (c) are responsible.

10. Two ice cubes are floating in water:

After the ice melts, will the water level be:

a. higher?
b. lower?
c. the same?

11. What is the reason for your answer to question 10?

a. The weight of water displaced is equal to the weight of the ice.
b. Water is more dense in its solid form (ice).
c. Water molecules displace more volume than ice molecules.
d. The water from the ice melting changes the water level.
e. When ice melts, its molecules expand.

12. A 1.0-gram sample of solid iodine is placed in a tube and the tube is sealed after all of the air is removed. The tube and the solid iodine together weigh 27.0 grams.

The tube is then heated until all of the iodine evaporates and the tube is filled
with iodine gas. Will the weight after heating be:

a. less than 26.0 grams.
b. 26.0 grams.
c. 27.0 grams.
d. 28.0 grams.
e. more than 28.0 grams.

13. What is the reason for your answer to question 12?

a. A gas weighs less than a solid.
b. Mass is conserved.
c. Iodine gas is less dense than solid iodine.
d. Gasses rise.
e. Iodine gas is lighter than air.

14. What is the approximate number of carbon atoms it would take placed next to each other to make a line that would cross this dot: •

a. 4
b. 200
c. 30,000,000
d. $6.02 \times 10^{23}$

15. Figure 1 represents a 1.0 L solution of sugar dissolved in water. The dots in the magnification circle represent the sugar molecules. In order to simplify the diagram, the water molecules have not been shown.

Which response represents the view after 1.0 L of water was added (Figure 2).
16. 100 mL of water at 25°C and 100 mL of alcohol at 25°C are both heated at the same rate under identical conditions. After 3 minutes the temperature of the alcohol is 50°C. Two minutes later the temperature of the water is 50°C. Which liquid received more heat as it warmed to 50°C?

a. The water.
b. The alcohol.
c. Both received the same amount of heat.
d. It is impossible to tell from the information given.

17. What is the reason for your answer to question 16?

a. Water has a higher boiling point than the alcohol.
b. Water takes longer to change its temperature than the alcohol.
c. Both increased their temperatures 25°C.
d. Alcohol has a lower density and vapor pressure.
e. Alcohol has a higher specific heat so it heats faster.

18. Iron combines with oxygen and water from the air to form rust. If an iron nail were allowed to rust completely, one should find that the rust weighs:

a. less than the nail it came from.
b. the same as the nail it came from.
c. more than the nail it came from.
d. It is impossible to predict.

19. What is the reason for your answer to question 18?

a. Rusting makes the nail lighter.
b. Rust contains iron and oxygen.
c. The nail flakes away.
d. The iron from the nail is destroyed.
e. The flaky rust weighs less than iron.
20. Salt is added to water and the mixture is stirred until no more salt dissolves. The salt that does not dissolve is allowed to settle out. What happens to the concentration of salt in solution if water evaporates until the volume of the solution is half the original volume? (Assume temperature remains constant.)

![Diagram](image)

The concentration

a. increases.
b. decreases.
c. stays the same.

21. What is the reason for your answer to question 20?

a. There is the same amount of salt in less water.
b. More solid salt forms.
c. Salt does not evaporate and is left in solution.
d. There is less water.

22. Following is a list of properties of a sample of solid sulfur:

i. Brittle, crystalline solid.
ii. Melting point of 113°C.
iii. Density of 2.1 g/cm³.
iv. Combines with oxygen to form sulfur dioxide

Which, if any, of these properties would be the same for one single atom of sulfur obtained from the sample?

a. i and ii only.
b. iii and iv only.
c. iv only.
d. All of these properties would be the same.

e. None of these properties would be the same.
These are the CCI questions used in the Anonymous Pre and Post CCI. They are from JCE Online:

http://www.jce.divched.org/JCEDLib/QBank/collection/CQandChP/CQs/ConceptsInventory/Concepts_Inventory.html
APPENDIX K

STUDENT INTERVIEW
Student Interview

1. How do you feel about being able to pass this chemistry course?

2. How relevant do you feel chemistry is to your life?

3. How much time do you spend each week studying for this chemistry course?

4. What are your goals for this course?

5. Is there anything you would like me to know?
APPENDIX L

REFLECTIONS ON CHEMQUEST1 SURVEY
Survey 'Reflections on ChemQuest1'

Please take a few moments to reflect on your experience in ChemQuest1. This is an anonymous survey with some questions added to help you think. Please feel free to add any thoughts you feel are important.

1. How well do you feel you have learned the chemical concepts that you have covered so far in this course?

2. How confident do you feel about your success in this course?

3. How well do you feel your grade in this course reflects your learning?

4. Were you able to complete the tasks assigned in a timely manner? If not, what prevented you from completing them on time?

5. Do you feel the expectations in the class were reasonable? If not, what suggestions do you have to improve them?

6. What was the most helpful part of the course?

7. What was the least helpful part of the course?

8. Is there else anything you would like me to know or that you feel needs to be said about the course?
APPENDIX M

EXAMPLE BOSS FIGHT WITH OPEN-ENDED ATTITUDE QUESTIONS AT END
1. Measure the following line with a ruler with as much precision and accuracy as possible.
   a. __________

2. Write the number of significant figures for each of the following numbers:
   a. 54.6 _______
   b. 9034 _______
   c. 0.00023 _______
   d. 0.02304 _______
   e. 90000 _______
   f. 42.000 _______
   g. 3.3 \times 10^3 _______
   h. 5.0 \times 10^{-2}_______
   i. 400. _______

3. Write the following numbers in scientific notation:
   a. 458000 ___________
   b. 8004 _______________
   c. 0.000230 ___________
   d. 0.0052 _____________

4. Write the following numbers in standard notation:
   a. 5.3 \times 10^{-3} _________________
   b. 2.90 \times 10^6 _________________

5. Solve the following problems using the correct significant figures and units.
a. \((3.4 \times 10^3\text{m}) \times (5.50 \times 10^2\text{m})\) 

b. \((5.640 \times 10^{-4}) / (1.50 \times 10^{-6})\)

c. \(4.44 \text{ m} + 5.6 \text{ m} + 3.23 \text{ m} + 8.70 \text{ m}\)

6. A student measured the mass of a substance three times and recorded masses of 2.40 g, 2.45 g and 2.42 g. The actual mass of the substance was 3.52 g. Was the student
a. Accurate
b. Precise
c. neither accurate nor precise
d. both accurate and precise

7. A student measured the length of a rod and recorded a measurement of 4.5 cm. The actual length of the rod was 4.35 cm. What was the student's percent error? SHOW YOUR WORK TO RECEIVE CREDIT!!

8. What is the name of this piece of equipment?

9. Safety goggles are worn in the lab
a. Only if you don't normally wear glasses.
b. Only when working with fire.
c. Only when working with heat, chemicals or glassware.
d. Only when working with chemicals.

10. What is the name of this piece of equipment?
11. Please take a moment and tell me one thing about ChemQuest1 that really works for you and one thing that doesn't. Is there anything you would like to tell me about the game?
APPENDIX N

EXAMPLE FORMATIVE ASSESSMENT
Quiz: Misconceptions quiz

Please answer the following questions.

1. Chemical Changes are irreversible.
   (1 point)
   ● True
   ● False

2. As water boils, this explanation below best describes what is happening.
   (1 point)
   ● Water is separating into hydrogen and oxygen.
   ● Water is separating from other waters.
   ● Water is turning into a new compound.
   ● The atoms which compose a single water are rearranging with other waters' atoms.

3. When water boils, the bubbles that form have fast moving air in them.
   (1 point)
   ● True
   ● False

4. Ice floats because when it freezes, it has air in it.
   (1 point)
   ● True
   ● False